MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE REPUBLIC OF KAZAKHSTAN

ҚАЗАҚСТАН РЕСПУБЛИКАСЫНЫҢ ҒЫЛЫМ ЖӘНЕ ЖОҒАРЫ БІЛІМ МИНИСТРЛІГІ

МИНИСТЕРСТВО НАУКИ И ВЫСШЕГО ОБРАЗОВАНИЯ РЕСПУБЛИКИ КАЗАХСТАН

KAZAKHSTAN

ХАЛЫҚАРАЛЫҚ УНИВЕРСИТЕТІ

INTERNATIONAL UNIVERSITY SINCE 2009

МЕЖДУНАРОДНЫЙ УНИВЕРСИТЕТ

INTERNATIONAL JOURNAL OF INFORMATION AND COMMUNICATION TECHNOLOGIES

Published since 2020.
Volume 7. 3 (27). 2026
July–September

ХАЛЫҚАРАЛЫҚ АҚПАРАТТЫҚ ЖӘНЕ КОММУНИКАЦИЯЛЫҚ ТЕХНОЛОГИЯЛАР ЖУРНАЛЫ

2020 жылдан бері шығарылады
Том 7. 3 (27). 2026
Шілде-Қыркүйек

МЕЖДУНАРОДНЫЙ ЖУРНАЛ ИНФОРМАЦИОННЫХ И КОММУНИКАЦИОННЫХ ТЕХНОЛОГИЙ

Издается с 2020 г.
Том 7. 3 (27). 2026
Июль-Сентябрь

Свидетельство о постановке на учет периодического печатного издания в Министерство информации и общественного развития Республики Казахстан № KZ82VPY00020475, выданное от 20.02.2020 г.

Зарегистрировано в Международном центре регистрации серийных изданий ISSN (ЮНЕСКО, Париж, Франция). ISSN 2708–2032 (print), ISSN 2708–2040 (online)

Журнал входит в Перечень научных изданий, рекомендуемых КОКНВО МНВО РК для публикации основных результатов научной деятельности.

EDITOR-IN-CHIEF:
Kateryna Kolesnikova — Doctor of Technical Sciences, professor, Vice-Rector for Research, International Information Technology University (Kazakhstan)

DEPUTY EDITOR-IN-CHIEF:
Madina Ipalakova — Candidate of Technical Sciences, associate professor, Director of the Research Department, International Information Technology University (Kazakhstan)

EDITORIAL BOARD:
Abdul Razak — PhD, professor, Department of Cybersecurity, International Information Technology University (Kazakhstan)
Lucio Tommaso De Paolis — Director of the R&D Department of the AVR Laboratory, Department of Engineering for Innovation, University of Salento (Italy)
Liz Bacon — Professor, Deputy Vice-Chancellor, Abertay University (United Kingdom)
Michele Pagano — PhD, Professor, University of Pisa (Italy)
Mukhtarbay Otelbayev — Doctor of Physical and Mathematical Sciences, professor, academician of the National Academy of Sciences of the Republic of Kazakhstan, professor of the Department of Mathematical and Computer Modeling, International Information Technology University (Kazakhstan)
Bolatbek Rysbaiuly — Doctor of Physical and Mathematical Sciences, professor, professor of the Department of Computing and Data Science, Astana IT University (Kazakhstan)
Yevgeniya Daineko — PhD, research professor, Department of Information Systems, International Information Technology University (Kazakhstan)
Nurzhan Duzbayev — PhD, associate professor, Vice-Rector for Digitalization and Innovation, International Information Technology University (Kazakhstan)
Bakhtgerei Sinchev — Doctor of Technical Sciences, professor, Department of Information Systems, International Information Technology University (Kazakhstan)
Nurgul Seilova — Candidate of Technical Sciences, Dean of the Faculty of Computer Technologies and Cybersecurity, International Information Technology University (Kazakhstan)
Ardak Mukhamediyeva — Candidate of Economic Sciences, Dean of the Faculty of Business, Media and Management, International Information Technology University (Kazakhstan)
Zamira Abdikalikova — PhD, associate professor, Head of the Department of Mathematical and Computer Modeling, International Information Technology University (Kazakhstan)
Yerlan Shildibekov — PhD, associate professor, Head of the Department of Economics and Business, International Information Technology University (Kazakhstan)
Damilya Yeskendirova — Candidate of Technical Sciences, associate professor, Head of the Department of Cybersecurity, International Information Technology University (Kazakhstan)
Aigul Niyazgulova — Candidate of Philological Sciences, Professor, Head of the Department of Media Communications and History of Kazakhstan, International Information Technology University (Kazakhstan)
Altai Aitmagambetov — Candidate of Technical Sciences, Professor, Department of Radio Engineering, Electronics and Telecommunications, International Information Technology University (Kazakhstan)
Yelena Bakhtiyarova — Candidate of Technical Sciences, associate professor, Head of the Department of Radio Engineering, Electronics and Telecommunications, International Information Technology University (Kazakhstan)
Kanibek Sansyzbay — PhD, research professor, Department of Cybersecurity, International Information Technology University (Kazakhstan)
Sakhybay Tynymbayev — Candidate of Technical Sciences, Professor, Research Professor, Department of Computer Engineering, International Information Technology University (Kazakhstan)
Ali Abd Almisreb — PhD, associate professor, Department of Cybersecurity, International Information Technology University (Kazakhstan)
Mohamed Ahmed Hamada — PhD, associate professor, Department of Information Systems, International Information Technology University (Kazakhstan)
Yang Im Chu — PhD, Professor, Gachon University (South Korea)
Tadeusz Wallas — PhD, Vice-Rector, Adam Mickiewicz University (Poland)
Orken Mamyrbayev — PhD, Deputy Director for Science, RSE Institute of Information and Computational Technologies, Committee for Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Kazakhstan)
Sergey Bushuyev — Doctor of Technical Sciences, professor, Director of the Ukrainian Project Management Association “UKRNET,” Head of the Department of Project Management, Kyiv National University of Construction and Architecture (Ukraine)
Svetlana Beloshitskaya — Doctor of Technical Sciences, professor, Department of Computing and Data Science, Astana IT University (Kazakhstan)

MANAGING EDITOR
Raushan Mrzabayeva — Master of Science, editor, International Information Technology University (Kazakhstan)

International Journal of Information and Communication Technologies
Periodicity: 4 times a year.
Languages: Kazakh, Russian, English
DOI prefix: 10.54309
ISSN 2708–2032 (print)
ISSN 2708–2040 (online)
Thematic focus: "Information technology"; "Digital technologies in the development of socio-economic systems"; "Information security and communication technologies".
Distribution: Materials are distributed under the Creative Commons Attribution 4.0
Journal website: https://journal.iitu.edu.kz
Owner: International Information Technology University JSC (Almaty).
Copyright: © International Journal of Information and Communication Technologies, 2026

РЕДАКЦИЯ

БАС РЕДАКТОР:

Колесникова Катерина Викторовна — техника ғылымдарының докторы, профессор, Халықаралық ақпараттық технологиялар университетінің ғылыми-зерттеу қызметі жөніндегі проректор (Қазақстан)

БАС РЕДАКТОРДЫҢ ОРЫНБАСАРЫ:

Ипалакова Мадина Тулегеновна — техника ғылымдарының кандидаты, қауымдастырылған профессор, Халықаралық ақпараттық технологиялар университетінің ғылыми-зерттеу қызметі жөніндегі департамент директоры (Қазақстан)

РЕДАКЦИЯЛЫҚ АЛҚА:

Разак Абдул — PhD, Халықаралық ақпараттық технологиялар университеті киберқауіпсіздік кафедрасының профессоры (Қазақстан)

Лучио Томмазо де Паолис — Саленто Университеті (Италия) инновация және технологиялық инжиниринг департаменті AVR зертханасының зерттеу және әзірлеу бөлімінің директоры

Лиз Бэкон — профессор, Абертей Университеті (Ұлыбритания) вице-канцлерінің орынбасары

Микеле Пагано — PhD, Пиза Университетінің (Италия) профессоры

Өтелбаев Мухтарбай Өтелбайұлы — физика-математика ғылымдарының докторы, профессор, ҚР ҰҒА академигі, Халықаралық ақпараттық технологиялар университеті математика және компьютерлік модельдеу кафедрасының профессоры (Қазақстан)

Рысбайулы Болатбек — физика-математика ғылымдарының докторы, профессор, Есептеу және деректер ғылымдары департаментінің профессоры, Astana IT University (Казахстан)

Дайнеко Евгения Александровна — PhD, Халықаралық ақпараттық технологиялар университеті ақпараттық жүйелер кафедрасының профессор-зерттеушісі (Қазақстан)

Дузбаев Нуржан Токкужаевич — PhD, қауымдастырылған профессор, Халықаралық ақпараттық технологиялар университеті цифрландыру және инновациялар жөніндегі проректор (Қазақстан)

Синчев Бахтгерей Куспанович — техника ғылымдарының докторы, профессор, Халықаралық ақпараттық технологиялар университеті ақпараттық жүйелер кафедрасының профессоры (Қазақстан)

Сейлова Нургуль Абадуллаевна — техника ғылымдарының докторы, Халықаралық ақпараттық технологиялар университеті компьютерлік технологиялар және киберқауіпсіздік факультетінің деканы (Қазақстан)

Мухамедиева Ардак Габитовна — экономика ғылымдарының кандидаты, Халықаралық ақпараттық технологиялар университеті бизнеса медиа және басқару факультетінің деканы (Қазақстан)

Абдикаликова Замира Турсынбаевна — PhD, қауымдастырылған профессор, Халықаралық ақпараттық технологиялар университеті математика және компьютерлік модельдеу кафедрасының меңгерушісі (Қазақстан)

Шильдибеков Ерлан Жаржанович — PhD, қауымдастырылған профессор, Халықаралық ақпараттық технологиялар университеті экономика және бизнес кафедрасының меңгерушісі (Қазақстан)

Дамеля Максутовна Ескендирова — техника ғылымдарының кандидаты, қауымдастырылған профессор, Халықаралық ақпараттық технологиялар университеті киберқауіпсіздік кафедрасының меңгерушісі (Қазақстан)

Ниязгулова Айгуль Аскарбековна — филология ғылымдарының кандидаты, доцент, профессор, Халықаралық ақпараттық технологиялар университеті медиакоммуникация және Қазақстан тарихы кафедрасының меңгерушісі (Қазақстан)

Айтмагамбетов Алтай Зуфарович — техника ғылымдарының кандидаты, Халықаралық ақпараттық технологиялар университеті радиотехника, электроника және телекоммуникация кафедрасының профессоры (Қазақстан)

Бахтиярова Елена Ажибековна — техника ғылымдарының кандидаты, қауымдастырылған профессор, Халықаралық ақпараттық технологиялар университеті радиотехника, электроника және телекоммуникация кафедрасының меңгерушісі (Қазақстан)

Канибек Сансызбай — PhD, қауымдастырылған профессор, Халықаралық ақпараттық технологиялар университеті киберқауіпсіздік кафедрасының профессор-зерттеушісі (Қазақстан)

Тынымбаев Сахибай — техника ғылымдарының кандидаты, профессор, Халықаралық ақпараттық технологиялар университеті компьютерлік инженерия кафедрасының профессор-зерттеушісі (Қазақстан)

Алмисреб Али Абд — PhD, Халықаралық ақпараттық технологиялар университеті киберқауіпсіздік кафедрасының қауымдастырылған профессоры (Қазақстан)

Мохамед Ахмед Хамада — PhD, Халықаралық ақпараттық технологиялар университеті ақпараттық жүйелер кафедрасының қауымдастырылған профессоры (Қазақстан)

Янг Им Чу — PhD, Гачон университетінің профессоры (Оңтүстік Корея)

Тадеуш Валлас – PhD, Адам Мицкевич атындағы (Польша) университеттің проректоры

Мамырбаев Оркен Жумажанович — PhD, ҚР ҒЖБМ Ғылым комитеті ақпараттық және есептеу технологиялары институты ӨМК директорының ғылым жөніндегі орынбасары (Қазақстан)

Бушуев Сергей Дмитриевич — техника ғылымдарының докторы, профессор, Украинаның "УКРНЕТ" жобаларды басқару қауымдастығының директоры, Киев ұлттық құрылыс және сәулет университеті жобаларды басқару кафедрасының меңгерушісі (Украина)

Белощицкая Светлана Васильевна — техника ғылымдарының докторы, доцент, Astana IT University есептеу және деректер ғылымы кафедрасының профессоры (Қазақстан)

ЖАУАПТЫ РЕДАКТОР:

Мрзабаева Раушан Жалиевна — магистр, Халықаралық ақпараттық технологиялар университетінің редакторы (Қазақстан)

Халықаралық ақпараттық және коммуникациялық технологиялар журналы
ISSN 2708–2032 (print)
ISSN 2708–2040 (online)
Префикс DOI: 10.54309
Мерзімділігі: жылына 4 рет.
Басылым тілі: қазақ, орыс, ағылшын.
Тақырып бағыты: "Ақпараттық технологиялар"; "Ақпараттық қауіпсіздік және коммуникациялық технологиялар"; "Әлеуметтік-экономикалық жүйелерді дамытудағы цифрлық технология".
Журнал сайты: https://journal.iitu.edu.kz
Тарату: материалдар Creative Commons Attribution 4.0 лицензиясы бойынша таратылады
Меншік иесі: АҚ «Халықаралық ақпараттық технологиялар университеті» (Алматы қ.).
Авторлық құқық: © Халықаралық ақпараттық және коммуникациялық технологиялар журналы, 2026

РЕДАКЦИЯ

ГЛАВНЫЙ РЕДАКТОР:

Колесникова Катерина Викторовна — доктор технических наук, профессор, проректор по научно-исследовательской деятельности Международного университета информационных технологий (Казахстан)

ЗАМЕСТИТЕЛЬ ГЛАВНОГО РЕДАКТОРА:

Ипалакова Мадина Тулегеновна — кандидат технических наук, ассоциированный профессор, директор департамента по научно-исследовательской деятельности Международного университета информационных технологий (Казахстан)

РЕДАКЦИОННАЯ КОЛЛЕГИЯ:

Разак Абдул — PhD, профессор кафедры кибербезопасности Международного университета информационных технологий (Казахстан)

Лучио Томмазо де Паолис — директор отдела исследований и разработок лаборатории AVR департамента инноваций и технологического инжиниринга Университета Саленто (Италия)

Лиз Бэкон — профессор, заместитель вице-канцлера Университета Абертей (Великобритания)

Микеле Пагано — PhD, профессор Университета Пизы (Италия)

Отелбаев Мухтарбай Отелбайулы — доктор физико-математических наук, профессор, академик НАН РК, профессор кафедры математического и компьютерного моделирования Международного университета информационных технологий (Казахстан)

Рысбайулы Болатбек — доктор физико-математических наук, профессор, профессор Astana IT University (Казахстан)

Дайнеко Евгения Александровна — PhD, профессор-исследователь кафедры информационных систем Международного университета информационных технологий (Казахстан)

Дузбаев Нуржан Токкужаевич — PhD, ассоциированный профессор, проректор по цифровизации и инновациям Международного университета информационных технологий (Казахстан)

Синчев Бахтгерей Куспанович — доктор технических наук, профессор, профессор кафедры информационных систем Международного университета информационных технологий (Казахстан)

Сейлова Нургуль Абадуллаевна — кандидат технических наук, декан факультета компьютерных технологий и кибербезопасности Международного университета информационных технологий (Казахстан)

Мухамедиева Ардак Габитовна — кандидат экономических наук, декан факультета бизнеса медиа и управления Международного университета информационных технологий (Казахстан)

Абдикаликова Замира Турсынбаевна — PhD, ассоциированный профессор, заведующая кафедрой математического и компьютерного моделирования Международного университета информационных технологий (Казахстан)

Шильдибеков Ерлан Жаржанович — PhD, ассоциированный профессор, заведующий кафедрой экономики и бизнеса Международного университета информационных технологий (Казахстан)

Дамеля Максутовна Ескендирова — кандидат технических наук, ассоциированный профессор, заведующая кафедрой кибербезопасности Международного университета информационных технологий (Казахстан)

Ниязгулова Айгуль Аскарбековна — кандидат филологических наук, доцент, профессор, заведующая кафедрой медиакоммуникаций и истории Казахстана Международного университета информационных технологий (Казахстан)

Айтмагамбетов Алтай Зуфарович — кандидат технических наук, профессор кафедры радиотехники, электроники и телекоммуникаций Международного университета информационных технологий (Казахстан)

Бахтиярова Елена Ажибековна — кандидат технических наук, ассоциированный профессор, заведующая кафедрой радиотехники, электроники и телекоммуникаций Международного университета информационных технологий (Казахстан)

Канибек Сансызбай – PhD, ассоциированный профессор, профессор-исследователь кафедры кибербезопасности, Международного университета информационных технологий (Казахстан)

Тынымбаев Сахибай – кандидат технических наук, профессор, профессор-исследователь кафедры компьютерной инженерии, Международного университета информационных технологий (Казахстан)

Алмисреб Али Абд — PhD, ассоциированный профессор кафедры кибербезопасности Международного университета информационных технологий (Казахстан)

Мохамед Ахмед Хамада — PhD, ассоциированный профессор кафедры информационных систем Международного университета информационных технологий (Казахстан)

Янг Им Чу — PhD, профессор университета Гачон (Южная Корея)

Тадеуш Валлас – PhD, проректор университета имен Адама Мицкевича (Польша)

Мамырбаев Оркен Жумажанович — PhD, заместитель директора по науке РГП Института информационных и вычислительных технологий Комитета науки МНВО РК (Казахстан)

Бушуев Сергей Дмитриевич — доктор технических наук, профессор, директор Украинской ассоциации управления проектами «УКРНЕТ», заведующий кафедрой управления проектами Киевского национального университета строительства и архитектуры (Украина)

Белощицкая Светлана Васильевна — доктор технических наук, доцент, профессор кафедры вычислений и науки о данных Astana IT University (Казахстан)

ОТВЕТСТВЕННЫЙ РЕДАКТОР:

Мрзабаева Раушан Жалиевна — магистр, редактор Международного университета информационных технологий (Казахстан)

Международный журнал информационных и коммуникационных технологий
ISSN 2708–2032 (print)
ISSN 2708–2040 (online)
Префикс DOI: 10.54309
Периодичность: 4 выпусков в год.
Язык издания: казахский, русский, английский.
Тематическая направленность: "Информационные технологии"; "Информационная безопасность и коммуникационные технологии"; "Цифровые технологии в развитии социо-экономических систем".
Сайт журнала: https://journal.iitu.edu.kz
Распространение: материалы распространяются по лицензии Creative Commons Attribution 4.0
Собственник: АО «Международный университет информационных технологий» (г. Алматы).
Авторские права: © Международный журнал информационных и коммуникационных технологий, 2026

CONTENTS

DIGITAL TECHNOLOGIES IN THE DEVELOPMENT OF SOCIO-ECONOMIC SYSTEMS

A Adalbek, S.Ye. Kerimkhulle, K.D. Kuliev, O. Mekesh, Zh.Zh. Khamitova
DEVELOPMENT OF RESULT-ORIENTED DATA SMOOTHING MODELS AND ANALYSIS OF THEIR EFFECTIVENESS 11
A.T. Iskakova, G.E. Kurmankulova, K. Gromaszek, K.O. Togzhanova, R.S. Algozhayeva
APPLICATION OF MACHINE LEARNING AND DEEP LEARNING FOR PREDICTIVE PLANNING AND RESOURCE EFFICIENCY IN PRODUCTION SYSTEMS 30
A.B. Kassymova, R.K. Uskenbayeva, Zh.A. Sydykov, D. Omirzak, S. Kalibekov
ARCHITECTURE OF AN INTELLIGENT CHATBOT FOR SMART CITY: AI-BASED RECEIVING, ANALYSIS AND ROUTING OF CITIZEN REQUESTS 46
O.M. Olzhayev, B.S. Omarov, A. Suliman
YOLO-CBAM: A LIGHTWEIGHT NEURAL NETWORK MODEL WITH INTEGRATED ATTENTION MECHANISM FOR ROAD DAMAGE ANALYSIS 66
K. Yermagambetova, A. Sarsekeyeva, Y. Akhlassov
OVERCOMING FRAGMENTATION IN THE CLASSIFICATION OF DIGITAL CULTURAL HERITAGE: AN INTEGRATIVE MULTIDIMENSIONAL MODEL 78

INFORMATION TECHNOLOGY

D. Abzhanova, S. Sharipova
ARCHITECTURE AND PRACTICAL IMPLEMENTATION OF A DIGITAL PLATFORM FOR MONITORING AND DATA EXCHANGE ON TRANSBOUNDARY WATER RESOURCES IN THE ZHAMBYL REGION 101
A. Aitanuly, O.A. Ussatova
ENHANCING TWO-FACTOR AUTHENTICATION FOR CLOUD HEALTHCARE SECURITY: THE ROLE OF DEEP LEARNING 122
O. Alseitov, O. Kuchanskyi
PHYSICS-INFORMED HYBRID LEARNING FOR HOURLY POWER-PLANT EMISSIONS: A MULTI-POLLUTANT BENCHMARK WITH UNCERTAINTY AND TRANSFER 141
A.M. Akhmetova, D.O. Baizhanova, Zh.N. Alisheva, B.A. Shaimov
ADAPTIVE OUTPUT ROUTER FOR NATURAL LANGUAGE MODELS CONSIDERING KEY PERFORMANCE INDICATORS 160
A.K. Aitim
AUTOMATIC AND SEMI-AUTOMATIC ANNOTATION OF KAZAKH TEXT CORPORA 180
Z.E. Balabayev, S.V. Biloshchytska
HANDWRITTEN TEXT RECOGNITION FOR CHAGATAI MANUSCRIPTS: COMPARING CRNN TRAINING FROM SCRATCH AND TRANSFORMER-BASED TRANSFER LEARNING 198
D.B. Baumuratova, T.K. Zhukabayeva, K.A. Abdrakhmanov, Z. Ahmad, A.A. Seitov
A NEURO-DIGITAL LEARNING MODEL FOR AI DRIVEN DIGITAL TRANSFORMATION IN HIGHER EDUCATION 219
T. Daoyun, G.A. Amirkhanova, Fu Yanwei, Y. Faruzkyzy
MULTIMODAL SEMANTIC MANIPULATION IN FAKE VIDEOS AND ITS INFLUENCE MECHANISM ON USERS' PERCEIVED TRUST 241
Zh. Doumchariyev, J. Tussupov, A. Akynbekova, M. Khassanova, M. Kassim
ENSEMBLE AND HYBRID LEARNING FOR DIGITAL TWIN MILK CLASSIFICATION 258
K.Z. Igibayev, A.Kh. Kozbakova, O. Auelbekov , T. Merembayev, K. Yessentayev
STUDY OF A DYNAMIC MIXING DEVICE IN A BIOREACTOR USING IOT TECHNOLOGIES 279
A.N. Ismukanova, G. Kochshanova, D.V. Pleskachev, Zh. Sarsenbayeva, P. Schmidt
AUTOMATED CLASSIFICATION OF SCIENTIFIC DATA USING ARTIFICIAL INTELLIGENCE: A COMPARATIVE ANALYSIS OF TRANSFORMER ARCHITECTURES AND HYBRID APPROACHES 306
T. Zh. Kamalov, Ali Abd. Almisreb, Mohammed A. Saleh
INVESTIGATION OF HYBRID QUANTUM-CLASSICAL ALGORITHMS FOR MACHINE LEARNING 323
B. Karimkyzy, K.G. Karasenko, N.A. Alisherov, N.M. Muratbek, A. Karim

KEY PUBLICATIONS OF 2021–2025 ON ARTIFICIAL INTELLIGENCE METHODS IN THE MANUFACTURING AND DIAGNOSTICS OF MEDICAL DEVICES FOR GLYCEMIC MONITORING: A THEMATIC ANALYTICAL REVIEW 338
S.K. Kumyzbaeva, K.E. Baglanbaev, K.S. Sarkyt, M.Zh. Konyrova
THREE-PHASE TRAINING OF INTELLIGENT ENERGY MANAGEMENT FOR A HYBRID ENERGY SYSTEM WITH A CLIMATE-AWARE STATE REPRESENTATION 357
N.E. Karabayev, S.K. Serikbayeva, E. Benkhelif, B. Tassuov
RESEARCH ON THE ROBUSTNESS OF ENSEMBLE MACHINE LEARNING MODELS TO ADVERSARIAL ATTACKS IN INTRUSION DETECTION SYSTEMS FOR IOT NETWORKS 369
M. Nurtas, G. Kapyshev
A METHODOLOGICAL FRAMEWORK FOR THE PREPROCESSING AND INTEGRATION OF GEOSPATIAL AND GEOPHYSICAL DATA FOR MINERAL PROSPECTIVITY PREDICTION USING MACHINE LEARNING 392
A. Neftissov, A. Biloshchytskyi, I. Kazambayev, A. Medetkhan, L. Kirichenko
ENERGY EFFICIENT MICROCLIMATE STABILIZATION FOR SEALED ARCHIVAL STORAGE ENCLOSURES 405
A.Zh. Omurtayeva, U.T. Makhazhanova, A.K. Adilova, Sh.K. Yelezhanova, J. Kultan
AN ADAPTIVE NEURAL-FUZZY MODEL FOR ASSESSING INVESTMENT RISKS IN THE AGRI-INDUSTRIAL COMPLEX: ODERNISATION OF THE DECISION-SUPPORT ARCHITECTURE THROUGH THE INTEGRATION OF MACHINE LEARNING 421
N. Shazhdekeyeva, A. Mukhanbetkaliyeva, A. Abdigaliyeva, A. Zhanekeshova, L. Nurgaliyeva
COMPARATIVE ANALYSIS OF MATHEMATICAL MODELS OF COLLABORATIVE FILTERING IN THE DEVELOPMENT OF A MOVIE RECOMMENDER SYSTEM 445
S. Sharmukhanbet, G. Turmukhanova, O. Findik, V. Makhatova, M. Rakhmetov
AN INTELLIGENT PIPELINE DEFECT DETECTION SYSTEM USING AN IN-PIPE ROBOT 461

INFORMATION SECURITY AND COMMUNICATIONTECHNOLOGIES

S.Z. Daruish, A.U. Utegenova, A.U. Kalizhanova, Zh.Zh. Zhumabekova
MACHINE LEARNING FOR POLLUTION CLASSIFICATION IN ROCKET BOOSTER IMPACT AREAS 480
S.N. Issabayeva, A.K. Rysbayeva, Zh.B. Ibrayeva, N.R. Mussabekov, N.Sh. Akimzhan
MACHINE LEARNING-BASED CYBERATTACK DETECTION IN OT-NETWORKS: A COMPARATIVE ANALYSIS OF NETWORK ANOMALY CLASSIFICATION METHODS 495
G. Shangytbayeva, A.N. Amanov, M.K. Issenova, G.E. Berikkhanova, K.O. Shakerkhan
INFORMATION SECURITY IN GOVERNMENT CLOUD SERVICES: RISK ASSESSMENT AND PROTECTION STRATEGIES 512
Ye. N. Tursynbek, N. Albanbay, D. Djenouri
OPTIMISATION OF COMMUNICATION COSTS IN TWO-TIER FEDERATED LEARNING FOR CYBERATTACK DETECTION IN IOT NETWORKS 529
A. Tastemirov, S.B. Mukhanov, S.T. Amanzholova, B. Aldosh
A COMPARATIVE EVALUATION OF MACHINE LEARNING MODELS FOR ACTIVE DIRECTORY THREAT DETECTION: FEATURE-LEAKAGE CONTROL AND CROSS-SCENARIO VALIDATION ON WINDOWS SECURITY EVENT LOGS 545

МАЗМҰНЫ
ӘЛЕУМЕТТІК-ЭКОНОМИКАЛЫҚ ЖҮЙЕЛЕРДІ ДАМЫТУДАҒЫ ЦИФРЛЫҚ ТЕХНОЛОГИЯЛАР

А Адалбек, С.Е. Керімқұл, К.Д. Кулиев, О. Мекеш, Ж.Ж. Хамитова
ДЕРЕКТЕРДІҢ НӘТИЖЕ БАҒДАРЛАНҒАН ТЕГІСТЕУ МОДЕЛЬДЕРІН ӘЗІРЛЕУ ЖӘНЕ ОЛАРДЫҢ ТИІМДІЛІГІН ТАЛДАУ 11
А.Т. Искакова, Г.Е. Курманкулова, Конрад Громашек, К.О. Тогжанова, Р.С. Алгожаева
ӨНДІРІС ЖҮЙЕЛЕРІНДЕ БОЛЖАМДЫ ЖОСПАРЛАУ ЖӘНЕ РЕСУРСТАРДЫ ҮНЕМДЕУ ҮШІН МАШИНАЛЫҚ ЖӘНЕ ТЕРЕҢ ОҚЫТУДЫ ҚОЛДАНУ 30
А.Б. Касымова, Р.К. Ускенбаева, Ж.А. Сыдыков, Д. Өмірзақ, С. Калибеков
SMART CITY ҮШІН ИНТЕЛЛЕКТУАЛДЫ ЧАТ-БОТ АРХИТЕКТУРАСЫ: АЗАМАТТАРДЫҢ

ӨТІНІШТЕРІН ЖАСАНДЫ ИНТЕЛЛЕКТ НЕГІЗІНДЕ ҚАБЫЛДАУ, ТАЛДАУ ЖӘНЕ БАҒЫТТАУ 46
О.М. Олжаев, Б.С. Омаров, A.Suliman
YOLO-CBAM: ЖОЛДЫҢ ЗАҚЫМДАНУЫН ТАЛДАУҒА АРНАЛҒАН ИНТЕГРАЦИЯЛАНҒАН ЗЕЙІН МЕХАНИЗМІ БАР ЖЕҢІЛ САЛМАҚТЫ НЕЙРОНДЫҚ ЖЕЛІ МОДЕЛІ 66
К. Ермагамбетова, А. Сарсекеева, Е. Ахласов
ЦИФРЛЫҚ МӘДЕНИ МҰРАНЫ ЖІКТЕУДЕГІ ФРАГМЕНТАЦИЯНЫ ЕҢСЕРУ: ИНТЕГРАТИВТІ КӨПӨЛШЕМДІ МОДЕЛЬ 78

АҚПАРАТТЫҚ ТЕХНОЛОГИЯЛАР

Д.Е. Абжанова, С.Е. Шарипова
ЖАМБЫЛ ӨҢІРІНІҢ ТРАНСШЕКАРАЛЫҚ СУ РЕСУРСТАРЫН МОНИТОРИНГТЕУ ЖӘНЕ ДЕРЕКТЕР АЛМАСУҒА АРНАЛҒАН ЦИФРЛЫҚ ПЛАТФОРМАНЫҢ АРХИТЕКТУРАСЫ МЕН ПРАКТИКАЛЫҚ ІСКЕ АСЫРЫЛУЫ 101
А.Айтанұлы, О.А. Усатова
БҰЛТТЫ МЕДИЦИНАЛЫҚ ЖҮЙЕЛЕРДЕ ЕКІ ФАКТОРЛЫ АУТЕНТИФИКАЦИЯНЫ ЖАҚСАРТУ: ТЕРЕҢ ОҚЫТУ ӘДІСТЕРІНІҢ ҚОЛДАНУ МҮМКІНДІКТЕРІ 122
О. Альсеитов, О. Кучанский
ЭЛЕКТР СТАНЦИЯЛАРЫНЫҢ САҒАТТЫҚ ШЫҒАРЫНДЫЛАРЫН ФИЗИКАЛЫҚ ЗАҢДЫЛЫҚТАРДЫ ЕСКЕРЕТІН ГИБРИДТІ ОҚЫТУ: БЕЛГІСІЗДІК ПЕН ТАСЫМАЛДАУДЫ ЕСКЕРЕТІН КӨПЛАСТАУЫШТЫ БЕНЧМАРК 141
А.М. Ахметова, Д.О. Байжанова, Ж.Н. Алишева, Б.А. Шаймов
КРІ КӨРСЕТКІШТЕРІН ЕСКЕРЕ ОТЫРЫП, ТАБИҒИ ТІЛ МОДЕЛЬДЕРІНЕ АРНАЛҒАН ШЫҒЫС МАРШРУТТАУЫНЫҢ АДАПТИВТІ ЖҮЙЕСІ 160
Ә.Қ. Әйтім
ҚАЗАҚ МӘТІНДІК КОРПУСТАРЫН АВТОМАТТЫ ЖӘНЕ ЖАРТЫЛАЙ АВТОМАТТЫ АННОТАЦИЯЛАУ 180
Ж.Е. Балабаев, С.В. Белощицкая
ШАҒАТАЙ ҚОЛЖАЗБАЛАРЫНЫҢ МӘТІНІН ТАНУ: CRNN-ДІ НӨЛДЕН БАСТАП ОҚЫТУ МЕН ТРАНСФОРМЕР НЕГІЗІНДЕГІ ТРАНСФЕРЛІК ОҚЫТУДЫ САЛЫСТЫРУ 198
Д.Б. Баумуратова, Т.К. Жукабаева, К.А. Абдрахманов, З. Ахмад, А.А. Сеитов
ЖОҒАРЫ БІЛІМ БЕРУДЕ AI НЕГІЗДЕЛГЕН ЦИФРЛЫҚ ТРАНСФОРМАЦИЯҒА АРНАЛҒАН НЕЙРО-ЦИФРЛЫҚ ОҚЫТУ МОДЕЛІ 219
Т. Даоюн, Г. Амирханова, Фу Яньвэй, Е. Фарузқызы
ФЕЙК ВИДЕОЛАРДАҒЫ МУЛЬТИМОДАЛЬДЫ СЕМАНТИКАЛЫҚ МАНИПУЛЯЦИЯНЫҢ ПАЙДАЛАНУШЫЛАРДЫҢ ҚАБЫЛДАЙТЫН СЕНІМІНЕ ӘСЕР ЕТУ МЕХАНИЗМІ 241
Ж. Доумчариева, Д. Тусупов, А. Акынбекова, М. Хасанова, М. Кассим
ЦИФРЛЫҚ ЕГІЗДЕГІ СҮТ САПАСЫН АНСАМБЛЬДІК ЖӘНЕ ГИБРИДТІ ОҚЫТУ АРҚЫЛЫ ЖІКТЕУ 258
Қ.З. Игибаев, А.Х. Козбакова, О. Әуелбеков, Т. Мерембаев, Қ. Есентаев
БИОРЕАКТОРДА IoT ТЕХНОЛОГИЯЛАРЫН ПАЙДАЛАНА ОТЫРЫП ДИНАМИКАЛЫҚ АРАЛАСТЫРУ ҚҰРЫЛҒЫСЫН ЗЕРТТЕУ 279
А.Н. Исмуканова, Г.Кощанова, Д.В. Плескачев, Ж.Сарсенбаева, П. Шмидт
ЖАСАНДЫ ИНТЕЛЛЕКТ НЕГІЗІНДЕ ҒЫЛЫМИ ДЕРЕКТЕРДІ АВТОМАТТЫ ТҮРДЕ ЖІКТЕУ: ТРАНСФОРМЕР АРХИТЕКТУРАЛАРЫ МЕН ГИБРИДТІ ТӘСІЛДЕРДІҢ САЛЫСТЫРМАЛЫ ТАЛДАУЫ 306
Т.Ж. Камалов, Али Абд. Альмисреб, Мохаммед А. Салех
МАШИНАЛЫҚ ОҚЫТУҒА АРНАЛҒАН ГИБРИДТІ КВАНТТЫҚ-КЛАССИКАЛЫҚ АЛГОРИТМДЕРІН ЗЕРТТЕУ 323
Б. Кәрімқызы, К.Г. Карасенко, Н.А. Әлішеров, Н.М. Мұратбек, А. Кәрім
2021–2025 ЖЫЛДАР АРАЛЫҒЫНДАҒЫ ГЛИКЕМИЯЛЫҚ МОНИТОРИНГКЕ АРНАЛҒАН МЕДИЦИНАЛЫҚ ҚҰРЫЛҒЫЛАРДЫ ӨНДІРУ ЖӘНЕ ДИАГНОСТИКАЛАУДАҒЫ ЖАСАНДЫ ИНТЕЛЛЕКТ ӘДІСТЕРІ БОЙЫНША НЕГІЗГІ ЖАРИЯЛАНЫМДАР 338
С. К. Кумызбаева, К.Е. Багланбаев, К.С. Саркыт, М. Конырова
КҮЙ-ЖАЙДЫ КЛИМАТҚА СЕЗІМТАЛ ҰСЫНУМЕН ГИБРИДТІ ЭНЕРГОЖҮЙЕНІҢ ИНТЕЛЛЕКТУАЛДЫ ЭНЕРГОМЕНЕДЖМЕНТІН ҮШФАЗАЛЫ ОҚЫТУ 357
Н.Е. Қарабаев, С.К. Серикбаева, Е. Бенкхелифа, Б. Тасуов

IOT-ЖЕЛІЛЕРІНДЕГІ БАСЫП КІРУДІ АНЫҚТАУЖҮЙЕЛЕРІНДЕ МАШИНАЛЫҚ ОҚЫТУДЫҢ АНСАМБЛЬДІ КҮЛГІЛЕРІНІҢ БӘСЕКЕЛЕС ШАБУЫЛДАРҒА ТӨЗІМДІЛІГІН ЗЕРТТЕУ 369
М. Нұртас, Ғ. Капышев
МАШИНАЛЫҚ ОҚЫТУДЫ ҚОЛДАНА ОТЫРЫП, ПАЙДАЛЫ ҚАЗБАЛАРДЫҢ ПЕРСПЕКТИВАЛЫЛЫҒЫН БОЛЖАУ ҮШІН ГЕОКЕҢІСТІКТІК ЖӘНЕ ГЕОФИЗИКАЛЫҚ ДЕРЕКТЕРДІ АЛДЫН АЛА ӨҢДЕУ ЖӘНЕ БІРІКТІРУДІҢ ӘДІСТЕМЕЛІК НЕГІЗІ 392
А. Нефтиссов, А. Билощицкий, И. Казамбаев, А. Медетхан, Л. Кириченко
ГЕРМЕТИКАЛЫҚ АРХИВТІК САҚТАУ ҚАПТАМАЛАРЫНДА МИКРОКЛИМАТТЫ ЭНЕРГИЯ ТИІМДІЛІГІН ЕСКЕРЕ ОТЫРЫП ТҰРАҚТАНДЫРУ 405
Ә.Ж. Омуртаева, У.Т. Махажанова, А.К. Адилова, Ш.К. Ележанова, Я. Култан
АГРОӨНЕРКӘСІПТІК КЕШЕНДЕГІ ИНВЕСТИЦИЯЛЫҚ ТӘУЕКЕЛДЕРДІ БАҒАЛАУҒА АРНАЛҒАН БЕЙІМДЕЛГІШ НЕЙРОНДЫҚ-БҰЛДЫР МОДЕЛЬ: МАШИНАЛЫҚ ОҚЫТУДЫ ИНТЕГРАЦИЯЛАУ АРҚЫЛЫ ШЕШІМ ҚАБЫЛДАУДЫ ҚОЛДАУ СӘУЛЕТІН ЖАҢҒЫРТУ 421
Н. Шаждекеева, А. Мұханбетқалиева, А. Әбдіғалиева, А. Жанекешова, Л. Нұрғалиева
ФИЛЬМДЕРДІ ҰСЫНУ ЖҮЙЕСІН ҚҰРУ КЕЗІНДЕГІ КОЛЛАБОРАТИВТІК СҮЗГІЛЕУДІҢ МАТЕМАТИКАЛЫҚ МОДЕЛЬДЕРІН САЛЫСТЫРМАЛЫ ТАЛДАУ 445
С. Шармұханбет, Г. Тұрмұханова, О. Финдик, В. Махатова, М. Рахметов
ҚҰБЫРІШІЛІК РОБОТТЫ ПАЙДАЛАНУ АРҚЫЛЫ ҚҰБЫР АҚАУЛАРЫН АНЫҚТАУДЫҢ ЗИЯТКЕРЛІК ЖҮЙЕСІ 461

АҚПАРАТТЫҚ ҚАУІПСІЗДІК ЖӘНЕ КОММУНИКАЦИЯЛЫҚ ТЕХНОЛОГИЯЛАРҒА АРНАЛҒАН

С.З. Дәруіш, А.У. Утегенова, А.У. Калижанова, Ж.Ж. Жумабекова
ЗЫМЫРАН ТАСЫМАЛДАУШЫЛАРДЫҢ ҚҰЛАУ АЙМАҚТАРЫНЫҢ ЛАСТАНУЫН МАШИНАЛЫҚ ОҚЫТУМЕН ЖІКТЕУ 480
С.Н. Исабаева, А.К. Рысбаева, Ж.Б. Ибраева, Н.Р. Муссабеков, Н.Ш. Акимжан
МАШИНАЛЫҚ ОҚЫТУ НЕГІЗІНДЕ ОТ-ЖЕЛІЛЕРІНДЕГІ КИБЕРШАБУЫЛДАРДЫ АНЫҚТАУ: ЖЕЛІЛІК АНОМАЛИЯЛАРДЫ ЖІКТЕУ ӘДІСТЕРІНІҢ САЛЫСТЫРМАЛЫ ТАЛДАУЫ 495
Г.А. Шангытбаева, А.Н. Аманов, М.К. Исенова, Г.Е. Берикханова, Қ.О. Шакерхан
МЕМЛЕКЕТТІК ОРГАНДАРДЫҢ БҰЛТТЫ СЕРВИСТЕРІНДЕГІ АҚПАРАТТЫҚ ҚАУІПСІЗДІК: ТӘУЕКЕЛДЕРДІ БАҒАЛАУ ЖӘНЕ ҚОРҒАУ СТРАТЕГИЯЛАРЫ 512
Е.Н. Турсынбек, Н. Албанбай, Д. Дженоури
IOT ЖЕЛІЛЕРІНДЕ КИБЕРШАБУЫЛДАРДЫ АНЫҚТАУ ҮШІН ЕКІ ДЕҢГЕЙЛІ ФЕДЕРАЦИЯЛАНҒАН ОҚЫТУДАҒЫ БАЙЛАНЫС ШЫҒЫНДАРЫН ОҢТАЙЛАНДЫРУ 529
А. Тастемиров, С.Т. Аманжолова, Б. Алдош, С.Б. Муханов
ACTIVE DIRECTORY ЖҮЙЕСІНДЕ ҚАУІПТЕРДІ АНЫҚТАУ ҮШІН МАШИНАЛЫҚ ОҚЫТУ МОДЕЛЬДЕРІН САЛЫСТЫРМАЛЫ БАҒАЛАУ: WINDOWS ҚАУІПСІЗДІК ОҚИҒАЛАРЫ ЖУРНАЛДАРЫНДА БЕЛГІ ЖЫЛЫСТАУЫН БАҚЫЛАУ ЖӘНЕ КРОСС-СЦЕНАРЛЫҚ ВАЛИДАЦИЯ 545

СОДЕРЖАНИЕ
ЦИФРОВЫЕ ТЕХНОЛОГИИ В РАЗВИТИИСОЦИО-ЭКОНОМИЧЕСКИХ СИСТЕМ

А Адалбек, С.Е. Керимкулов, К.Д. Кулиев, О. Мекеш, Ж.Ж. Хамитова
РАЗРАБОТКА РЕЗУЛЬТАТИВНО-ОРИЕНТИРОВАННЫХ МОДЕЛЕЙ СГЛАЖИВАНИЯ ДАННЫХ И АНАЛИЗ ИХ ЭФФЕКТИВНОСТИ 11
А.Т. Искакова, Г.Е. Курманкулова, К. Громашек, К.О. Тогжанова, Р.С. Алгожаева
ПРИМЕНЕНИЕ МЕТОДОВ МАШИННОГО И ГЛУБОКОГО ОБУЧЕНИЯ ДЛЯ ПРОГНОЗНОГО ПЛАНИРОВАНИЯ И РЕСУРСОСБЕРЕЖЕНИЯ В ПРОИЗВОДСТВЕННЫХ СИСТЕМАХ 30
А.Б. Касымова, Р.К. Ускенбаева, Ж.А.Сыдыков, Д. Омирзак, С. Калибеков
АРХИТЕКТУРА ИНТЕЛЛЕКТУАЛЬНОГО ЧАТ-БОТА ДЛЯ SMART CITY: ПРИЁМ, АНАЛИЗ И МАРШРУТИЗАЦИЯ ОБРАЩЕНИЙ ГРАЖДАН НА ОСНОВЕ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА 46
О.М. Олжаев, Б.С. Омаров, A.Suliman
YOLO-CBAM: ЛЕГКОВЕСНАЯ НЕЙРОСЕТЕВАЯ МОДЕЛЬ С ИНТЕГРИРОВАННЫМ МЕХАНИЗМОМ ВНИМАНИЯ ДЛЯ АНАЛИЗА ДОРОЖНЫХ ПОВРЕЖДЕНИЙ 66
К. Ермагамбетова, А. Сарсекеева, Е. Ахласов
ПРЕОДОЛЕНИЕ ФРАГМЕНТАЦИИ В КЛАССИФИКАЦИИ ЦИФРОВОГО КУЛЬТУРНОГО НАСЛЕДИЯ:

ИНТЕГРАТИВНАЯ МНОГОМЕРНАЯ МОДЕЛЬ 78

ИНФОРМАЦИОННЫЕ ТЕХНОЛОГИИ

Д.Е. Абжанова, С.Е. Шарипова
АРХИТЕКТУРА И ПРАКТИЧЕСКАЯ РЕАЛИЗАЦИЯ ЦИФРОВОЙ ПЛАТФОРМЫ МОНИТОРИНГА И ОБМЕНА ДАННЫМИ О ТРАНСГРАНИЧНЫХ ВОДНЫХ РЕСУРСАХ ЖАМБЫЛСКОГО РЕГИОНА 101
А. Айтанулы, О.А. Усатова
СОВЕРШЕНСТВОВАНИЕ ДВУХФАКТОРНОЙ АУТЕНТИФИКАЦИИ ДЛЯ ОБЕСПЕЧЕНИЯ БЕЗОПАСНОСТИ ОБЛАЧНЫХ МЕДИЦИНСКИХ СИСТЕМ: ВОЗМОЖНОСТИ ПРИМЕНЕНИЯ МЕТОДОВ ГЛУБОКОГО ОБУЧЕНИЯ 122
О. Альсеитов, О. Кучанский
ФИЗИЧЕСКИ ИНФОРМИРОВАННОЕ ГИБРИДНОЕ ОБУЧЕНИЕ ДЛЯ ПОЧАСОВОГО ПРОГНОЗИРОВАНИЯ ВЫБРОСОВ ЭЛЕКТРОСТАНЦИЙ: МНОГОКОМПОНЕНТНЫЙ БЕНЧМАРК С ОЦЕНКОЙ НЕОПРЕДЕЛЁННОСТИ И ПЕРЕНОСИМОСТЬЮ МОДЕЛЕЙ 141
А.М. Ахметова, Д.О. Байжанова, Ж.Н. Алишева, Б.А. Шаймов
АДАПТИВНЫЙ МАРШРУТИЗАТОР ВЫВОДА С УЧЕТОМ КЛЮЧЕВЫХ ПОКАЗАТЕЛЕЙ ЭФФЕКТИВНОСТИ ДЛЯ МОДЕЛЕЙ ЕСТЕСТВЕННОГО ЯЗЫКА 160
Ә.Қ. Әйтім
АВТОМАТИЧЕСКАЯ И ПОЛУАВТОМАТИЧЕСКАЯ АННОТАЦИЯ КАЗАХСКИХ ТЕКСТОВЫХ КОРПУСОВ 180
Ж.Е. Балабаев, С.В. Белощицкая
РАСПОЗНАВАНИЕ РУКОПИСНОГО ТЕКСТА ШАГАТАЙСКИХ РУКОПИСЕЙ: СРАВНЕНИЕ ОБУЧЕНИЯ CRNN С НУЛЯ И ТРАНСФЕРНОГО ОБУЧЕНИЯ НА БАЗЕ ТРАНСФОРМЕРОВ 198
Д.Б. Баумуратова, Т.К. Жукабаева, К.А. Абдрахманов, З. Ахмад, А.А. Сеитов
НЕЙРО-ЦИФРОВАЯ МОДЕЛЬ ОБУЧЕНИЯ ДЛЯ ЦИФРОВОЙ ТРАНСФОРМАЦИИ ВЫСШЕГО ОБРАЗОВАНИЯ С ПОМОЩЬЮ AI 219
Т. Даоюн, Г. Амирханова, Фу Яньвэй, Е. Фарузкызы
МЕХАНИЗМ ВЛИЯНИЯ МУЛЬТИМОДАЛЬНОЙ СЕМАНТИЧЕСКОЙ МАНИПУЛЯЦИИ В ФЕЙКОВЫХ ВИДЕО НА ВОСПРИНИМАЕМОЕ ДОВЕРИЕ ПОЛЬЗОВАТЕЛЕЙ 241
Ж. Доумчариева, Д. Тусупов, А. Акынбекова, М. Хасанова, М. Кассим
КЛАССИФИКАЦИЯ КАЧЕСТВА МОЛОКА В ЦИФРОВОМ ДВОЙНИКЕ АНСАМБЛЕВЫМИ И ГИБРИДНЫМИ МЕТОДАМИ 258
К.З. Игибаев, А.Х. Козбакова, О. Ауелбеков, Т. Мерембаев, К. Есентаев
ИССЛЕДОВАНИЕ УСТРОЙСТВА ДИНАМИЧЕСКОГО ПЕРЕМЕШИВАНИЯ В БИОРЕАКТОРЕ С ИСПОЛЬЗОВАНИЕМ ТЕХНОЛОГИЙ IoT 279
А. Н. Исмуканова, Г.Кощанова, Д.В. Плескачев, Ж.Сарсенбаева, П. Шмидт
АВТОМАТИЗИРОВАННАЯ КЛАССИФИКАЦИЯ НАУЧНЫХ ДАННЫХ НА ОСНОВЕ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА: СРАВНИТЕЛЬНЫЙ АНАЛИЗ ТРАНСФОРМЕРНЫХ АРХИТЕКТУР И ГИБРИДНЫХ МЕТОДОВ 306
Т.Ж. Камалов, Али Абд. Альмисреб, Мохаммед А. Салех
ИССЛЕДОВАНИЕ ГИБРИДНЫХ КВАНТОВО-КЛАССИЧЕСКИХ АЛГОРИТМОВ ДЛЯ МАШИННОГО ОБУЧЕНИЯ 323
Б. Каримкызы, К.Г. Карасенко, Н.А. Алишеров, Н.М. Муратбек, А. Карим
КЛЮЧЕВЫЕ ПУБЛИКАЦИИ 2021–2025 ГОДОВ ПО МЕТОДАМ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА В ПРОИЗВОДСТВЕ И ДИАГНОСТИКЕ МЕДИЦИНСКИХ ИЗДЕЛИЙ ДЛЯ ГЛИКЕМИЧЕСКОГО МОНИТОРИНГА 338
С.К. Кумызбаева, К.Е. Багланбаев, К.С. Сарқыт, М.Ж. Конырова
ТРЁХФАЗОВОЕ ОБУЧЕНИЕ ИНТЕЛЛЕКТУАЛЬНОГО ЭНЕРГОМЕНЕДЖМЕНТА ГИБРИДНОЙ ЭНЕРГОСИСТЕМЫ С КЛИМАТО-ОСВЕДОМЛЁННЫМ ПРЕДСТАВЛЕНИЕМ СОСТОЯНИЯ 357
Н.Е. Қарабаев, С.К. Серикбаева, Е. Бенкхелифа, Б. Тасуов
ИССЛЕДОВАНИЕ УСТОЙЧИВОСТИ АНСАМБЛЕВЫХ МОДЕЛЕЙ МАШИННОГО ОБУЧЕНИЯ К СОСТЯЗАТЕЛЬНЫМ АТАКАМ В СИСТЕМАХ ОБНАРУЖЕНИЯ ВТОРЖЕНИЙ IOT-СЕТЕЙ 369
М. Нуртас, Г. Капышев
МЕТОДОЛОГИЧЕСКАЯ ОСНОВА ПРЕДВАРИТЕЛЬНОЙ ОБРАБОТКИ И ИНТЕГРАЦИИ ГЕОПРОСТРАНСТВЕННЫХ И ГЕОФИЗИЧЕСКИХ ДАННЫХ ДЛЯ ПРОГНОЗИРОВАНИЯ ПЕРСПЕКТИВНО-

СТИ МИНЕРАЛЬНЫХ РЕСУРСОВ С ИСПОЛЬЗОВАНИЕМ МАШИННОГО ОБУЧЕНИЯ 392
А. Нефтиссов, А. Билощицкий, И. Казамбаев, А. Медетхан, Л. Кириченко
ЭНЕРГОЭФФЕКТИВНАЯ СТАБИЛИЗАЦИЯ МИКРОКЛИМАТА В ГЕРМЕТИЧНЫХ АРХИВНЫХ ХРАНИЛИЩАХ 405
А.Ж. Омуртаева, У.Т. Махажанова, А.К. Адилова, Ш.К. Ележанова, Я.Култан
АДАПТИВНАЯ НЕЙРО-НЕЧЕТКАЯ МОДЕЛЬ ДЛЯ ОЦЕНКИ ИНВЕСТИЦИОННЫХ РИСКОВ В АГРОПРОМЫШЛЕННОМ КОМПЛЕКСЕ: МОДЕРНИЗАЦИЯ АРХИТЕКТУРЫ ПОДДЕРЖКИ ПРИНЯТИЯ РЕШЕНИЙ ПОСРЕДСТВОМ ИНТЕГРАЦИИ МАШИННОГО ОБУЧЕНИЯ 421
Н. Шаждекеева, А. Муханбеткалиева, А. Абдигалиева, А. Жанекешова, Л. Нургалиева
СРАВНИТЕЛЬНЫЙ АНАЛИЗ МАТЕМАТИЧЕСКИХ МОДЕЛЕЙ КОЛЛАБОРАТИВНОЙ ФИЛЬТРАЦИИ ПРИ ПОСТРОЕНИИ РЕКОМЕНДАТЕЛЬНОЙ СИСТЕМЫ ФИЛЬМОВ 445
С. Шармуханбет, Г. Турмуханова, О.Финдик, В.Махатова, М. Рахметов
ИНТЕЛЛЕКТУАЛЬНАЯ СИСТЕМА ОБНАРУЖЕНИЯ ДЕФЕКТОВ ТРУБОПРОВОДОВ С ИСПОЛЬЗОВАНИЕМ ВНУТРИТРУБНОГО РОБОТА 461

ИНФОРМАЦИОННАЯ БЕЗОПАСНОСТЬ И КОММУНИКАЦИОННЫЕ ТЕХНОЛОГИИ

С.З. Дәруіш, А.У. Утегенова, А.У. Калижанова, Ж.Ж. Жумабекова
МАШИННОЕ ОБУЧЕНИЕ ДЛЯ КЛАССИФИКАЦИИ ЗАГРЯЗНЕНИЯ РАЙОНОВ ПАДЕНИЯ РАКЕТ-НОСИТЕЛЕЙ 480
С.Н. Исабаева, А.К. Рысбаева, Ж.Б. Ибраева, Н.Р. Муссабеков, Н.Ш. Акимжан
ОБНАРУЖЕНИЕ КИБЕРАТАК В ОТ-СЕТЯХ НА ОСНОВЕ МАШИННОГО ОБУЧЕНИЯ: СРАВНИТЕЛЬНЫЙ АНАЛИЗ МЕТОДОВ КЛАССИФИКАЦИИ СЕТЕВЫХ АНОМАЛИЙ 495
Г.А. Шангытбаева, А.Н. Аманов, М.К. Исенова, Г.Е. Берикханова, Қ.О. Шакерхан
ИНФОРМАЦИОННАЯ БЕЗОПАСНОСТЬ В ОБЛАЧНЫХ СЕРВИСАХ ГОСУДАРСТВЕННЫХ ОРГАНОВ: ОЦЕНКА РИСКОВ И СТРАТЕГИИ ЗАЩИТЫ 512
Е.Н. Турсынбек, Н. Албанбай, Д. Дженоури
ОПТИМИЗАЦИЯ КОММУНИКАЦИОННЫХ ЗАТРАТ В ДВУХУРОВНЕВОМ ФЕДЕРАТИВНОМ ОБУЧЕНИИ ДЛЯ ОБНАРУЖЕНИЯ КИБЕРАТАК В IOT-СЕТЯХ 529
А. Тастемиров, С.Т. Аманжолова, Б. Алдош, С.Б. Муханов
СРАВНИТЕЛЬНАЯ ОЦЕНКА МОДЕЛЕЙ МАШИННОГО ОБУЧЕНИЯ ДЛЯ ОБНАРУЖЕНИЯ УГРОЗ В ACTIVE DIRECTORY: КОНТРОЛЬ УТЕЧКИ ПРИЗНАКОВ И КРОСС-СЦЕНАРНАЯ ВАЛИДАЦИЯ НА ЖУРНАЛАХ БЕЗОПАСНОСТИ WINDOWS 545

INTERNATIONAL JOURNAL OF INFORMATION AND COMMUNICATION TECHNOLOGIES
ISSN 2708–2032 (print)
ISSN 2708–2040 (online)
Vol. 7. Is.3. Number 27 (2026). Pp. 219–240
Journal homepage: https://journal.iitu.edu.kz
https://doi.org/10.54309/IJICT.2026.27.3.012

A NEURO-DIGITAL LEARNING MODEL FOR AI DRIVEN DIGITAL TRANSFORMATION IN HIGHER EDUCATION

D.B. Baumuratova[1,2,3], T.K. Zhukabayeva[1,2,3], K.A. Abdrakhmanov[2,3], Z. Ahmad[2,4], A.A. Seitov[5]*

[1]L.N. Gumilyov Eurasian National University, Astana, Kazakhstan;
[2]International Science Complex Astana, Astana, Kazakhstan;
[3]Astana International University, Astana, Kazakhstan;
[4]Hazara University, Mansehra, Pakistan;
[5]M. Auezov South Kazakhstan University, Shymkent, Kazakhstan.
E-mail: seitovaskar853@gmail.com

Dilaram B. Baumuratova — PhD, Senior Lecturer, Pedagogical Institute, Astana International University, Astana, Kazakhstan
https://orcid.org/0009-0009-4621-1886;
Tamara K. Zhukabayeva — PhD, Professor at L.N. Gumilyov Eurasian National University, Astana, Kazakhstan
https://orcid.org/0000-0001-6345-5211;
Kairat A. Abdrakhmanov — PhD, Vice President for International Cooperation and Student Affairs, Astana International University, Astana, Kazakhstan
https://orcid.org/0000-0002-7387-7191;
Zulfiqar Ahmad — PhD, Department of Computer Science and Information Technology Hazara University, Mansehra, Pakistan
https://orcid.org/0000-0002-6278-9516;
Askar A. Seitov — PhD Student, M. Auezov South Kazakhstan University, Shymkent, Kazakhstan
E-mail: seitovaskar853@gmail.com, https://orcid.org/0009-0009-7539-9806.

© D.B. Baumuratova, T.K. Zhukabayeva K.A. Abdrakhmanov, Zulfiqar Ahmad, A.A. Seitov

Abstract. The rapid development of artificial intelligence (AI) is transforming higher education from a traditional mode of information distribution to an intelligent, adaptive, and self-renewing system. In this paper, we analyze the evolution of paradigms of education in the so-called “presingularity era” when AI has attained a high level of capability and when final decisions are still made by humans. The goal is to construct a digital learning model for higher education using the theoretical bases of neuroeducation, brain-based learning and AI-based cognition. The methodology of

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

the work is based on a methodical analysis of scientific publications, international strategic documents and domestic experience, integrated with a qualitative approach and grounded Theory. The analysis considers the evolution of educational models from "Education 1.0" to "Education 6.0", emphasizing a transition from a teacher-centered system to an anthropo-digital synergy where the learner is a subject of coevolution and the teacher acts as a cognitive partner in collaboration with AI. This study also provides insights into the relationships among neuroeducation, brain-based learning and AI-based cognition. Cognitive load theory is used to explain how AI reduces the intrinsic load, limits the extraneous load and increases the germane load. The risks of AI cognition, such as weakening cognitive activity, fragmented attention and AI dependence, are also identified. The suggested paradigm combines neuroplasticity, brain-based learning, cognitive load optimization and AI cognition into a single model in which AI supports human thinking but does not replace it. The results have theoretical and practical consequences for educational science and the digital transformation of higher and postgraduate education in Kazakhstan (Smart.EDU).

Keywords: technological singularity, neuro-digital learning, neuroeducation, brain-based learning, AI cognition, cognitive load theory

For citations: Baumuratova D.B., Zhukabayeva T.K., Abdrakhmanov K.A., Ahmad Z., Seitov A.A. (2026). A Neuro-Digital Learning Model for AI Driven Digital Transformation in Higher Education // International journal of information and communication technologies. Vol. 7. No. 27. Pp. 219–240. https://doi.org/10.54309/IJICT.2026.27.3.012. (In Eng.).

Conflict of interest: The authors declare that there are no conflicts of interest.

Acknowledgment. *This research was funded by the Committee of Science of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Grant №BR28713531 Intelligent digital system of higher and postgraduate education organizations Smart.EDU).*

ЖОҒАРЫ БІЛІМ БЕРУДЕ AI НЕГІЗДЕЛГЕН ЦИФРЛЫҚ ТРАНСФОРМАЦИЯҒА АРНАЛҒАН НЕЙРО-ЦИФРЛЫҚ ОҚЫТУ МОДЕЛІ

Д.Б. Баумуратова[1,2,3], Т.К. Жукабаева[1,2,3], К.А. Абдрахманов[2,3], З. Ахмад[2,4], А.А. Сеитов[5]*

[1]Л.Н. Гумилев атындағы Еуразия ұлттық университеті, Астана, Қазақстан;
[2]Астана халықаралық ғылыми кешені, Астана, Қазақстан;
[3]Астана Халықаралық университеті, Астана, Қазақстан;
[4]Хазара университеті, Мансехра, Пәкістан;
[5]М.Әуезов атындағы Оңтүстік Қазақстан университеті, Шымкент, Қазақстан.
E-mail: seitovaskar853@gmail.com

Баумуратова Диларам Бекбулатовна — PhD, Астана халықаралық университетінің Педагогикалық институтының аға оқытушысы, Астана, Қазақстан
https://orcid.org/0009-0009-4621-1886;

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

Жукабаева Тамара Кокеновна — PhD, Л.Н. Гумилев атындағы Еуразия ұлттық университетінің профессоры, Астана, Қазақстан
https://orcid.org/0000-0001-6345-5211;
Абдрахманов Қайрат Амангельдинович — PhD, Астана халықаралық университетінің халықаралық ынтымақтастық және студенттер ісі жөніндегі вице-президенті, Астана, Қазақстан
https://orcid.org/0000-0002-7387-7191;
Зулфиқар Ахмад — PhD, Хазара университетінің компьютерлік ғылымдар және ақпараттық технологиялар кафедрасы, Мансехра, Пәкістан
https://orcid.org/0000-0002-6278-9516;
Сеитов Аскар Абилханович — докторант, М.Әуезов атындағы Оңтүстік Қазақстан университеті, Шымкент, Қазақстан
E-mail: seitovaskar853@gmail.com, https://orcid.org/0009-0009-7539-9806.

© Д.Б. Баумуратова, Т.К. Жукабаева, К.А. Абдрахманов, З. Ахмад, А.А. Сеитов

Аннотация. Мақалада жасанды интеллекттің (AI) қарқынды дамуы жоғары білім беруді ақпаратты таратудың дәстүрлі режимінен интеллектуалды, бейімделгіш және өзін-өзі жаңартатын жүйеге айналдыруда. Бұл мақалада біз AI жоғары деңгейдегі мүмкіндіктерге жеткен және соңғы шешімдерді адамдар әлі де қабылдайтын «сингулярлыққа дейінгі дәуір» деп аталатын білім беру парадигмаларының эволюциясын талдаймыз. Мақсат жоғары білім беруде нейробілім берудің, миға негізделген оқытудың және AI-танымның теориялық негіздерін пайдалана отырып, нейроцифрлық оқыту моделін құру. Жұмыстың әдіснамасы ғылыми басылымдардың, халықаралық стратегиялық құжаттардың және отандық тәжірибенің әдіснамалық талдауына негізделген, сапалық тәсілмен және негізделген теориямен біріктірілген. Талдау білім беру модельдерінің «Білім 1.0»-ден «Білім 6.0»-ге эволюциясын қарастырады, педагогке бағытталған жүйеден антропо-цифрлық синергияға ауысуды баса көрсетеді. Білім алушы бірлескен эволюцияның субъектісі болып табылады, ал педагог AI-мен бірлесіп когнитивті серіктес ретінде әрекет етеді. Зерттеу сонымен қатар нейробілім беру, миға негізделген оқыту және AI-таным арасындағы байланыс туралы түсінік береді. Когнитивті жүктеме теориясы AI-мен ішкі жүктемені қалай азайтатынын, сыртқы жүктемені қалай шектейтінін және қосымша жүктемені қалай арттыратынын түсіндіру үшін қолданылады. Сондай-ақ, AI-танымның когнитивті белсенділіктің әлсіреуі, фрагменттелген зейін және AI тәуелділік сияқты қауіптері анықталған. Ұсынылған парадигма нейропластикалықтықты, миға негізделген оқытуды, когнитивті жүктемені оңтайландыруды және AI танымдықты AI-мен тұлғаның ойлауын қолдайтын, оны алмастырмайтын бірыңғай модельге біріктіреді. Алынған нәтижелер білім беру ғылымы мен Қазақстандағы жоғары және жоғары оқу орнынан кейінгі білім берудің цифрлық трансформациясы үшін теориялық және практикалық салдарға әкеледі (Smart.EDU).

Түйінді сөздер: технологиялық сингулярлық, нейро-цифрлық оқыту, ней-

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

робілім беру, миға негізделген оқыту, AI-таным, когнитивті жүктеме теориясы

Дәйексөздер үшін: Баумуратова Д.Б., Жукабаева Т.К., Абдрахманов К.А., Ахмад З., Сеитов А.А. (2026). Жоғары білім беруде AI негізделген цифрлық трансформацияға арналған нейро-цифрлық оқыту моделі // Халықаралық ақпараттық және коммуникациялық технологиялар журналы. Т. 7. No 27. Б. 219–240. https://doi.org/10.54309/IJICT.2026.27.3.012. (Ағыл. тіл.).

Мүдделер қақтығысы: Авторлар осы мақалада мүдделер қақтығысы жоқ деп мәлімдейді.

Қаржыландыру. *Бұл зерттеу Қазақстан Республикасы Ғылым және жоғары білім министрлігінің Ғылым комитеті тарапынан қаржыландырылды (№ BR28713531 гранты «Жоғары және жоғары оқу орнынан кейінгі білім беру ұйымдарына арналған Smart.EDU интеллектуалды цифрлық жүйесі»).*

НЕЙРО-ЦИФРОВАЯ МОДЕЛЬ ОБУЧЕНИЯ ДЛЯ ЦИФРОВОЙ ТРАНСФОРМАЦИИ ВЫСШЕГО ОБРАЗОВАНИЯ С ПОМОЩЬЮ AI

Д.Б. Баумуратова[1,2,3], Т.К. Жукабаева[1,2,3], К.А. Абдрахманов[2,3], З. Ахмад[2,4], А.А. Сеитов[5]*

[1]Евразийский университет имени Л.Н. Гумилева, Астана, Казахстан;
[2]Международный научный комплекс Астана, Астана, Казахстан;
[3]Международный Университет Астана, Астана, Казахстан;
[4]Университет Хазара, Мансехра, Пакистан;
[5]Южно-Казахстанский университет имени М. Ауэзова, Шымкент, Казахстан.
E-mail: seitovaskar853@gmail.com

Баумуратова Диларам Бекбулатовна — PhD, старший преподаватель, Педагогический институт Международного университета Астана, Астана, Казахстан
https://orcid.org/0009-0009-4621-1886;
Жукабаева Тамара Кокеновна — PhD, профессор Евразийского национального университета имени Л.Н. Гумилева, Астана, Казахстан
https://orcid.org/0000-0001-6345-5211;
Абдрахманов Кайрат Амангельдинович — PhD, Вице-президент по международному сотрудничеству и делам студентов Международного университета Астана, Астана, Казахстан
https://orcid.org/0000-0002-7387-7191;
Зульфикар Ахмад — PhD, кафедра компьютерных наук и информационных технологий, Университет Хазара, Мансехра, Пакистан
https://orcid.org/0000-0002-6278-9516;
Сеитов Аскар Абилханович — докторант, Южно-Казахстанский университет им. М. Ауэзова, Шымкент, Казахстан
E-mail: seitovaskar853@gmail.com, https://orcid.org/0009-0009-7539-9806.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

© Д.Б. Баумуратова, Т.К. Жукабаева, К.А. Абдрахманов, З. Ахмад, А.А. Сеитов

Аннотация. В статье исследуются быстрое развитие искусственного интеллекта (AI) трансформирует высшее образование из традиционного способа распространения информации в интеллектуальную, адаптивную и самообновляющуюся систему. В данной работе анализируется эволюция парадигм образования в так называемую «предсингулярную эпоху», когда AI достиг высокого уровня возможностей, а окончательные решения по-прежнему принимаются людьми. Цель состоит в построении нейро-цифровой модели обучения в высшем образовании с использованием теоретических основ нейрообразования, обучения на основе работы мозга и AI-когниции. Методология работы основана на методическом анализе научных публикаций, международных стратегических документов и отечественного опыта, интегрированном с качественным подходом и обоснованной теорией. Анализ рассматривает эволюцию образовательных моделей от «Образования 1.0» до «Образования 6.0», подчеркивая переход от системы, ориентированной на преподавателя, к антропо-цифровой синергии, где обучающийся является субъектом коэволюции, а преподаватель выступает в качестве когнитивного партнера в сотрудничестве с AI. Исследование также позволяет понять взаимосвязь между нейрообразованием, обучением на основе работы мозга и когнитивными функциями AI. Теория когнитивной нагрузки используется для объяснения того, как AI снижает внутреннюю нагрузку, ограничивает внешнюю нагрузку и увеличивает релевантную нагрузку. Также выявлены риски когнитивных функций AI, такие как ослабление когнитивной активности, фрагментация внимания и зависимость от AI. Предложенная парадигма объединяет нейропластичность, обучение на основе работы мозга, оптимизацию когнитивной нагрузки и когнитивные функции AI в единую модель, где AI поддерживает человеческое мышление, а не заменяет его. Полученные результаты имеют теоретические и практические последствия для педагогической науки и цифровой трансформации высшего и послевузовского образования в Казахстане (Smart.EDU).

Ключевые слова: Технологическая сингулярность, нейро-цифровое обучение, нейрообразование, обучение на основе работы мозга, AI -когниция, теория когнитивной нагрузки

Для цитирования: Баумуратова Д.Б., Жукабаева Т.К., Абдрахманов К.А., Ахмад З., Сеитов А.А. (2026). Нейроцифровая модель обучения для цифровой трансформации высшего образования с помощью AI // Международный журнал информационных и коммуникационных технологий. Т. 7. No. 27. Стр. 219–240. https://doi.org/10.54309/IJICT.2026.27.3.012. (На англ.).

Конфликт интересов: авторы заявляют об отсутствии конфликта интересов.

Благодарность. *Данное исследование финансировалось Комитетом науки Министерства науки и высшего образования Республики Казахстан (грант № BR28713531 «Интеллектуальная цифровая система организаций высшего и*

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

послевузовского образования Smart.EDU»).

Introduction.

At the present stage, the development of the education system is considered closely connected with the concept of technological singularity. The rapid development of AI has had a very large impact on the existing sphere of society, including education. Owing to this, education began to move from the traditional model of information delivery to an intelligent, independent and adaptive system. Standard knowledge of an industrial nature is gradually losing its importance, and new approaches are coming to replace it on the basis of joint development and wisdom. Previously, the system was based on the accumulation of documentary data, but its limitations are clearly visible. AI can perform the functions of processing, analyzing, and synthesizing information itself. Therefore, the content and methods of education need to be revised. In the works of Vernor Vinge and Ray Kurzweil, technological singularity is described as a hypothetical stage in which AI surpasses human intelligence (Luksha, 2025). The present title is referred to in the scientific literature as the "presingular era". At this stage, AI has not yet become a fully autonomous system, although it has reached a high level. The labor market is also changing. Nevertheless, the decision is still made by a person, and this has a large weight. At this point, one question becomes relevant: will AI limit human capabilities or open the way to a new civilizational stage? There is no unambiguous answer to it. Therefore, the impact of AI on human potential is considered from a double point of view: whether it is an extender or a deterrent. Such changes are already felt, so it is advisable to systematically analyze them from a scientific point of view and prepare them in advance in the fields of education, economics, and management.

The idea of developing a singularity has been attributed to a number of researchers. One of the first to note the progressive character of technical advancement was John von Neumann (Acuña, 2021). In the footsteps of I. J. Goode's notion of an "intellectual explosion" (Good, 1966) that described the potential of AI to enhance itself. Vernor Vinge defined singularity as a qualitative turning point in human civilization (Vinge, 2008). However, Ray Kurzweil associated it with the exponential increase in technology development and suggested real-time projection (Kurzweil, 2005). The concept of singularity has developed at the confluence of scientific and philosophical perspectives and has become an important component of modern technology discourse. It is better preserved in John von Neumann's opinions about this in his obituary of Stanislav Ulam in 1957 than in his own work (Ulam, 1980). The gradual nature of technological advancement is emphasized, as the growth of humans is approaching a specific boundary. This notion is clarified by analogy with the concept of singularity in physics. Whatever the limit at which the law of space and time alters, the same qualitative shift in human history can be brought about by technological growth. Later, J. Hood had this thinking. He went on with his task. He developed idea of "intellectual explosion" on the basis of the self-improvement of AI. From this perspective, intelligent systems can recursively develop themselves and lead to very

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

fast intelligence growth.

The concept of singularity has been systematized in a unique way by Vernor Vinge (Vinge, 2017). This phenomenon he connected with the arrival of superintelligence and the "intellectual explosion". He considered it a qualitative boundary in the history of mankind. In his latest publications, Vinge paid more attention to the integration of human intelligence and machine intelligence. In this sense, singularity began to be understood not as a solely technological transformation but as a product of the connection between man and technology. This means a change in the social and cognitive system. Singularity was popularized in the broader scientific community by Kurzweil (Kurzweil, 2026). He said that technology advancement is exponential, and could have occurred approximately 2045. Kurzweil predicts that the development of AI will go hand-in-hand with biotechnology and human-machine fusion, thus enhancing human cognition. This view enables us to understand singularity not only as a technological event but as a time of evolution of the planet. It reflects the phrase of Pierre Teilhard de Chardin "Omega Point" (de Chardin, 2021). Therefore, singularity is a notion of an evolutionary process emerging from the merging of different scientific and philosophical concepts. However, today's science has not adopted it as a universal model. This statement cannot encompass the complexity of technical and social development. Thus, singularity in this study is not a speculative one-time event but a continual and complicated process of human growth. It is not only a mirror of the future but also of the transformation that is occurring now (Cunningham, 2019). This method provides a way to look at the development of AI, which intensified significantly after 2020, from a broad evolutionary perspective. In contemporary scientific and public discussions, word singularity is often connected with the notion of superintelligence and an "intellectual explosion". However, that is not the whole of its nature. The increasing complexity and restriction of human control were also features of earlier historical times.

With the development of technology, the introduction of neuroscience into education is also deepening. Brain-computer interfaces are considered the next stage of neurolearning. In the future, people can interact with digital content directly on a neurophysiological level. Such systems measure brain activity and provide feedback at the same time. AI systems can control the level of human attention and independently adjust the complexity of the material. This reduces excessive cognitive load. Intelligent systems that consider emotions are also being developed. For example, they could control anxiety, consolidate attention and direct themselves to adapt to learning. Independent neuroscience-based technologies are transforming education into a more flexible system (Goodwin, 2022).

The rapid development of AI has a deep impact on all spheres of society, especially education. Education is moving from a traditional model of information delivery to an intelligent, independent and adaptive system. Since AI itself can process, analyze and synthesize information, the limitations of the former system based on the accumulation of documentary data are clearly visible. In this regard, there is a need for a radical review of the content and methods of education. Today's period is called

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

the "era before singularity" in the scientific literature: Although AI has reached a high level, the decision is still made by man. It is at this point that the double question of whether AI is an extender or a deterrent to human potential becomes relevant. A systematic analysis of these changes from a scientific point of view and a preliminary preparation of the areas of education, economics and management have become urgent tasks. For Kazakhstan, this relevance is due to the digital transformation of higher and postgraduate education ("Smart.EDU" direction) is directly related. Development of a neuro-digital learning model for higher education through a systematic analysis of the transformation of educational paradigms in the era of singularity, the conceptual foundations of neuroeducation and learning, and international and domestic experience. Our six research questions are as follows:

RQ1: Will AI limit human capabilities or pave the way for a new civilizational stage?

RQ2: How have educational paradigms been transformed to meet the demands of society and the development of technology?

RQ3: How are the areas of neuroeducation, brain-based learning, and AI related and why are they separated?

RQ4: How can the cognitive load (internal, excessive, useful) be effectively balanced in AI-supported learning?

RQ5: Will AI support a person's thinking, or will it make him or her dependent on it?

RQ6: What learning model that combines neuroscience, cognitive psychology and AI can meet the requirements of modern education?

The scientific novelty of the study consists of the reconceptualization of technological singularity not as a single future event, but as a continuous, multidimensional evolutionary process already in progress, which makes it possible to consider the development of artificial intelligence in education in the broad evolutionary environment of human cognition rather than in a narrow technological environment. On this basis, the study systematizes the evolution of educational paradigms from "Education 1.0" to "Education 6.0" and substantiates the regular transition from a teacher-centered model to an anthropo-digital synergy, in which the learner becomes a subject of coevolution and the teacher a cognitive partner acting together with AI. Neuroeducation, brain-based learning and AI-based learning are integrated and differentiated for the first time in a common analytical framework by their goals, scientific foundations, methods and dangers, and cognitive load theory is employed to characterize AI-supported learning to demonstrate how AI can decrease the intrinsic load, increase the germane load and constrain extraneous load while generating hazards such as cognitive offloading, attention fragmentation and AI dependency. The main contribution is an original neuro-digital learning model that combines neuroplasticity, brain-based learning, cognitive load optimization and AI cognition into a single anthropo-digital pedagogical system based on the principle of AI complementing and reinforcing human thinking, not replacing it, thus turning the learner from a passive user of the digital environment into an active subject who

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

manages his/her own cognitive development. The theoretical and practical value of the study is also increased by the application of the model to the digital transformation of higher and postgraduate education in Kazakhstan (Smart.EDU).

Materials and methods.

Research methodology

The methodological basis of the study is a systematic analysis of scientific publications, international strategic documents and domestic experience in the transformation of educational paradigms, neuroeducation and teaching in the era of singularity, and digital transformation in higher education. Such an analysis is aimed at identifying the scientific and theoretical foundations of the digitalization of the educational environment, as well as a comparative study of foreign and national approaches. To achieve this goal, methods of a qualitative methodological approach and grounded theory are used. (Turner, 2021). This approach allows one to construct a conceptual model from empirical data on the basis of systematic analysis. The proposed methodology consists of five stages aimed at developing a model of neuro-digital learning in higher education and identifying and analyzing the conceptual foundations and international and domestic experience. These stages are described in Fig.1 and presented as a practical example.

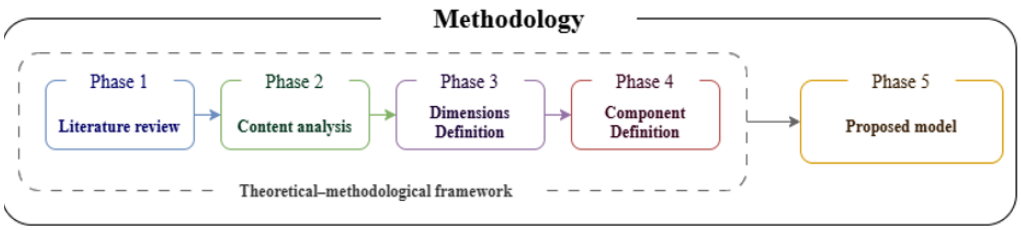


Fig. 1. Applied research methodology

Figure 1 presents the methodological basis for the development of a neuro-digital learning model. It shows a five-step research process that combines theoretical analysis, conceptual synthesis, comparative analysis, model construction and interpretation of its application to higher education. Additionally, in the literature review, we identified the advantages and disadvantages of the Education 6.0 model (Table 1).

Research has also influenced these changes. They allowed us to take a different look at the learning process and paved the way from pedagogically oriented models to student-oriented paradigms. In addition, technological progress has changed the content and format of education. This has created new opportunities for personalization, expansion, and flexible organization of training. As a continuation of these changes, the concept of “Knowledge 6.0” was formed. This model characterizes the education system both in the present and in the future. Its main features are high-level personalization; immersive learning; and the wide use of new technologies such as AI, IoT, and blockchain (Gandawa, 2026; Gandawa, 2025). Such a “smart evolution” is carried out through high-quality technological programs and takes the education

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

system to a new level.

Table 1. Advantages and disadvantages of the Education 6.0 model

Advantages	Disadvantages
Through high-level personalization of AI and data analytics, the ability of each student to form an individual learning trajectory is expanded.	Data security and privacy risks exacerbate the problems of collecting large amounts of student data, protecting personal data, ethical use of data, cybersecurity, there is a need to implement the principle of "privacy by design".
The integration of technology and the human factor in the educational process, AI, Big Data and neurotechnologies are combined with supporting human cognitive and social development.	Ethical issues and personality the balance of technology risks that technology is not seen as an end, but as a means, and that humanistic values may be weakened.
Support for continuing education the education system will focus on continuous training and retraining.	Effects on psychological well-being increased digital workload, the influence of AI tools on motivation, and an increase in stress and emotional distress.
Experiential and real - life oriented learning the integration of theory and practice on the basis of experiential learning is enhanced.	Digital inequality inequality of infrastructure and resources, an increase in the gap between students.
The development of metacritics develops critical thinking, adaptability, self-regulation and the ability to solve complex problems.	The negative effects of generative AI are reduced cognitive effort, dependence on ready-made responses, and the risk of weakening critical thinking skills.
Inclusive and accessible educational opportunities digital technologies provide a wide range of access to education, which reduces geographical and physical restrictions.	The complication of the role of a teacher is the merger of the roles of a facilitator, mentor, analyst, an increase in the professional load, the need for continuous acquisition of new competencies.
Data-based management and decision-making it is possible to improve the quality of education through the analysis of learning outcomes.	The risk of hyper personalization is a weakening of the common educational base, fragmentation of educational content, a decrease in social cohesion.

"Education 6.0" is not only the continuation of the previous models or just another new version. It is a wider and more systematic approach to the overall development of the individual. Here, education is not a matter of giving out information. The emphasis is on leadership, entrepreneurship, critical thinking and the development of a personality designed to cope with future change. Nontraditional thinking, new ideas and innovative activities are important. In this model, the use of advanced technology plays a main role. However, technology is considered only as a tool, and in its application, it is considered important to respect the principles of ethics and sustainable development. This favor the social responsibility of the student and develops the ability to adapt to a changing environment

Results.

Educational models are constantly evolving. They are also subject to change with a changing society. If the economy is refreshed, new technology is introduced, or people's values move, and then education, the style and the content of its instruction become clear. At any stage of the education system, it was possible to prepare a

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

competitive specialist that society needed. Consequently, learning theories have also changed, with a focus on providing people with the knowledge, skills and competences needed to address complex social challenges. The old system, gained through the industrial revolution, was based on a fixed curriculum, the leading role of a teacher and a rigorous evaluation. It is designed primarily for the training of skilled personnel for manufacturing. Society needed something else later. The theories of learning have evolved, the pedagogical method has been reformed, different technologies have become widespread and the economy has gradually shifted to a knowledge-based paradigm. These developments called for the reform of the school system (Shaji, 2025). A stepwise evolution was developed from the "Education 1.0" model, where the teacher plays a key role in the "Education 6.0" model, where the student is an active participant (Fig. 2). Figure 2 describes the evolution of educational paradigms from "Education 1.0" to "Education 6.0".

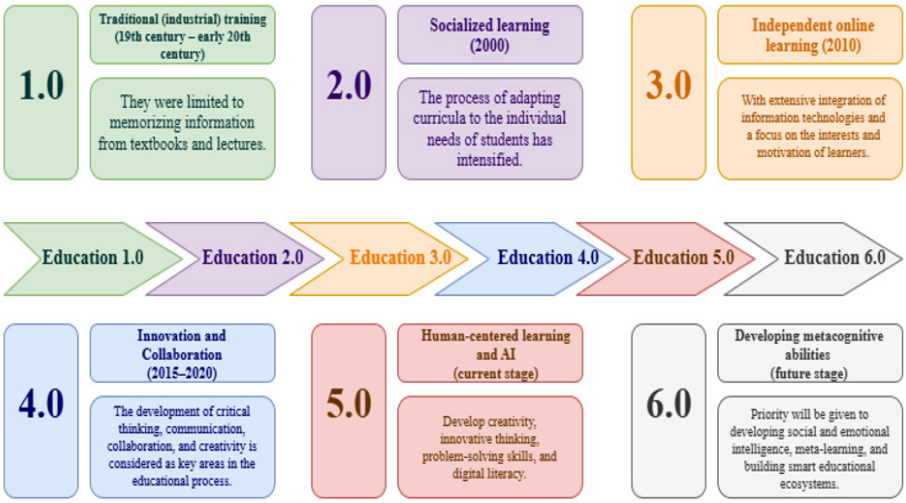


Fig. 2. Evolution of educational models

The development of educational models does not stop with changes in the content and methods of training. It is aimed at identifying and revising the role of the student in the process. The "Education 1.0" model, which was formed at the beginning of the XX century under the influence of the industrial revolution, relied on strict discipline, standardized content and conveyor logic. At that time, the learner was often considered a passive person who received ready-made information. The main goal of the system is to train the personnel needed by industry. However, over time, this model began to be criticized since it did not consider the personality, interests and thinking of a person. During this period, scientists such as John Dewey, Jean Piaget, and Lev Vygotsky reported that learning should be based on experience, personal development and social interaction. Thus, the idea was formed that knowledge is not transmitted ready-made but is actively compiled by a person himself. By the middle and end of the XX century, the amount of data related to the analysis of educational results increased,

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

and the internet became widespread. This influenced the formation of the "Education 2.0" model. Although elements of personalization were introduced during this period, the main role of the teacher in teaching remained. Even if the technology was used, it did not radically change the learning system.

At the beginning of the XXI century, the development of digital technologies and the spread of constructivist theories paved the way for the "Knowledge 3.0" model. In this model, more attention was given to the interests of the student and the individual educational trajectory. However, excessive emphasis on personalization in some cases weakens the skills of communication between people. After that, the "Education 4.0" model was formed. Joint reading, problem-oriented tasks and the application of knowledge in a life situation came to the fore here. However, too much attention to a specific practical skill inhibits the full development of metacritics. To reduce this limitation, the "Education 5.0" model began to be developed. It focuses on personal development, creativity, critical thinking, innovation, problem solving, digital literacy, and continuing education. In addition, it aims to create an intelligent educational environment that relies on the interaction between humans and AI. Here, learning is adapted to the cognitive, emotional, and social identities of the learner through AI, big data and adaptive algorithms. Metalearning, digital ethics and algorithmic thinking are considered important competencies. In this way, the evolution of education was accompanied by a change in teaching approaches, technologies and educational philosophies. These changes are important for understanding the possibility of the concept of "Education 6.0" (Table 2).

Table 2. Comparative knowledge analysis 1.0 – 6.0

Criterion	Education 1.0	Education 2.0	Education 3.0	Education 4.0	Education 5.0	Education 6.0
Pedagogical paradigm	Teacher-oriented	Standardization and control	Student-oriented	Competence-oriented	Personality-oriented	Anthropo-digital synergy
The role of the teacher	Main source of knowledge	Observer, appraiser	Mentor, facilitator	Moderator	Curator, consultant	Cognitive partner (with AI)
The role of the student	Passive receiver	Performer	Active participant	Problem solver	Personal trajectory owner	Coevolution subject
Learning approach	Lecture, memorization	Standardized tasks	Project-based	Problem-based learning	Personalized learning	Hyper-personalized, adaptive
Educational content	Fixed	Standardized	Flexible, inquisitive	Interdisciplinary	Interdisciplinary creativity	Dynamic, self-renewing
Rating system	Written tests	National standardized tests	Formative assessment	Based on competence	Personalized assessment	Predictive and data-driven
The role of technology	No or minimum	Additional tool	Integrated	Active use	AI and analytics	AI, XR, neurotechnologies
Training format	Classy, traditional	Mixed	Online, offline	Hybrid	Digital system	Virtual environment, MR
Basic skills	Memory	Performance	Creativity, collaboration	Critical thinking, communication	Meta-learning, innovation	Cognitive flexibility, conscious thinking
Cooperation	Low	Limited	High	Teamwork	Global cooperation	Human-AI collaboration
Personalization level	No	Low	Average	Average	High	Hyper-personalization
Training environment	Physical class	Organizational	Digital space	Smart environment	Intelligent system	Digital Without Borders-bioenvironment
The main purpose	Education	Compliance with standards	Self-study	Formation of competence	Disclosure of personal potential	Transformation of consciousness

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

These transformations are proof that the teacher-student connection is constructed in a very different manner than before. The main role was played by the teacher, but now the activities and independence of the student are coming to the fore. Digital technologies and AI are becoming basic elements of the educational process at the same time. If we see the evolution of the education system, it is quite evident that the aim of the education system is not only to provide information, as it was earlier. Today, it is about the attitude of a person, his ingenuity and ability to swiftly adapt to a new circumstance. Technology and AI have fundamentally changed the learning space. As the trend of EdTech becomes more extreme, future training systems will likely evolve to a more flexible style with more intelligence. Thus, the main task of the education system of today is to teach a person who is easily adaptable to change, thinks independently, and does not rely on a ready-made answer and freely masters it in a digital environment.

At the heart of the concept of "Education 6.0" is the idea of complementarity between man and machine. That is, technology is not used to replace a person but to strengthen his or her creativity, problem-solving ability and innovation ability. In addition, this model aims to create an environment that supports continuing education, interdisciplinary solidarity, and ethical decision-making (Nieto, 2026). Owing to this, the education system strives to become more flexible, more efficient and accessible to everyone. The main features of this model are as follows (Fig. 3):

- Adaptive AI-based learning has been widely applied. AI can customize the learning process automatically depending on the student's abilities and needs;

- The application of blockchain in the preservation and validation of educational achievements has already started. This enhances the security, openness and credibility of educational certifications;

- Immersive and interactive learning has developed. Through technologies such as VR, AR, and MR, the learning process is organized in a format that is closer and more interesting to practice;

- More emphasis was placed on personal skills. Universal abilities such as creativity, empathy, and critical thinking have become among the core competencies;

- The principle of continuous education has been strengthened. As the labor market is changing rapidly, people's need to constantly reread and acquire new skills is seen as an important factor. Figure 3 presents the main components of "Education 6.0".

The development of "Education 6.0" has led to the increasing integration of technology and pedagogy. This makes the educational process more adaptable than ever and adaptable to the needs of all (Moleka, 2023). Six guiding concepts underpin the model. There is one final goal. Completion of the development of personality. To prepare it for the complicated requirements of today's society (Fig. 4). Figure 4 presents the key principles of the Education 6.0 system that support the holistic development of learners.

The core ideas of the "Education 6.0" model suggest the all-round growth of the student. They are:

- Holistic learning develops the student's mind and emotions and social and

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

ethical dimensions in conjunction. Therefore, he develops a feeling of sympathy, responsibility, and the ability to communicate with a person.

- The multidisciplinary approach involves blurring the boundaries between different areas. Afterward, the student will be able to learn the full knowledge and see a complicated topic from multiple sides.

- The premise of sustainability and ethics is the concept of environmental responsibility and sustainable development. Here, the pupil is taught to estimate what trail his doings leave to society and nature.

- Awareness of the world's civic cultural diversity, not apathetic to global problems, the ability to operate freely in varied contexts.

- The idea of lifelong learning encourages continuous learning. Technology and the labor market are changing so fast that a person has to keep up with it.

- Advanced technologies in the learning process. This includes such tools as AI, VR, AR and blockchain. With their guidance, you can view a complex concept with the naked eye and feel it with your hands.

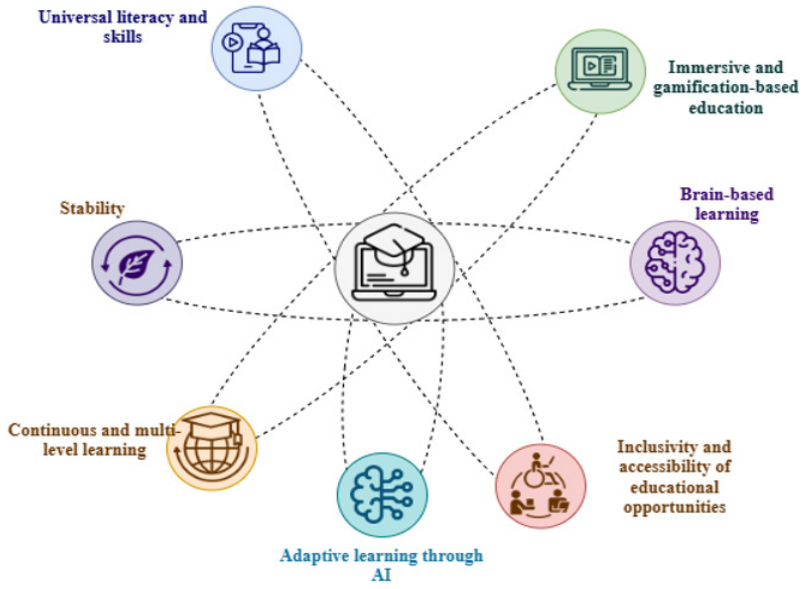


Fig. 3. Components of "Education 6.0"

Thus, these principles educate the learner not only with knowledge but also with the skills and values needed in the current world. In an age of rapid technological progress, education will need to be drastically altered (Swargiary, 2026).

Brain-based learning (educational neuroscience) is a pedagogical approach that involves organizing learning on the basis of the functioning of the brain. The main idea here is to create a learning environment that meets the natural perception feature of the human brain. For this reason, it is not enough to simply provide information in this teaching. In contrast, active action, experience, and the parallel connection of several senses come to the fore. This approach helps students to better master knowledge and skills. In brain-based learning, understanding brain function is central. This is because

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

it allows the teacher to compose the educational material not just as a theory but also by taking into account how the person perceives it. For example, a task involving several senses, joint work, or an activity that requires active participation keeps information firmly in memory. Then, a person will be able not only to perceive the material but also to apply it later in practice. The development of this direction is associated with the deepening of the scientific understanding of the brain.

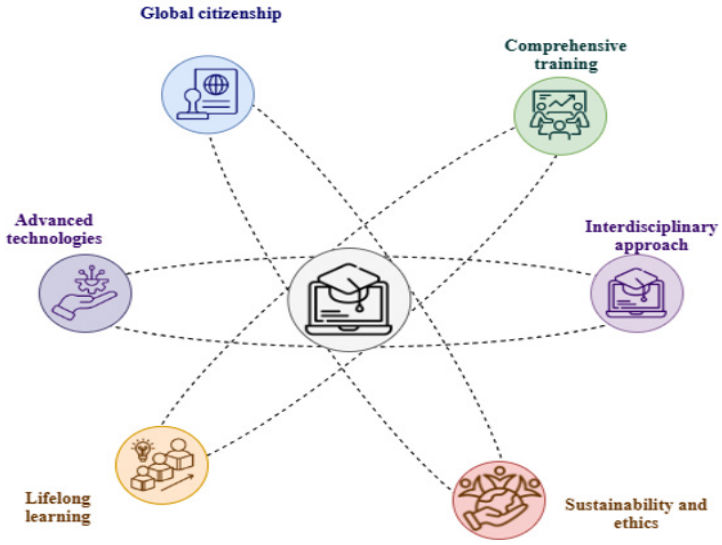


Fig. 4. Principles of "Education 6.0"

Brain-based learning is based on several fundamental ideas. One way to do this is to consider the specificity of the memory system; that is, information must be organized according to the ability of a person to recall. It would also be good if the educational content is structured so that attention is kept. New information together with past expertise help make a person understand the content better. If there is much knowledge, and it is disorganized, the cognitive load increases, and learning becomes more difficult. Hence, the proper amount of information is also among the main factors. Additionally, the role of emotions in learning and memory is considered: material that touches the soul is usually stored for a long period. One advantage of this method is that it is free of "neuromyths", for which there is no scientific basis. Not so here. It is not unusual, but it is a concept not explained by science. Brain activity was first explained at a very basic level. Later, the theories of the right and left cerebral hemispheres began to propagate. The triple-brain notion of Paul McLean also became widespread. The paradigm suggested that the bottom of the brain was for life, the middle for emotions and the top for thinking. Although these theories are now subject to critique, they have shaped the development of educational neuroscience.

The parallel use of such a strategy allows the results of training to be consistently improved. In the modern education system, neuroeducation, brain-based learning and AI-based cognition are closely related (Table 3). The ultimate goal of all three is to

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

increase the cognitive effectiveness of one study, but the theoretical basis, method, and technology used are separate. Moreover, the intensive introduction of AI into education has raised the problem of cognition to a completely new level. Now, a surprise question came to the fore: will AI support human thinking, or will it make it dependent on it? The balance between these two extremes has become an urgent problem.

Table 3. Neuroeducation, brain-based learning and AI-based communication

Criterion	Neuroeducation	Brain-based learning	AI-cognition
Purpose	Implementation of neuroscience data in the educational process	Aligning learning with the natural principles of brain functioning	Support and modeling cognitive processes through AI
Scientific basis	Cognitive neuroscience, psychology, pedagogy	Neuropsychology and learning science	AI, Cognitive Science, Learning Analytics
Main focus	Neural mechanisms of learning and memory	Attention, emotion, memory and motivation	The cognitive interaction between human and AI
Methods	Neuroeducation, active recall, intermediate repetition	Multi sensory learning, storytelling, collaboration	Adaptive learning, AI pedagogue, predictive analytics
Cognitive impact	Strengthening neural connections	Deep assimilation of information and increased motivation	Cognitive reinforcement and information automation
Advantages	Strengthens long-term memory	Increases training efficiency	Creates a personalized learning environment
Risks	Cognitive overload	Separation of attention	AI dependency and cognitive load reduction
The role of the student	Active cognitive subject	Emotional and cognitive participant	Hybrid learner (personality + AI)
The result	Cognitive flexibility	Deep learning and involvement	Formation of neuro-digital cognition

AI-based cognition has become one of the street areas of Science today. It is not limited to the automation of education. AI began to influence the cognitive activity of a person itself (Table 4).

Table 4. Cognitive implications of AI cognition

AI-the phenomenon of cognition	Description	Cognitive implications
Reducing cognitive load	Transfer of the functions of thinking and memory to AI	Weakening of independent cognitive activity
AI-generated memory	Memory support via AI	Quick search and organization of information
Attention fragmentation	Fragmentation of attention due to digital stimuli	A decrease in deep focus and analytical thinking
Algorithmic thinking	Thinking through algorithmic logic	Structural analysis intensifies, but creativity may be limited
AI dependency	Excessive dependence on AI tools	The weakening of metacognition and critical thinking

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

Cognitive load theory has a separate place in the interpretation of neuroeducation and AI-supported learning. It allows you to distinguish what load the brain is facing in a digital learning environment where AI is used (Fig. 5). Figure 5 describes the cognitive load structure in digital learning supported by AI.

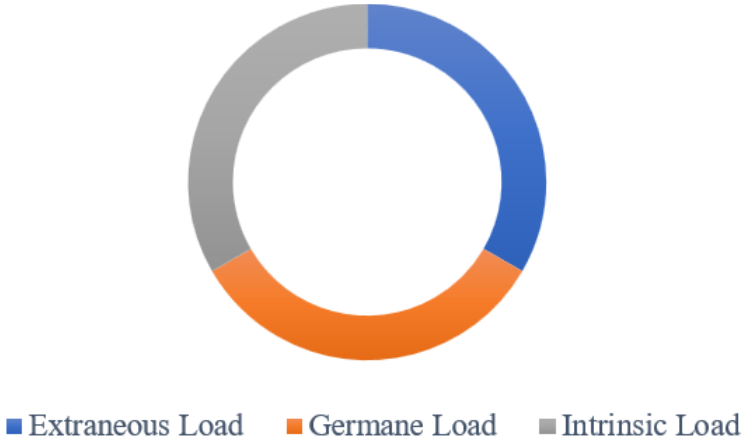


Fig. 5. The structure of the cognitive load in digital learning

The internal load accounts for the largest share. It depends on a few variables. Complexity of the educational material and initial pupil preparation. AI systems can alleviate this burden slightly by organizing information, analyzing it for everyone and providing individual feedback. An overload not directly related to learning content is an overload. In the digital world, it is due to the collision of several activities, a variety of notifications, an excess of information and the dispersion of attention. Rather, AI systems are more prone to overclock this overload if they are not pedagogically adequately developed. Exercise that uses valuable mental energy for meaningful thought, deep learning and the creation of new neural pathways. This load is closely related to neuroplasticity and is crucial for improving analytical thinking, metacognition and problem-solving skills (Table 5).

Table 5. Cognitive load theory and AI relationship

Cognitive load component	Content	AI communication
Intrinsic Load	Natural complexity of the material	AI interprets complex content step by step
Extraneous Load	Excess information load	Excessive digital stimuli increase cognitive load
Germane Load	Cognitive resource aimed at structuring knowledge	Strengthens the concept of AI through mapping and reflexive learning

Discussion.

Research shows how necessary it is to properly balance the cognitive load in AI-supported learning. AI is not a tool that replaces all human thinking. It should be used as a system that supports, and strengthens cognitive ability. In the modern era

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

of AI, the education system is not limited to digitalization but is being rebuilt on a neurocognitive basis. Neuroeducation, the relationship between brain-based learning and cognitive load theory, formed the basis for the formation of a new anthropo-digital pedagogy supplemented by AI. In the framework of, the proposed neuro-digital learning model sees the learner as an active participant in the cognitive partnership between humans and AI and not as a mere user of AI. This is one of the new paradigm directions in modern educational science. Today, the education system is changing significantly under the influence of neuroscience, cognitive psychology and AI. Thus, neuroeducation and brain-based learning have become the leading scientific directions for understanding the changeable and adaptive nature of the learner's brain. In the framework of neuroeducation, the learning process affects the formation of new neural connections in the brain. Brain-based learning involves aligning learning approaches to the natural cognitive mechanisms of the brain.

The development of AI technology has also brought the problem of cognition to a new level. Now several concepts describe the change in human cognition. Reduced cognitive load, memory with AI, distraction, algorithmic thinking, and AI dependency. In reducing the cognitive load, a person transfers part of the work of memory to a digital device and an AI system. This, at first glance, allows you to focus more on a complex analytical task, but also carries the risk of weakening long-term memory. External memory systems created by AI make it easier to store and rediscover information. Only in this case may the activity of independent thinking decrease. In addition, the continuous flow of information in the digital environment destabilizes attention and dulls the ability to read deeply and focus for a long time. Therefore, in the modern education system, honing deep thinking and constant attention has become one of the main tasks. In the era of AI, algorithmic thinking is a new type of logical, structured thinking. It helps to solve the problem systematically, although if it is exceeded, it can introduce creativity and critical reflection. AI dependency is the risk that a person relies excessively on AI in decision-making. Therefore, the main pedagogical principle of using AI is not to replace human intelligence but to support and strengthen it. Cognitive load theory plays an important role in explaining these problems.

AI technology can optimize the quality of training by tuning and changing the major component of the load. For example, picturing a complex idea decreases the internal load, filtering out unnecessary information lessens the overload, and reflection and knowledge mapping increase the useful cognitive load. The integration of AI and neurotechnology into higher education raises ethical issues that extend beyond the effectiveness of digital learning. Within the proposed neuro-digital learning model, ethical governance should therefore be considered an integral component of human AI cognitive interaction rather than an additional technological requirement (Fig. 6). Figure 6 shows a neuro-digital learning model that integrates neuroplasticity, brain-based learning, cognitive load, and AI cognition into an anthropo-digital pedagogical system aimed at supporting AI cognitive synergy.

This model is an anthropo-digital pedagogical system that combines neuroplasticity, brain-based learning, cognitive load theory and AI cognition in one

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

channel. His original idea is simple. AI should not replace students' thinking but should again support and strengthen their cognitive abilities. In the model, while neuroplasticity is the adaptive backbone of the learner's brain, brain-based learning involves creating a learning environment that is compatible with the natural cognitive process. The cognitive load optimization mechanism attempts to strike a balance between internal, external and useful cognitive load. In the AI-cognition phase, AI systems function as tools for metacognitive support, reflection, and cognitive partnership. Then a cognitive synergy is born between a person and the AI: the learner ceases to be an indifferent user in the digital environment and becomes an active subject who himself or herself controls his or her cognitive development. In short, the neuro-digital learning model combines neuroscience, cognitive psychology and AI, a new paradigm trend in modern educational science. His ultimate idea is that AI does not replace human intelligence but rather expands its cognitive potential.

The major contribution of this study is the neuropedagogical learning model, which merges four previously separate research areas, namely, neuroscience (neuroplasticity), brain-based learning, cognitive load theory, and AI-driven cognitive processes, into one operational framework. Most of the present digital learning models make use of only one of the areas or are neutral with respect to the cognitive architecture of the learner. However, the proposed model sees them as interdependent layers within a single process, where neuroplasticity forms the adaptive base, brain-based learning forms the learning environment, and cognitive load theory provides the regulation of the distribution of mental effort and cognitive processes driven by AI to provide metacognitive support.

The second aspect of innovation is the explicit technique of artificial intelligence intervention. Instead of describing AI as a general tool of "adaptation", the model describes its function from the perspective of cognitive load theory: AI alleviates internal load by structuring complex information, reduces external load by filtering irrelevant stimuli, and increases relevant load through reflection and matching of knowledge. The learner is not conceived as an object that can be optimized by an algorithm but as a codeveloping entity that maintains agency in its own cognitive development. The model structurally embeds meta-awareness and reflection rather than having to add them as a way of dealing with the known dangers of using AI, such as reduced independent cognition, fragmentation of attention, and excessive dependence.

These features distinguish this model from the approaches that currently dominate in this field. Adaptive learning optimizes content delivery on the basis of performance data but does not consider either brain function or student independence; intelligent education focuses on technologically saturated environments; and AI-enabled learning complements the performance of specific tasks, while largely ignoring the risk of addiction; and "Education 6.0", although broad and humanistic, functions as a social paradigm rather than an operational learning model. The proposed model connects the microlevel neurocognitive processes with the macrolevel digital infrastructure and management in the context of the Kazakh program Smart.EDU.

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

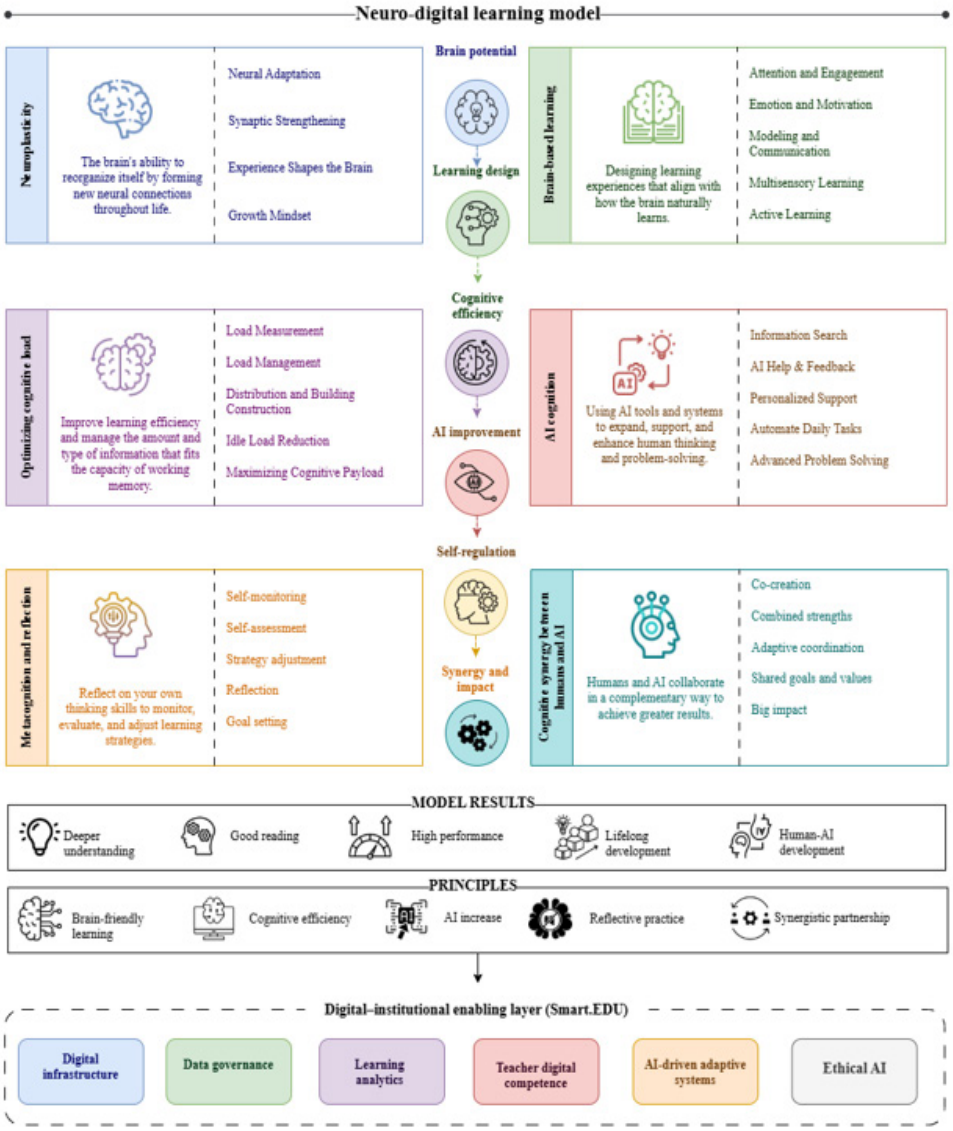


Fig. 6. Neuro-digital learning model

Conclusion.

This study examined changes in educational paradigms during the presingularity period. The results of the research provide a description of the singularity as a continuing, multidimensional evolutionary process that is taking place in the present, not a single event that is to take place in the future. From this point of view, it was demonstrated that considering the development of AI not in the limited technological context but in the broad evolutionary context of human cognition and the education system is necessary.

The analysis of the changes in educational models from "Education 1.0" to "Education 6.0" demonstrates a legal movement from the traditional teacher-oriented

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

system to the anthropo-digital synergy. The reason for this transition is a fundamental change in the role of the teacher and the learner. The learner becomes a subject of coevolution, not a passive recipient, and the pedagogue evolves into a cognitive partner working together with AI rather than a sole supplier of knowledge. The concept of "Education 6.0" is an expanded systematic approach that does not limit education to the supply of information but is focused on the overall development of the individual and the formation of critical thinking and meta-processes.

This study revealed the synergy of neuroeducation and brain-based learning with AI cognition. All of them are different from each other in terms of theory and tactics, but the final purpose is to improve the cognitive effectiveness of shared learning. Cognitive load theory helps explain this relationship. AI systems can reduce the internal burden by parsing complex content in phases, minimize overload by filtering out extraneous information, and increase useful cognitive load by mapping reflection and knowledge. Moreover, the results of this study revealed that the negative effects of AI cognition should not be ignored, as they involve a weakening of cognitive activity, fragmentation of attention and a dependence on AI.

The proposed neuroscience learning model is not a universal technological solution, but a conceptual and methodological framework that adapts to a specific educational environment. The model combines neuroplasticity, brain-based learning, cognitive load regulation, and AI supported learning in a single educational system. Its main principle is that AI should not replace the student's thinking, but complement and contribute to the development of cognitive capabilities. This approach maintains the cognitive autonomy of the learner and sees him as an active subject who controls his learning and cognitive development, and not as a passive consumer of the digital environment. The implementation of the model requires pedagogical support of the teacher, technological accessibility and compliance with ethical requirements. At the present stage, due to the fact that its educational effectiveness has not been empirically confirmed, widespread generalization of the results is limited. In this regard, at the next stage of the study, it is necessary to pilot the model in higher education and assess its impact on cognitive autonomy, metacognitive consciousness, critical thinking, learning activity, cognitive load, as well as the risks of over-dependence on AI. Thus, the developed model is aimed at combining the principles of neuroscience, cognitive psychology and AI in the process of higher education and is of theoretical and practical importance amid the ongoing digital transformation of higher education in Kazakhstan (Smart.EDU).

REFERENCES

Acuña, P. (2021). von Neumann's Theorem Revisited. Foundations of Physics. — Vol. 51. — No. 3. DOI: https://doi.org/10.1007/s10701-021-00474-5 [In Eng.].

Cunningham, I. (2019). A new educational paradigm for the 21st century. Development and Learning in Organizations // An International Journal. — Vol. 34. — No. 2. — Pp. 5–7. DOI: https://doi.org/10.1108/dlo-10-2019-0253 [In Eng.].

de Chardin, T. (2021). the Omega Point // Debating Faith: Essays on Science, Religion and Secularism. — Pp. 317. [In Eng.].

Gandawa, G. (2025). The STEMMA Classroom: Engineering Emotionally Literate Pedagogy in Secondary Technical Education // Journal of Advanced Engineering and Technology (JAET). [In Eng.].

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

Gandawa, G. (2026). Digital Transformation and Quality Assurance in Universities in the Age of Education 6.0 Author // Journal of Education and Learning Sciences. [In Eng.].

Good, I. J. (1966). Speculations concerning the first ultraintelligent machine // In Advances in computers. — Vol. 6. — Pp. 31-88. Elsevier. [In Eng.].

Goodwin, L. (2022). Educational neuroscience, artificial intelligence, and technology in higher education. University of Pennsylvania. [In Eng.].

Kurzweil, R. (2026). The singularity is nearer: When we merge with AI. Penguin Group. [In Eng.].

Luksha, P. (2025, March 16). Careers in the pre-singularity age: Is everything already lost, or are we on the verge of reinvention? https://pavel-luksha-protopia.medium.com/careers-in-the-pre-singularity-age-is-everything-already-lost-or-are-we-on-the-verge-of-b4899e5ef28e [In Eng.].

Moleka, P. (2023). Exploring the Role of Artificial Intelligence in Education 6.0: Enhancing Personalized Learning and Adaptive Pedagogy. DOI: https://doi.org/10.20944/preprints202309.0562.v1 [In Eng.].

Nieto Jalil, J. M. (2026). Emerging Technologies and Regenerative Pedagogies in the Era of Education 6.0. Learning Analytics. — Pp. 141–159. DOI: https://doi.org/10.1201/9781003678250-9 [In Eng.].

Shaji George, A., Baskar, T., & Siranchuk, N. (2025). The evolution of Education 5.0 in the innovation era: A review of the progression from teacher-centered learning to student-driven models // Partners Universal International Innovation Journal. — Vol. 3. — No. 1. — Pp. 19–28. [In Eng.].

Swargiary, K. (2026). Education 6.0: Envisioning the Symbiotic Future of Learning and Innovation. Atlantis Publication House (Russia). [In Eng.].

Turner, C., & Astin, F. (2021). Grounded theory: what makes a grounded theory study? // European Journal of Cardiovascular Nursing. — Vol. 20. — No. 3. — Pp. 285–289. DOI: https://doi.org/10.1093/eurjcn/zvaa034 [In Eng.].

Ulam, S. M. (1980). Von Neumann: The Interaction of Mathematics and Computing // A History of Computing in the Twentieth Century. — Pp. 93–99. DOI: https://doi.org/10.1016/b978-0-12-491650-0.50014-9 [In Eng.].

Vinge, V. (2008). Signs of the singularity // IEEE Spectrum. — Vol. 45. — No. 6. — Pp. 76–82. DOI: https://doi.org/10.1109/mspec.2008.4531467 [In Eng.].

Vinge, V. (2017). The coming technological singularity: How to survive in a post-human era // Science Fiction Criticism. DOI: https://doi.org/10.5040/9781474248655.0037 [In Eng.].

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

INTERNATIONAL JOURNAL OF INFORMATION AND COMMUNICATION TECHNOLOGIES

ХАЛЫҚАРАЛЫҚ АҚПАРАТТЫҚ ЖӘНЕ КОММУНИКАЦИЯЛЫҚ ТЕХНОЛОГИЯЛАР ЖУРНАЛЫ

МЕЖДУНАРОДНЫЙ ЖУРНАЛ ИНФОРМАЦИОННЫХ И КОММУНИКАЦИОННЫХ ТЕХНОЛОГИЙ

Собственник:
АО «Международный университет информационных технологий» (Казахстан, Алматы)

Главный редактор:
Колесникова Катерина Викторовна

Ответственный редактор:
Мрзабаева Раушан Жалиевна

Компьютерная верстка:
Калабай Замзагуль Ертугановна

Сайт журнала: https://journal.iitu.edu.kz
ISSN 2708–2032 (print)
ISSN 2708–2040 (online)

Подписано в печать 30.09.2026.
050040 г. Алматы, ул. Манаса 34/1, каб. 709, тел: +7 (727) 244-51-09).

Издание АО "Международного университета информационных технологий"