

# INNOVATION SCIENCE AND TECHNOLOGY

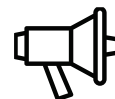


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**CONTACTS**

Phone: **+998 50 737 87 88**

Website: <https://ist-journal.uz>

Email: [innovationist2025@gmail.com](mailto:innovationist2025@gmail.com)

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# CONTENTS

|                                                                                                                                                        |     |
|--------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| BRIEF FEEDBACK ON “AGAT CREDIT” MICROFINANCE ORGANIZATION BASED ON THE REPORT OF “KAPDEPO” INVESTMENT COMPANY: CAVEATS FOR LENDERS (BONDHOLDERS) ..... | 16  |
| Abduganiev Abdulaziz Alisher ugli                                                                                                                      |     |
| IMPLEMENTATION OF EU BEST AGRICULTURAL TRADE PRACTICES IN UZBEKISTAN.....                                                                              | 20  |
| Khulkar Karimova Rakhmanali qizi                                                                                                                       |     |
| THE ROLE OF FOREIGN DIRECT INVESTMENT IN INCREASING SERVICE EXPORTS OF UZBEKISTAN .....                                                                | 26  |
| Jamshid Mirzakhmedov                                                                                                                                   |     |
| THE ROLE AND IMPORTANCE OF FINANCIAL MARKETS IN ECONOMIC DEVELOPMENT .....                                                                             | 30  |
| Baymanova Mavlyuda Djuraevna, Abdullaeva Shohista, Ubaydullaeva Gulchehra Erkabaevna                                                                   |     |
| КЛИНИЧЕСКАЯ ОЦЕНКА СОСТОЯНИЯ МЕСТНЫХ ИММУННЫХ МЕХАНИЗМОВ ПОЛОСТИ РТА У ПАЦИЕНТОВ НА ЭТАПАХ ОРТОДОНТИЧЕСКОГО ЛЕЧЕНИЯ .....                              | 36  |
| Рахимбердыев Рустам Абдунасинович, Сайфулаева Азиза Анваровна                                                                                          |     |
| INTEGRATING AI-BASED CUSTOMER ANALYTICS INTO INNOVATIVE RETAIL MARKETING STRATEGIES .....                                                              | 40  |
| Ostonaqulova Gulsaraxon Muhammadyoqub qizi                                                                                                             |     |
| FINANCIAL STIMULATION OF INNOVATIVE ACTIVITIES OF ENTERPRISES THROUGH INVESTMENTS .....                                                                | 48  |
| Bahriddinov Nodirbek Zamirdinovich                                                                                                                     |     |
| DIGITAL DENTISTRY: LITERATURE REVIEW .....                                                                                                             | 52  |
| Tursunov Begzod Sherzodovich, Zokirova Nodira Sobitovna                                                                                                |     |
| THE LATEST ADHESIVE TECHNOLOGIES IN DENTISTRY .....                                                                                                    | 56  |
| Rahimberdiyev Rustam Abdunasirovich, Chinibayeva Ibagul Sarsenbayevna                                                                                  |     |
| ENSURING THE ACCEPTABILITY OF QUANTITATIVE AND QUALITATIVE INDICATORS IN THE EFFECTIVE ORGANIZATION OF HOUSING FUNDS IN KHOREZM .....                  | 61  |
| Otajonov Tohirjon Khojanazar o'g'li                                                                                                                    |     |
| WAYS TO IMPROVE CUSTOMS ADMINISTRATION IN THE REPUBLIC OF UZBEKISTAN.....                                                                              | 67  |
| Usmonova Dilfuza Ilhomovna                                                                                                                             |     |
| CLINICAL ASSESSMENT OF THE STATE OF LOCAL IMMUNE MECHANISMS OF THE ORAL CAVITY IN PATIENTS AT DIFFERENT STAGES OF ORTHODONTIC TREATMENT .....          | 72  |
| Rakhimberdiyev Rustam Abdunasirovich, Saifulaeva Aziza Anvarovna                                                                                       |     |
| IMPROVING THE ALGORITHM FOR CONTROLLING THE CUSTOMS TRANSIT INFORMATION SYSTEM E-TRANSIT OF THE REPUBLIC OF UZBEKISTAN .....                           | 76  |
| Musayeva Shoiraz Azimovna                                                                                                                              |     |
| DEVELOPMENT TRENDS OF THE AUTOMOTIVE BUSINESS IN UZBEKISTAN .....                                                                                      | 82  |
| Saidov Dilshodbek Razzakovich                                                                                                                          |     |
| INTEGRATION OF MARKETING STRATEGIES IN RETAIL TRADE ACTIVITIES.....                                                                                    | 87  |
| Akramov Toxir Abdiraxmanovich                                                                                                                          |     |
| CHALLENGES OF ADOPTING ISLAMIC FINANCE WITHIN CONVENTIONAL BANKING SYSTEMS .....                                                                       | 91  |
| Safarov Shuhrat Ismatovich                                                                                                                             |     |
| CRM SYSTEMS AND THEIR IMPACT ON THE RESULTS OF MARKETING STRATEGY IN DISTRIBUTION COMPANIES .....                                                      | 95  |
| Jamoliddinov Fakhriyor Shodiyor o'g'li                                                                                                                 |     |
| LEXICAL-SEMANTIC ARCHITECTURE OF MODERN WORDNET SYSTEMS .....                                                                                          | 101 |
| Aynura Axmedova                                                                                                                                        |     |
| METHODOLOGY FOR ANALYZING THE EFFECTIVENESS OF INNOVATIVE PROCESSES AT ENTERPRISES.....                                                                | 108 |
| Kurbanova Shakhnoza Yuldashbayevna                                                                                                                     |     |
| COMPANY VALUATION IN MERGERS AND ACQUISITIONS: A STRATEGIC AND GOVERNANCE-BASED APPROACH .....                                                         | 113 |
| Lee Illarion Georgievich                                                                                                                               |     |

|                                                                                                                                  |     |
|----------------------------------------------------------------------------------------------------------------------------------|-----|
| A REVIEW OF THE LITERATURE ON CAD/CAM TECHNOLOGIES IN DENTAL<br>ECTOPROSTHETICS.....                                             | 118 |
| Tursunov Begzod Sherzodovich, Hazratqulov Asrbek Ulugbek ugli                                                                    |     |
| TRENDS AND DIFFICULTIES IN THE INTEGRATION OF DIGITAL TECHNOLOGIES IN ORTHOPEDIC<br>DENTISTRY.....                               | 123 |
| Khojimurodov Burkhon Ravshanovich                                                                                                |     |
| PRIORITY DIRECTIONS FOR IMPROVING THE MECHANISM OF ENHANCING THE ECONOMIC<br>SECURITY LEVEL OF THE KASHKADARYA REGION.....       | 127 |
| Tuyev Abdurahmon Yusubopvich                                                                                                     |     |
| THE ROLE OF PSYCHOPHYSIOLOGICAL TRAINING OF DRIVERS IN REDUCING ROAD TRAFFIC<br>ACCIDENTS.....                                   | 132 |
| Uralbayev Anvar Ubaydullayevich                                                                                                  |     |
| THE ROLE OF SUSTAINABLE DEVELOPMENT PRINCIPLES IN DEVELOPING GREEN MARKETING<br>STRATEGIES FOR ENTERPRISES.....                  | 135 |
| Sapayev Akhmad Durdibayevich                                                                                                     |     |
| MANAGEMENT MODEL OF INFORMATION RESOURCES IN SMALL BUSINESS ENTITIES AND ITS<br>IMPACT ON ECONOMIC EFFICIENCY.....               | 140 |
| Yo'ldoshev Nodirbek Ne'matjon o'g'li                                                                                             |     |
| WAYS TO DEVELOP THE INVESTMENT ACTIVITY OF COMMERCIAL BANKS THROUGH<br>THE SECURITIES MARKET.....                                | 145 |
| Yuldashev Fozil Turapovich                                                                                                       |     |
| INTERNATIONAL EXPERIENCE IN THE USE OF CROSS-BORDER REMITTANCES IN THE<br>DEVELOPMENT OF THE NATIONAL ECONOMY.....               | 152 |
| Gimranova O. B.                                                                                                                  |     |
| FREE ECONOMIC ZONES AND FOREIGN INVESTMENT.....                                                                                  | 158 |
| Sheraliyeva Saida Azatovna                                                                                                       |     |
| ISSUES OF FORMATION AND MANAGEMENT OF PRODUCT ASSORTMENT IN RETAIL<br>ENTERPRISES.....                                           | 162 |
| Safarov Baxtiyor Djurakulovich                                                                                                   |     |
| STATE SUPPORT IN THE REPUBLIC OF UZBEKISTAN FOR ORGANIZING SHORT-TERM SCIENTIFIC<br>INTERSHIPS OF YOUNG SCIENTISTS ABROAD.....   | 167 |
| Kabashev Tairjon                                                                                                                 |     |
| LEGAL FOUNDATIONS OF DIVIDEND POLICY: EVIDENCE FROM DEVELOPED AND DEVELOPING<br>COUNTRIES.....                                   | 172 |
| Eshev Furqat A'zamovich                                                                                                          |     |
| IMPROVING SMART CITY GOVERNANCE BASED ON DIGITAL PLATFORMS: A HUMAN-CENTERED<br>APPROACH.....                                    | 176 |
| Rakhimova Madina Shukhrat qizi                                                                                                   |     |
| THE INVESTMENT CLIMATE AND ITS IMPACT ON THE DEVELOPMENT OF FOREIGN TRADE:<br>A CASE STUDY OF UZBEKISTAN.....                    | 182 |
| Mirzamukhamedova Shakhzoda Akmaljon qizi                                                                                         |     |
| CONSUMER CREDITS IN USA.....                                                                                                     | 187 |
| Zunnunova Xulkar Muxtorovna                                                                                                      |     |
| INSTITUTIONAL BASES AND FUNCTIONAL MECHANISMS OF CONTROLLING IN THE EFFECTIVE<br>MANAGEMENT OF THE RAILWAY TRANSPORT SYSTEM..... | 194 |
| Kayumov Zafarbek Odil ugli                                                                                                       |     |
| ANALYSIS OF CUSTOMER RELATIONSHIP MANAGEMENT PROCESSES AND PROBLEMS IN SERVICE<br>ENTERPRISES.....                               | 199 |
| Ismailova Ma'mura Eldorovna                                                                                                      |     |
| PROBLEMS FACED BY COMMERCIAL BANKS IN BANK RISK MANAGEMENT AND WAYS<br>TO ADDRESS THEM.....                                      | 205 |
| Qayimova Ismigul Ilhom qizi, Tuxsanov Eldor Dilmurod o'g'li                                                                      |     |

|                                                                                                                                                                                                  |     |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| DESIGN OF ENGINEERING STRUCTURES AND CONSTRUCTION OF A REGIONALLY BRANCHED HIGHWAY COMPLEX.....                                                                                                  | 209 |
| Yakubov Maqsadkhon Sultaniyazovich, Norinov Muhammadyunus Usibjonovich, Zikraev Akmaljon Alimovich                                                                                               |     |
| THE ROLE OF COOPERATIVE RELATIONS IN THE SUSTAINABLE DEVELOPMENT OF THE REGIONAL TOURISM MARKET .....                                                                                            | 216 |
| Mirzabayev Jamshid Irkinovich                                                                                                                                                                    |     |
| THE ROLE OF FREE ECONOMIC ZONES IN IMPROVING THE INVESTMENT CLIMATE OF THE KHOREZM REGION.....                                                                                                   | 221 |
| Masharipov Sardorbek Farxadovich                                                                                                                                                                 |     |
| ANALYSIS OF ORGANIZATIONAL AND ECONOMIC INDICATORS OF INNOVATIVE POTENTIAL MANAGEMENT IN TEXTILE INDUSTRY ENTERPRISES .....                                                                      | 228 |
| Khosilov Shavkat Bekmurodovich                                                                                                                                                                   |     |
| MAIN WAYS TO DEVELOP INTEREST RATE RISK MANAGEMENT PRACTICES IN COMMERCIAL BANKS OF UZBEKISTAN .....                                                                                             | 234 |
| Seytnazarov Daniyar Baxadirovich                                                                                                                                                                 |     |
| THEORETICAL AND METHODOLOGICAL ASPECTS OF ESG STRATEGY IMPLEMENTATION.....                                                                                                                       | 239 |
| Xusenova Mexrangiz                                                                                                                                                                               |     |
| ADVANTAGES OF USING TRADITIONAL CONSTRUCTION MATERIALS IN THE CONSTRUCTION OF LOW-RISE RESIDENTIAL BUILDINGS.....                                                                                | 244 |
| Otabek Hakimovich Toshniyozov                                                                                                                                                                    |     |
| THE METHODOLOGY FOR SELECTING AND INTEGRATING DATA SOURCES AND USING OFFICIAL STATISTICAL ENTERPRISE DATA, QUESTIONNAIRES, AND PROXY INDICATORS IN FORMING THE EMPIRICAL BASIS OF THE STUDY..... | 247 |
| Usmonov Maxsud Tulqin o'g'li, Qodirov Farrux Ergash o'g'li                                                                                                                                       |     |
| PRACTICAL SOLUTIONS FOR THE PLACEMENT OF MULTI-STOREY GREENHOUSES IN INDUSTRIAL AREAS .....                                                                                                      | 254 |
| Abdujabbarova Maktuba To'xtasinovna, Salayeva Ma'rifat Yashin qizi                                                                                                                               |     |
| INNOVATIONS IN DENTISTRY: DIGITAL SOLUTIONS FOR MODERN PRACTICE .....                                                                                                                            | 258 |
| Sadriyev Nizom Najmiddinovich, Usarov Nuriddin                                                                                                                                                   |     |
| ARCHITECTURAL AND PLANNING PRINCIPLES FOR THE ORGANIZATION OF MANAGEMENT SERVICE COMPANY BUILDINGS IN THE URBAN DEVELOPMENT CONTEXT OF UZBEKISTAN.....                                           | 263 |
| Adilova Madina Sobirovna, Khusainova Gulhayo Norbek qizi                                                                                                                                         |     |
| METHODS OF SEDATIVE THERAPY IN DENTISTRY (REVIEW OF LITERATURE) .....                                                                                                                            | 268 |
| Vasitov Otabek, Burkhonova Zarafruz Kobilovna                                                                                                                                                    |     |
| SPECIFIC FEATURES OF THE FORMATION AND OPERATION OF A REGIONAL TOURISM CLUSTER.....                                                                                                              | 272 |
| Ollanazarov Bekmurod Davlatmuratovich                                                                                                                                                            |     |
| ESTIMATING ELECTRICITY CONSUMPTION OF PUMPING PLANTS IN IRRIGATION SYSTEMS.....                                                                                                                  | 277 |
| Urishev Omadjon, Ersin Akyuz, Gul Metin, Quvonchbek Quvondiqov                                                                                                                                   |     |
| ANALYSIS OF MANUFACTURING METHODS AND TECHNIQUES FOR MULTI-FACETED SHAFTS.....                                                                                                                   | 287 |
| Khasanov B.M., Valikhonov D.A., Abdullaev B.I., Alibekov R.K.                                                                                                                                    |     |
| DENTAL IMPRESSIONS AND GYPSUM MODEL SCANNING ACCURACY USING A LASER SCANNER ARE COMPARED .....                                                                                                   | 292 |
| Akhmadov Inomjon Nizomitdinovich, Matchanov Boburbek Ulug'bekovich                                                                                                                               |     |
| ORAL FLUID BIOCHEMICAL AND PHYSICOCHEMICAL CHARACTERISTICS IN CHILDREN WITH ABNORMALITIES AFTER URANOPLASTY .....                                                                                | 297 |
| Anvarova Muhtasar Anvarovna                                                                                                                                                                      |     |
| INDUSTRIAL DIVERSIFICATION AS A KEY FACTOR IN ENHANCING UZBEKISTAN'S EXPORT POTENTIAL.....                                                                                                       | 302 |
| Kholikova Rukhsora Sanjarovna, Rizayeva Ezoza Bahodir kizi                                                                                                                                       |     |
| INNOVATIVE APPROACHES TO REDUCING UNEMPLOYMENT IN UZBEKISTAN'S ECONOMY AND THEIR IMPACT ON SUSTAINABLE ECONOMIC GROWTH.....                                                                      | 308 |
| Botirova Sarvinov Boburjon kizi                                                                                                                                                                  |     |

|                                                                                                                                                  |     |
|--------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| INVESTMENT ATTRACTIVENESS OF SYRDARYA REGION: AN ANALYSIS OF DEVELOPMENT DYNAMICS AND STRATEGIC OPPORTUNITIES .....                              | 313 |
| <b>Mamatkulova Mukhlisa Komiljon kizi</b>                                                                                                        |     |
| THE EVOLUTION OF UZBEKISTAN'S FISCAL POLICY DURING 2020–2025 AND ITS CONTRIBUTION TO SUSTAINABLE ECONOMIC GROWTH .....                           | 318 |
| <b>Saidakbarova Madinakhan Anisbekovna</b>                                                                                                       |     |
| THE ROLE OF MACROECONOMIC MECHANISMS AND FOREIGN TRADE POTENTIAL IN ACHIEVING INCLUSIVE ECONOMIC GROWTH IN UZBEKISTAN.....                       | 324 |
| <b>Rahimov Eshmurod Normuradovich</b>                                                                                                            |     |
| PROMOTING SUSTAINABLE GROWTH THROUGH STRENGTHENING EXPORT POTENTIAL IN THE NATIONAL ECONOMY .....                                                | 332 |
| <b>Berdivaliyeva Madina Komiljon kizi</b>                                                                                                        |     |
| THE ESSENCE AND IMPORTANCE OF FOREIGN TRADE POLICY IN MODERN ECONOMIC DEVELOPMENT .....                                                          | 339 |
| <b>Askarova Mavluda Turabovna</b>                                                                                                                |     |
| THE ONTOLOGY OF WAGES: HUMAN CAPITAL, DIGITALISATION, AND INSTITUTIONAL MEDIATION IN A TRANSITIONAL ECONOMY.....                                 | 345 |
| <b>Zakhidov Azizbek Rustamovich</b>                                                                                                              |     |
| FORMATION OF OFFICIAL SALARIES OF CIVIL SERVANTS ON THE BASIS OF A UNIFIED PRINCIPLE: ANALYSIS OF THE CURRENT TARIFF GRADES .....                | 351 |
| <b>Oqiljonov Azizjon Olimjon o'g'li</b>                                                                                                          |     |
| MULTI-INDICATOR SYSTEM FOR ASSESSING THE FINANCIAL INDEPENDENCE OF LOCAL BUDGETS AND THE METHODOLOGY FOR FORMING AN INTEGRAL INDEX .....         | 356 |
| <b>Muxitdinov Sidikkhoja Akobirkhoja ugli</b>                                                                                                    |     |
| THEORETICAL BASIS FOR OBTAINING ORGANOMINERAL FERTILIZER IN THE SYSTEM $2K^+, 2NH_4^+ // 2Cl^-, SO_4^{2-} - H_2O$ .....                          | 361 |
| <b>Koshanova B.T., Toshtemirov A.B., Erkaev A.U., Reimov A.M.</b>                                                                                |     |
| DIRECTIONS FOR IMPROVING THE INCENTIVE SYSTEM IN MANAGING FINANCIAL RESOURCES OF LOCAL BUDGETS IN THE SOCIO-ECONOMIC DEVELOPMENT OF REGIONS..... | 365 |
| <b>Imanova Umida Bakhtiyorovna</b>                                                                                                               |     |
| DIRECTIONS FOR USING ARTIFICIAL INTELLIGENCE TO ENHANCE ECONOMIC EFFICIENCY OF MANUFACTURING PROCESSES.....                                      | 370 |
| <b>Rikhsiboyev Nozimbek Abdurasul ugli</b>                                                                                                       |     |
| INSTITUTIONAL AND ECONOMIC MECHANISMS FOR DEVELOPING KNOWLEDGE AND COMPETENCIES IN REGIONAL HUMAN CAPITAL DEVELOPMENT .....                      | 375 |
| <b>Bozorova Madina Raxmat qizi</b>                                                                                                               |     |
| DEVELOPMENT OF MECHANISMS FOR IMPLEMENTING A SUSTAINABLE DEVELOPMENT AND GREEN GOVERNANCE MODEL IN THE REGIONS .....                             | 379 |
| <b>Siradjev Ilkhom Tokhirovich</b>                                                                                                               |     |
| ECONOMIC EFFICIENCY OF PUBLIC PROCUREMENT EVALUATION BASED ON TOTAL COST OF OWNERSHIP (TCO) .....                                                | 383 |
| <b>Turabov Sarvar Abdumalikovich</b>                                                                                                             |     |
| IMPROVING THE METHODOLOGY FOR TEACHING ALTERNATIVE ENERGY SOURCES: THE MIREL INTEGRATED MODEL FOR HIGHER EDUCATION.....                          | 387 |
| <b>Bobobekov Ergash Abdumalikovich</b>                                                                                                           |     |

# IMPROVING THE METHODOLOGY FOR TEACHING ALTERNATIVE ENERGY SOURCES: THE MIREL INTEGRATED MODEL FOR HIGHER EDUCATION

**Bobobekov Ergash Abdumalikovich**

Tashkent State University of Economics

Department of "Green Economy"

**Annotatsiya.** O'zbekiston oliy ta'lim tizimida muqobil energiya manbalarini o'qitish metodologiyasini takomillashtirish masalalari tadqiq etilgan. Kompetensiyaviy yondashuv, problem-based learning, project-based learning, flipped classroom, simulyatsiya va dual ta'lim metodlari qiyosiy tahlil qilinib, ularning muqobil energetika mutaxassislarini tayyorlashdagi imkoniyatlari tizimlashtirilgan. Taqdim etilgan materiallar asosida O'zbekiston oliy ta'lim sharoitiga mos MIREL (Methodology of Integrated Renewable Energy Learning) modeli takomillashtirilgan. Model fundamental bilimlar, raqamli kompetensiyalar, iqtisodiy-huquqiy bilimlar, amaliy loyiha hamda ilmiy tadqiqot va innovatsiya modullarini yagona ta'lim sikliga birlashtiradi. Olingan natijalar amaliy va loyiha asosidagi komponentlar ulushini oshirish, raqamli simulyatsiya vositalaridan foydalanish hamda sanoat va akademik soha hamkorligini kuchaytirish zarurligini ko'rsatadi. Taklif etilgan yondashuv muqobil energetika bozorining texnik, raqamli, iqtisodiy va ekologik kompetensiyalarga bo'lgan talablarini oliy ta'lim natijalari bilan muvofiqlashtirishga xizmat qiladi.

**Kalit so'zlar:** muqobil energiya, o'qitish metodologiyasi, MIREL, oliy ta'lim, kompetensiyaviy yondashuv, PBL, loyiha asosida o'qitish, raqamli ta'lim, simulyatsiya, yashil iqtisodiyot.

**Аннотация.** Исследованы вопросы совершенствования методологии преподавания альтернативных источников энергии в системе высшего образования Узбекистана. Проведён сравнительный анализ компетентностного подхода, problem-based learning, project-based learning, flipped classroom, методов симуляционного и дуального обучения, а также систематизированы их возможности при подготовке специалистов в области альтернативной энергетики. На основе представленных материалов усовершенствована модель MIREL (Methodology of Integrated Renewable Energy Learning), адаптированная к условиям высшего образования Узбекистана. Модель объединяет фундаментальные знания, цифровые компетенции, экономико-правовые знания, практическую проектную деятельность, научные исследования и инновации в единый образовательный цикл. Полученные результаты свидетельствуют о необходимости увеличения доли практических и проектно-ориентированных компонентов, использования средств цифрового моделирования, а также укрепления сотрудничества между промышленностью и академической сферой. Предложенный подход способствует согласованию требований рынка альтернативной энергетики к техническим, цифровым, экономическим и экологическим компетенциям с результатами высшего образования.

**Ключевые слова:** альтернативная энергетика, методология преподавания, MIREL, высшее образование, компетентностный подход, PBL, проектное обучение, цифровое образование, симуляция, зелёная экономика.

**Abstract.** The improvement of the methodology for teaching alternative energy sources in the higher education system of Uzbekistan is investigated. The competency-based approach, problem-based learning, project-based learning, flipped classroom, simulation, and dual education methods are comparatively analyzed, and their potential for training specialists in alternative energy is systematized. Based on the presented materials, the MIREL (Methodology of Integrated Renewable Energy Learning) model, adapted to the higher education context of Uzbekistan, is improved. The model integrates fundamental knowledge, digital competencies, economic and legal knowledge, practical projects, scientific research, and innovation modules into a unified educational cycle. The results indicate the importance of increasing the share of practical and project-based components, using digital simulation tools, and strengthening industry-academia collaboration. The proposed approach contributes to aligning higher education outcomes with the alternative energy market's demand for technical, digital, economic, and environmental competencies.

**Keywords:** alternative energy, teaching methodology, MIREL, higher education, competency-based approach, PBL, project-based learning, digital education, simulation, green economy.

## INTRODUCTION

The global energy transformation is creating new requirements for workforce development within the higher education system. The design, installation, operation, and economic assessment of alternative energy facilities require not only theoretical knowledge but also a comprehensive set of technical, digital, economic, and environmental competencies.

The presented research materials highlight opportunities for further development of practical laboratories, instructors' competencies in emerging technologies, digital learning tools, and industry collaboration within existing educational programs in the context of the expanding alternative energy sector in Uzbekistan. Therefore, further alignment between curriculum content and labor market needs represents an important methodological priority.

The purpose of the study is to comparatively assess international teaching methodologies, systematize the current state of higher education in Uzbekistan, and scientifically and methodologically improve the MIREL integrated model for training specialists in alternative energy.

## LITERATURE REVIEW

The competency-based approach prioritizes students' ability to apply knowledge in real-world situations rather than merely reproduce theoretical knowledge. In alternative energy education, this approach requires the integrated development of technical, digital, economic, and environmental competencies.

The problem-based learning methodology developed by Barrows promotes independent learning and critical thinking through the solution of real-world problems. Project-based learning, in turn, enables students to complete the entire project cycle, ranging from calculating energy demand to selecting appropriate technologies, conducting NPV/IRR analysis, and managing projects.

The presented international experience from Germany, Denmark, the United States, and Asian countries emphasizes the importance of integrating theory and practice, project-based learning, flipped classroom approaches, real-world energy data, and industrial practice. These experiences are considered not as ready-made models for direct implementation in Uzbekistan but as methodological elements that can be effectively adapted to the national higher education system.

## RESEARCH METHODOLOGY

The study employed systematic analysis, comparative analysis, a competency-based approach, content analysis, methodological benchmarking, and modular design methods. The information base consisted of international educational methodologies presented in the research materials, indicators reflecting the current state of higher education institutions in Uzbekistan, digital tools, and the modular structure of the MIREL model.

International methodologies were compared in terms of the theory-to-practice ratio, advantages, and areas for further development. The current state of higher education institutions in Uzbekistan was systematized according to such criteria as the number of courses, their share in the curriculum, the availability of laboratories, and the level of industry collaboration.

The MIREL model was divided into five modules based on the principle of ensuring alignment between learning outcomes and labor market competencies. The proportions of the modules were maintained in accordance with the indicators presented in the source: fundamental knowledge — 20%, digital competencies — 20%, economic and legal knowledge — 15%, practical projects — 35%, and scientific research and innovation — 10%.

## ANALYSIS AND RESULTS

The first result indicates that, in a rapidly evolving field such as alternative energy, integrating the traditional lecture model with project-based, simulation-based, and practical activities can enhance educational effectiveness. Among the presented methodologies, project-based and simulation-based approaches have the highest proportion of practical components. Therefore, combining these approaches with laboratory activities and industrial practice can strengthen competency-based learning outcomes.

**Table 1**  
**Comparative Characteristics of Teaching Methodologies in Alternative Energy Education<sup>1</sup>**

| Methodology         | Main Principle                            | Theory/Practice | Advantage                            | Area for Improvement                                           |
|---------------------|-------------------------------------------|-----------------|--------------------------------------|----------------------------------------------------------------|
| Traditional lecture | Knowledge transfer                        | 80/20           | Systematic theoretical foundation    | Opportunity to develop practical skills                        |
| PBL                 | Problem solving                           | 40/60           | Critical thinking                    | Requires effective time management                             |
| PrBL                | Project cycle                             | 30/70           | Real project experience              | Requires appropriate resources                                 |
| Flipped classroom   | Theory at home, practice in the classroom | 50/50           | Active learning                      | Requires advance preparation                                   |
| Simulation          | Virtual experimentation                   | 20/80           | Safe and repeatable environment      | Opportunity for integration with real-world conditions         |
| Dual education      | Industry + academia                       | 50/50           | Proximity to the working environment | Requires the development of sustainable industry collaboration |

The analysis of Table 1 demonstrates that the traditional lecture method has a high proportion of theoretical content, whereas practical activities predominate in PBL, PrBL, and simulation methods. In particular, the 70% practical component in the PrBL model and the 80% practical component in the simulation approach are more suitable for developing the design, modeling, and decision-making skills required in alternative energy. At the same time, considering the resource and organizational requirements of these methods, their implementation in a combined format is appropriate.

**Table 2**  
**Current State of Alternative Energy Courses in Higher Education Institutions of Uzbekistan<sup>2</sup>**

| HEI                                      | Number of Courses | Share in the Curriculum | Laboratory                            | Industry Collaboration                |
|------------------------------------------|-------------------|-------------------------|---------------------------------------|---------------------------------------|
| TSTU                                     | 4                 | 8%                      | Partial                               | Opportunities for further development |
| TSUE                                     | 3                 | 6%                      | Opportunities for further development | Opportunities for further development |
| NUUz                                     | 5                 | 10%                     | At the research level                 | Opportunities for further development |
| Turin Polytechnic University in Tashkent | 6                 | 12%                     | Available                             | With the University of Turin          |
| Samarkand State University               | 2                 | 4%                      | Opportunities for further development | Opportunities for further development |
| TUIT                                     | 2                 | 5%                      | IT laboratory                         | Opportunities for further development |

The data presented in Table 2 indicate that, across the higher education institutions studied, the share of alternative energy courses in the curriculum ranges from 4% to 12%. Further development of laboratory facilities and industry collaboration can expand opportunities for developing practical competencies. This finding provides a methodological basis for allocating the largest share, 35%, to the practical project module within the MIREL model.

<sup>1</sup> Source: Systematized by the author based on the presented article materials.

<sup>2</sup> Source: Compiled based on the data presented in the article.

Table 3  
Module Structure of the MIREL Integrated Model<sup>3</sup>

| Module                             | Share | Main Content                                                        | Teaching Format                       |
|------------------------------------|-------|---------------------------------------------------------------------|---------------------------------------|
| Fundamental knowledge              | 20%   | Thermodynamics, electrical engineering, solar physics, aerodynamics | Lectures, video lessons               |
| Digital competencies               | 20%   | IoT, Python, MATLAB/Simulink, AutoCAD Electrical, PVsyst            | Laboratory, online platform           |
| Economic and legal knowledge       | 15%   | NPV/IRR, project finance, energy law, green finance                 | Case study, mini-project              |
| Practical project                  | 35%   | Real or simulated energy project                                    | Group project, mentoring, defense     |
| Scientific research and innovation | 10%   | Mini-research, article, conference                                  | Research and scientific communication |

Table 3 demonstrates that the MIREL model integrates theoretical, digital, economic, and scientific components with practical projects within a unified system. The 35% share allocated to the practical project module is the principal distinguishing feature of the model, directing students toward applying their knowledge in real or simulated energy projects. The allocation of a 20% share to digital competencies also reflects the increasing dependence of modern energy systems on data, modeling, and automated management.

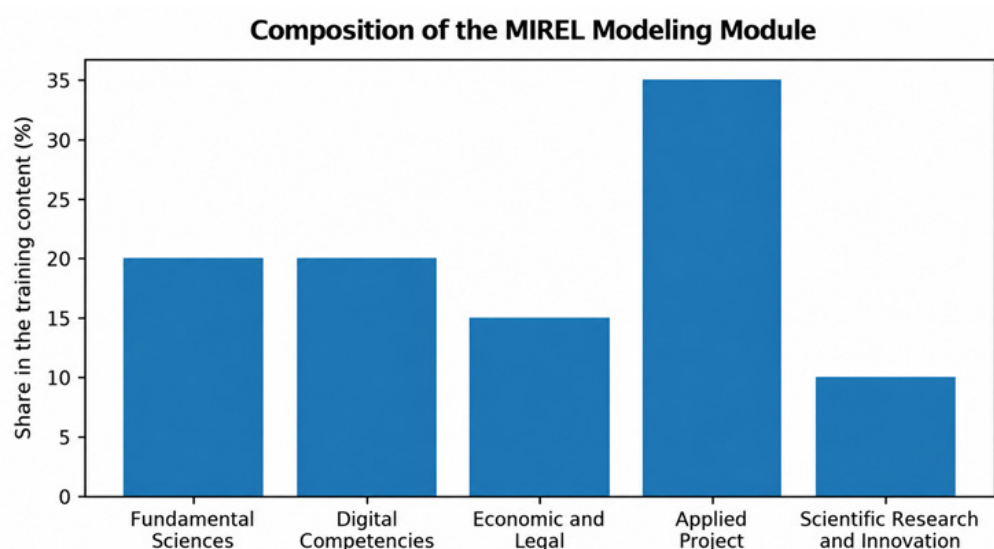


Figure 1. Module Structure of the MIREL Integrated Model<sup>4</sup>

As shown in Figure 1, the practical project accounts for the largest share of the MIREL model, directing the educational process toward solving real-world problems alongside the acquisition of theoretical knowledge. The equal proportions allocated to fundamental and digital competencies, complemented by economic-legal and scientific research modules, contribute to the development of a multidisciplinary competency profile for graduates.

#### DISCUSSION OF THE RESULTS OF DIGITAL EDUCATIONAL TOOLS

The presented materials identify PVsyst, HOMER Energy, MATLAB/Simulink, virtual laboratories, MOOCs, and AR/VR tools as important instruments in alternative energy education. The methodological value of these tools is reflected in their capacity to repeatedly model complex energy systems in a safe environment, compare different technological alternatives, and connect theoretical knowledge with practical calculations. Considering that the percentage-based efficiency indicators presented in the source are derived from different studies, it is appropriate to interpret them as indicative measures reflecting methodological potential.

#### CONCLUSION AND SUGGESTIONS

The research results demonstrate that integrating the traditional lecture model with competency-based,

<sup>3</sup> Source: Improved by the author based on the presented MIREL model.

<sup>4</sup> Source: Author's elaboration based on the presented research data.

project-based, and digital approaches in teaching alternative energy courses in higher education institutions in Uzbekistan can enhance educational effectiveness. A comparison of international methodologies highlights the advantages of PBL, PrBL, simulation, and dual education in developing practical competencies.

The improved MIREL model is designed to develop technical, digital, economic, legal, and scientific competencies within a unified educational trajectory through five interconnected modules. Allocating 35% of the model to practical projects provides an opportunity to link learning outcomes with real-world energy projects.

From a practical perspective, it is appropriate to continuously improve national educational standards, enhance instructors' qualifications, develop regional laboratories, institutionalize industry-academia collaboration, and gradually introduce international accreditation requirements. Future research should empirically evaluate the effectiveness of the MIREL model using experimental and control groups and assess changes in students' competencies through statistical methods.

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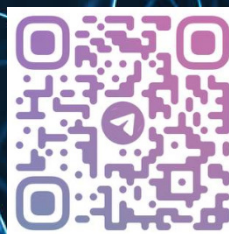
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