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Economic sciences

TRAINING PATHWAYS FOR INNOVATION MANAGEMENT TALENT IN CHINA–KYRGYZSTAN CROSS-BORDER E-COMMERCE UNDER THE DIGITAL SILK ROAD

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Abstract

Against the backdrop of the unfolding Digital Silk Road initiative and the concomitant rapid expansion of the regional digital economy, cross-border e-commerce cooperation between China and Kyrgyzstan has deepened considerably, giving rise to a growing demand for composite talent professionals who possess not only digital technical proficiency but also cross-cultural literacy and innovative managerial capabilities. However, Kyrgyzstan's ongoing educational digital transformation continues to face systemic impediments, including incomplete institutional mechanisms, unevenly developed digital infrastructure, and insufficient digital competence among faculty members. These constraints have resulted in a pronounced mismatch between the existing talent cultivation system and the exigencies of industry. Moreover, university curricula are slow to update, remaining heavily oriented toward basic operational skills while lacking advanced competencies such as data analytics, digital marketing, and brand management. The degree of industry–education integration remains low, and practical teaching components are underdeveloped factors which further impede the effective supply of high-level talent.

In light of the foregoing, this paper draws upon the relevant literature and the actual development of China–Kyrgyzstan cross-border e-commerce in order to construct a talent development pathway specifically designed for innovative, multidisciplinary management professionals within the context of the Digital Silk Road. The study unfolds along three interconnected dimensions. First, it reconstructs an interdisciplinary curriculum system that integrates “technology, business, and culture”, incorporating such components as AI-driven marketing, big data analytics, and the digital representation of the ethnic cultures of both China and Kyrgyzstan. Second, it leverages the “Silk Road E-commerce” cooperation mechanism to establish a cross-border industry–education collaborative training platform, thereby enhancing students' practical capabilities through engagement with authentic cross-border business scenarios and the introduction of a dual-mentorship model. Third, it devises a diversified evaluation mechanism, constructing a comprehensive competency-based assessment system that moves beyond traditional metrics.

The findings suggest that this multidimensional, collaborative talent development model helps to alleviate the acute shortage of high-level cross-border e-commerce professionals between China and Kyrgyzstan, while simultaneously fostering the deep integration of the education system with the digital economy. As such, the model carries substantial significance for promoting regional economic development and educational cooperation under the Belt and Road Initiative.

Keywords: *Digital Silk Road; cross-border e-commerce; talent development; China -Kyrgyzstan cooperation; digital economy*

The Digital Silk Road continues to expand its reach across Central Asia, and that expansion brings profound transformations to regional trade architectures. Within such a dynamic environment, transnational electronic commerce between China and Kyrgyzstan has emerged as one of the most vibrant sectors. [2, 3, 4, 5, 8]. Yet the rapid evolution of digital trading platforms, logistical networks, and consumer behaviour outpaces the capacity of educational systems to supply appropriate human capital. A growing body of industry reports indicates that the most pressing bottleneck for further growth is not infrastructure or investment, but a severe shortage of professionals who can manage innovation across technological, commercial, and cross cultural domains [1, 6].

Conventional training models inherited from the pre digital era remain widely entrenched in Kyrgyzstani higher education. Those models prioritise narrow operational skills, such as listing products or processing orders, while neglecting advanced competencies like data driven market intelligence, artificial intelligence aided promotion, and brand storytelling adapted to local ethnic sensibilities. Consequently, a widening gap separates what employers actually demand from what graduating students can deliver. That gap manifests itself in extended recruitment cycles, frequent staff turnovers, and underperforming cross border ventures.

Several structural obstacles explain why existing talent pipelines fail to meet industry needs. University curricula evolve slowly due to rigid approval procedures, leaving little room for emerging topics like predictive analytics or conversational commerce. Digital infrastructure varies dramatically between urban centres and rural campuses, restricting hands on experience with authentic platform ecosystems. Teaching staff often lack firsthand exposure to real time cross border transactions, which limits their ability to design practice oriented assignments. Moreover, assessment systems remain heavily weighted toward theoretical examinations rather than portfolio based demonstrations of problem solving under uncertainty.

Under these circumstances, designing deliberate training pathways for innovation management talent becomes not merely desirable but urgent. A training pathway, understood as a structured sequence of learning experiences that bridges academic knowledge with workplace realities, can address multiple deficits simultaneously. First, such a pathway can embed interdisciplinary modules that fuse technical proficiencies, managerial reasoning, and cultural literacy. Second, it can mobilise industry university collaboration through shared projects, dual mentoring arrangements, and immersion in live trading scenarios. Third, it can introduce competency based evaluation that captures how learners navigate ambiguous situations, negotiate across cultural boundaries, and adapt to shifting market signals [7, 11, 12].

Focusing on the China Kyrgyzstan corridor offers a particularly instructive case. The two countries enjoy dense historical ties, geographical proximity, and growing mutual investments in digital infrastructure. Kyrgyz entrepreneurs increasingly source finished goods from Chinese platforms while exporting local agricultural and artisanal products in reverse direction. However, successful operation in that bidirectional flow requires nuanced understanding of distinct regulatory regimes, payment preferences, logistics nodes, and consumer trust building mechanisms. Without dedicated training pathways tailored to these specificities, businesses will continue to rely on costly expatriate hires or trial and error learning, both of which constrain scalability.

From a broader academic perspective, the present investigation fills an evident research lacuna. Existing literature on cross border e commerce talent concentrates overwhelmingly on mature markets such as Europe or Southeast Asia. Post Soviet Central Asia, particularly the intersection of Chinese outbound investment and local capacity building, remains underexplored. Furthermore, most studies treat cultural competence as a generic soft skill rather than an integrated component of innovation management. By contrast, the proposed framework elevates ethnodigital fusion, that is the deliberate weaving of Sino Kyrgyz heritage elements into digital storefronts and brand narratives, to a central design principle.

In practical terms, the outcomes of designing such training pathways can inform curriculum reform efforts at multiple universities across Kyrgyzstan. They can also provide actionable guidance for policy-makers seeking to align educational standards with digital economy roadmaps. Regional integration initiatives under the Shanghai Cooperation Organisation and other multilateral frameworks increasingly stress digital connectivity. However, connectivity without corresponding human capability remains

hollow. Therefore, deploying systematic talent development trajectories constitutes a foundational investment for sustained mutual benefit.

The urgency is further amplified by demographic and technological trends. Kyrgyzstan possesses a relatively young population with high digital device penetration among youth, yet many graduates lack the advanced analytical and managerial competences that command premium wages in the labour market. Meanwhile, artificial intelligence tools are automating routine e commerce tasks, from product categorisation to chat based customer service. That automation shifts the value of human labour toward higher order functions, namely strategic planning, creative branding, intercultural negotiation, and adaptive problem solving. Training pathways that neglect those higher order functions risk producing graduates who are obsolete upon arrival.

To summarise the line of reasoning, the present study addresses a concrete socioeconomic necessity: the mismatch between a rapidly digitising trade corridor and an education system struggling to catch up. By proposing structured, evidence informed training pathways for innovation management talent, the research contributes both to scholarly debates on digital talent formation and to on the ground efforts to strengthen China Kyrgyzstan economic cooperation under the broader umbrella of the Digital Silk Road.

1. The Essence and Development Logic of Cross-Border E-Commerce Talent Development in the Context of the Digital Silk Road

1.1 The New Landscape of Cross-Border E-Commerce Development Driven by the Digital Silk Road

The iterative evolution of digital technologies together with the progressive deepening of the Belt and Road Initiative has gradually turned the Digital Silk Road into a core vector for regional economic cooperation and for transforming trade regimes. Within the institutional architecture of the Shanghai Cooperation Organization, and more specifically within its evolving digital and economic agenda, the ongoing convergence between the digital economy and cross border e commerce is becoming increasingly pronounced. That convergence accelerates a fundamental shift in international trade, moving away from traditional offline transaction models and toward trade mediated by digital platforms. Viewed from the specific angle of China Kyrgyzstan bilateral cooperation, what can be observed is a steady embedding of China's mature cross border e commerce platforms, digital payment infrastructures, and logistics networks into Kyrgyzstan's domestic market system. That embedding process has in turn catalyzed a kind of leapfrog growth in Kyrgyzstan's digital infrastructure and market scale. Nevertheless, and here lies a critical caveat, despite a notable increase in internet penetration across Kyrgyzstan over recent years, the educational system's feedback loop remains painfully long [2]. Consequently, the capacity to develop relevant talent lags significantly behind the pace of technological change. The result takes the form of a fairly stark structural contradiction: technological evolution consistently outruns the supply of adequately trained human capital. Adding further complexity, cross border e commerce has itself matured into a comprehensive ecosystem comprising at least four interrelated layers, namely platforms, data, supply chains, and brands. That shift toward an ecosystem based logic has not only reshaped the operational principles of individual firms but has also elevated the competency requirements for practitioners. What is now demanded is a broad and integrated skill set spanning digital technology application, international market analysis, and cross cultural communication. For that reason, and it can be argued that such a consideration is no longer a matter of mere recommendation, constructing a talent development system truly aligned with those emerging demands has become a critical, indeed non negotiable, pillar for sustaining further growth of the regional digital economy.

1.2 Defining the Essence of Multidisciplinary Innovative Management Talent in Cross-Border E-Commerce

The ongoing reconfiguration of professional competence requirements within cross border e commerce, as outlined above, deserves a more granular institutional critique. The tripartite framing, namely the technological, managerial, and cultural dimensions, though analytically convenient, risks obscuring several tensions inherent in actual educational practice across post Soviet Central Asian contexts. Kyrgyzstan is no exception to that pattern.

A start can be made with the technological dimension. There is no denying that artificial intelligence and big data analytics are becoming infrastructural to platform operations. However, the widespread assumption that higher education institutions can promptly integrate these modules into existing curricula appears empirically weak. The time lag between corporate adoption of AI driven marketing tools and their first appearance in university syllabi typically spans three to five years. During this interval, graduates emerge with competencies that are already semi obsolete. Consequently, any talent

development pathway must incorporate continuous upskilling loops rather than rely solely on front loaded disciplinary training.

Turning to the business management axis, the shift from price based competition to brand and supply chain battles is undeniable. Nevertheless, the expectation that an individual practitioner should simultaneously master international trade law, brand architecture, and entrepreneurial risk taking verges on what might be termed competency overload. In real world settings, such polymathic demands rarely materialise. Instead, effective teams exhibit distributed expertise. Hence a more realistic pedagogical target involves fostering meta cognitive abilities, namely knowing when to delegate, how to synthesise inputs from legal, logistical, and marketing specialists.

The cultural dimension, specifically the inclusion of Sino Kyrgyz ethnic heritage into digital business education, is where the argument becomes genuinely innovative. Most existing frameworks treat culture as a static backdrop. In contrast, the earlier text gestures toward what can be called *ethnodigital fusion*. By that is meant the deliberate embedding of traditional patterns, narratives, and visual codes into e commerce user interfaces, product descriptions, and brand stories. That approach holds promise for localised differentiation in a crowded regional market. Yet operationalising such fusion demands instructional designers who themselves possess bicultural fluency, a resource currently scarce in Kyrgyz higher education.

Finally, the proposed definition of composite innovative management talent, that is high level applied professionals capable of integrating data analytics, operations, and cross cultural communication, requires an institutional scaffold that most universities lack. Without sustained industry university partnerships, authentic cross border project work, and performance based assessment aligned with real time platform metrics, such definitions remain aspirational. The real research challenge, therefore, lies not in further refining the definition but in engineering implementation protocols that accommodate systemic inertia and variable faculty readiness.

In conclusion, while the conceptual model offers a coherent response to digital economic pressures, its practical viability hinges on solving three prior problems: curricular update velocity, teacher digital literacy, and sustained cross border business involvement. Addressing those would convert a well phrased typology into actionable transformation.

1.3 The Logic Behind the Transformation of Talent Development Models in the Context of the Digital Silk Road

Facing deep shifts in how industries operate, old fashioned ways of training people based on pouring knowledge into their heads and drilling isolated skills no longer fit today's needs. What we urgently require is a move toward a model built on three pillars: bridging multiple disciplines, immersing learners in real practice, and forging close ties with the business world [9, 10].

That move manifests itself across four fronts. First, training goals are changing. Instead of merely teaching someone to operate a tool, we now aim to grow a person who holds broad capabilities, especially original thinking and the capacity to untangle complicated practical problems. Second, the structure of what gets taught is shifting away from rigid separate subjects. We reconstruct the body of knowledge by weaving together several modules: marketing powered by artificial intelligence, analysis of large data flows, and content drawn from regional cultural traditions.

Third, how teaching happens is being transformed. The main stage moves from a lecture hall into a learning environment driven by collaboration with real companies. Tools of choice include industry embedded academies and project based workshops. Here corporate mentors join the process, and students work on genuine cross border tasks, which closes the loop of practical feedback. Fourth, the way we assess learners is also evolving. Rather than looking only at final results, we pay equal attention to the process and to the competences a person builds along the way. We put together a multidimensional measurement framework that covers technical know how, creative potential, and tangible outputs. That gradually turns a learner into a problem solver.

All together, this change represents a systemic rethinking of educational logic. We move away from simply transmitting information and toward cultivating real world abilities in a person. Such a reorientation not only answers the inner needs of higher quality education but also provides a foundation for the regional digital economy.

2. Analysis of the Current Challenges in Cross-Border E-Commerce Talent Development in China and Kyrgyzstan

2.1 Structural Constraints in Educational Digital Transformation

The Digital Silk Road keeps advancing, and that trajectory places severe digital transformation pressures upon Kyrgyzstan's higher education system. Yet the institutional setting and how resources get

distributed still contain quite formidable limitations. At the governance level, university management structures remain overly rigid. Curriculum overhaul and programme design enjoy little discretionary freedom. Most relevant initiatives never go beyond broad declarations; they lack workable implementation routes and any genuine evaluation frameworks.

Turning to infrastructure, digital learning assets are spread unevenly across the country. A deep gap separates urban institutions from rural ones, and also different regions from one another. Although internet access has grown, such disparity continues to harm educational fairness and the overall calibre of trained personnel. Regarding learning outcomes, one observes a worrying pattern. In digitally mediated teaching environments, interaction between instructors and students stays insufficient. That signals a basic misalignment between the adopted teaching models and what learners actually require.

Taken together, three interlocked problems obstruct the cultivation of cross border e commerce talent: weak institutional provision, uneven distribution of educational resources, and outdated pedagogical approaches. Each reinforces the others, creating a stubborn barrier to progress.

2.2. Deep Disconnect Between the Curriculum System and Industry Demands

The lag in the curriculum system is the core issue constraining the cultivation of multidisciplinary talent. Existing courses primarily focus on foundational theory and traditional trade operations, lacking a systematic framework for building core cross-border e-commerce competencies. On the one hand, curriculum updates struggle to keep pace with industry developments; courses on key technologies such as AI and big data account for a low proportion, highlighting a prominent "supply-side lag." On the other hand, the curriculum structure lacks systematic coherence and has yet to form an integrated "technology-business-culture" framework, resulting in a narrow knowledge base among students. Furthermore, insufficient corporate involvement in curriculum design has led to a disconnect between teaching content and industry practices, making it difficult to meet the demand for high-quality, practice-oriented talent.

2.3. The Discrepancy Between Insufficient Digital Literacy and the Supply of High-End Talent As the digital economy grows, the demand for high-end, multidisciplinary talent in cross-border e-commerce continues to rise, but insufficient digital literacy has become a critical bottleneck. Although students possess basic operational skills, they are significantly lacking in areas such as data analysis and intelligent marketing; the teaching faculty also suffers from a lack of digital technology proficiency, making it difficult to support interdisciplinary instruction. This has led to an imbalance in the talent structure and a "mismatch between supply and demand" for high-end talent. The root cause lies in the education system's failure to effectively align with industry needs, resulting in significant gaps in talent capabilities regarding technology application, innovative thinking, and cultural expression.

2.4. Insufficient Industry-Education Integration and Lack of Cross-Border Collaboration Mechanisms

Insufficient integration of industry and education is a major shortcoming in the current training system. School-enterprise cooperation often remains at a superficial level, such as internships and employment, with limited corporate involvement in the teaching process, making it difficult to achieve collaborative talent development. At the same time, the development of practical platforms lags behind, lacking support from real cross-border business scenarios, which limits the improvement of students' practical skills. At the international cooperation level, cross-border e-commerce education collaboration between China and Kyrgyzstan is still immature. Although the "Silk Road E-commerce" initiative provides policy support, there is a lack of stable and efficient resource-sharing mechanisms. Furthermore, practical resources are concentrated in Chinese enterprises, with insufficient local participation from the Kyrgyz side. The absence of local market contexts in teaching hinders the development of cross-cultural adaptability and local innovation capabilities. The cumulative effect of these issues systematically constrains the quality of training for composite innovative management talent.

3. Building a Talent Development Pathway for China-Kyrgyzstan Cross-Border E-Commerce in the Context of the Digital Silk Road

Based on an analysis of the developmental logic and current challenges, it is evident that the issues in China-Kyrgyzstan cross-border e-commerce talent development do not stem from a single factor but are the result of the combined influence of multiple factors, including the curriculum system, practical environment, and evaluation mechanisms. Therefore, it is necessary to adopt a holistic perspective to construct a composite training pathway that promotes the coordinated development of knowledge, skills, and practical experience, enabling the educational system to better align with the development needs of the cross-border e-commerce industry under the Digital Silk Road framework.

3.3. Reconstructing a Curriculum System Based on Interdisciplinary Integration

Traditional, single-discipline-oriented curriculum systems can no longer meet the requirements for composite competencies in cross-border e-commerce. Curriculum content is gradually expanding toward the integration of technology, business, and culture, combining technologies such as AI marketing and big data analysis with e-commerce operational practices, enabling students to understand the practical value of technology within real-world business contexts. At the same time, by incorporating Kyrgyz national culture into the curriculum in light of the regional cultural characteristics of China-Kyrgyzstan cross-border e-commerce, we can enhance students' market comprehension and brand cultural expression capabilities, transforming digital technology from a mere tool into a vital medium connecting markets and cultures. During implementation, content such as e-commerce operations, digital marketing, supply chain management, and innovation and entrepreneurship can be integrated through modular approaches, while project-based learning reinforces the connections between knowledge domains, enabling students to make a natural transition from knowledge acquisition to skill application through practical tasks.

3.4. Building a Practical Platform for Cross-Border Industry-Education Collaboration

Classroom instruction alone cannot sufficiently support the cultivation of cross-border e-commerce talent; the development of practical training environments has gradually become critical. Leveraging the Digital Silk Road and the "Silk Road E-commerce" cooperation mechanism, the foundation of the China-Kyrgyzstan cross-border e-commerce industry continues to improve. The deep involvement of Chinese enterprises in Kyrgyzstan provides authentic business scenarios for teaching. Building on this, a university-enterprise collaborative practice platform is established by integrating corporate resources, combining coursework with real-world business operations. Under the guidance of corporate mentors, students participate in cross-border e-commerce operations, gaining an understanding of market demands and operational logic in real-world contexts, thereby bridging the gap between theory and practice. As cooperation deepens, a model of transnational collaborative training is gradually taking shape. By integrating resources from Chinese enterprises with the local market environment in Kyrgyzstan, a practical training system for real cross-border transactions has been established. This enables students to gain experience in a multicultural setting, enhancing both their professional competencies and cross-cultural adaptability.

3.5. Innovation in Competency-Based Multi-Dimensional Assessment Mechanisms

As industry demands for innovation and practical skills increase, traditional assessment methods centered on knowledge testing are no longer sufficient to fully reflect students' capabilities. Consequently, evaluation is shifting toward a multidimensional and process-oriented approach. In practice, assessment criteria can be expanded from single-skill testing to include data analysis, innovative thinking, cross-cultural communication, and project execution capabilities. By comprehensively evaluating the learning process, project outcomes, and practical performance, we can more fully reflect students' developmental progress. At the same time, involving corporate mentors and industry experts in the evaluation process enhances its practical orientation. Integrating market feedback into the comprehensive assessment of project outcomes ensures that evaluations are closely aligned with real-world application scenarios. Furthermore, evaluation methods centered on competitions and projects serve as important supplements. By testing competencies through practical application, these approaches not only boost learning motivation but also further reinforce the competency-oriented talent development model.

4. Empirical Analysis: A Case Study of the China-Kyrgyzstan Cross-Border E-Commerce Talent Development Model

Building upon the established talent development pathway, this study selects the "cross-border e-commerce industry collaboration + university-industry collaborative training" model as a representative case to verify its feasibility and practical value, providing an in-depth analysis of its operational mechanisms and outcomes in a real-world setting. The China-Kyrgyzstan cross-border e-commerce talent development system under the "Digital Silk Road" framework is illustrated in the figure below:

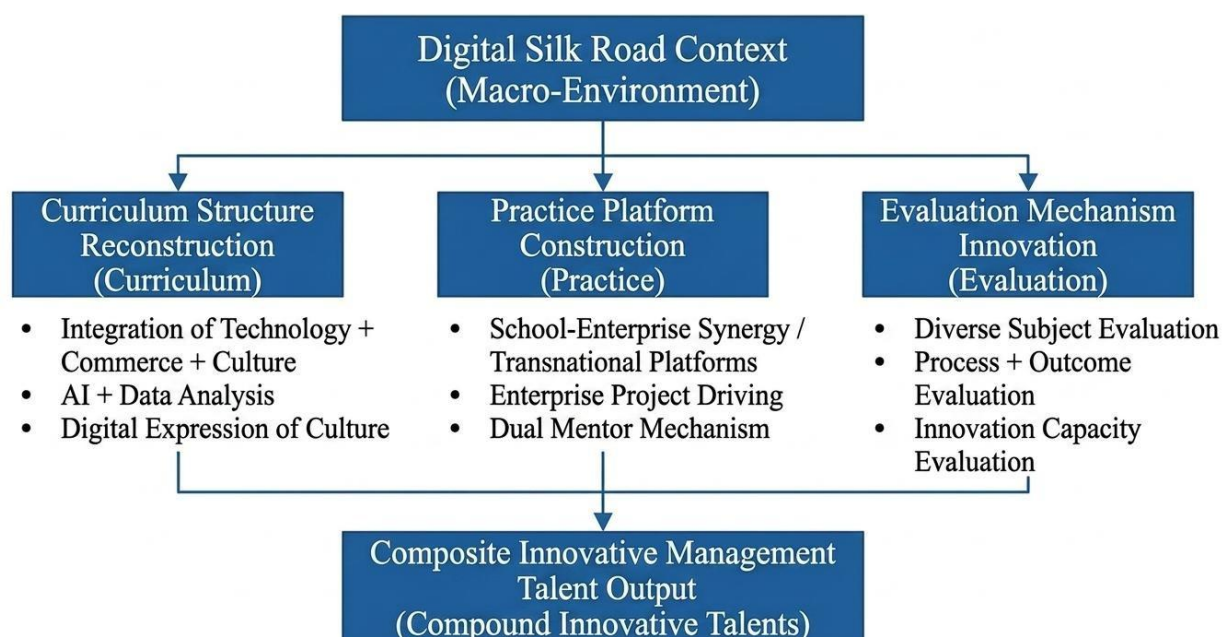


Figure 1. Talent Cultivation Framework Model for China-Kyrgyzstan Cross-border E-commerce

4.3. Case Background: The Practical Foundation of China-Kyrgyzstan Cross-Border E-Commerce Cooperation

In recent years, driven by the “Digital Silk Road” and “Silk Road E-commerce” frameworks, China-Kyrgyzstan cross-border e-commerce cooperation has entered a more advanced stage. Marked by the Bishkek E-commerce Expo and related trade cooperation, Chinese e-commerce platforms and the Kyrgyz market have established an initial collaborative system in areas such as logistics, payment, and platform transactions. This “enterprise localization + market localization” development model provides a real-world industrial environment for talent cultivation. In response to this trend, some universities have begun exploring ways to integrate practical resources from Chinese enterprises into their educational systems. Through project collaboration and the development of practical training platforms, students are deeply engaged in real business processes, thereby breaking the limitations of traditional classroom teaching and providing solid empirical support for the implementation of a pathway to cultivate multi-disciplinary talent.

Implementation Model: A Closed-Loop Mechanism of Curriculum—Practice—Evaluation In practice, this training model has established an operational logic where “course learning—project practice—multi-dimensional evaluation” are seamlessly interconnected. During the course phase, the focus of instruction lies on interdisciplinary knowledge integration, enabling students to master core theories such as e-commerce operations, big data analysis, and digital marketing through modular learning. Subsequently, in the practical phase, corporate projects are fully embedded into the teaching process, with students working in teams to undertake real-world tasks such as product selection, market analysis, and promotional management. Under the guidance of dual mentors from both the university and industry, students continuously refine their operational strategies through task-driven learning, thereby reinforcing and internalizing theoretical knowledge. Finally, in performance, and corporate feedback. Since evaluation criteria are directly aligned with market demands, the results hold greater practical value, driving the continuous optimization of course content and practical activities and forming a virtuous cycle of education.

4.4. Implementation Outcomes: Multidimensional Competency Enhancement and Alignment of Supply and Demand

Based on implementation feedback, this model has demonstrated positive outcomes across multiple dimensions. First, students’ practical problem-solving abilities have significantly improved. Through end-to-end business operations, they have mastered systematic methods ranging from macro-level market insights to micro-level operational execution. Second, digital literacy and cross-cultural literacy have been simultaneously strengthened. While using data tools for user profiling and forecasting, students must also conduct in-depth research into cultural differences and consumer habits between China and Kyrgyzstan; this “real-world” training has effectively broadened their international perspective. Most

importantly, this model has, to a certain extent, alleviated the mismatch between talent supply and industry demand: by getting involved in the training process early on, enterprises can secure a talent pool with high alignment; universities, in turn, can dynamically adjust their teaching priorities based on front-line industry feedback, achieving a win-win situation for both industry and education.

4.5. Discussion: Feasibility and Practical Challenges of Scaling Up

Although this case study validates the effectiveness of industry-education collaboration, its large-scale implementation still faces practical constraints. On the one hand, the stability of cross-border collaboration mechanisms is constrained by differences in the institutional environments and educational systems of the two countries, and the sustainability of cooperation still requires policy guarantees at a higher level; on the other hand, the uneven distribution of high-quality corporate resources leads to a shortage of practical training platforms in some regions. Furthermore, the pressure on the teaching faculty to undergo digital transformation remains significant, and the lack of interdisciplinary teaching capabilities may become a "bottleneck" constraining the model's expansion. Therefore, future efforts must focus on coordinated initiatives in policy design, cross-border resource integration, and specialized faculty development to ensure that this composite innovative management talent cultivation model can yield tangible results in China and Kyrgyzstan, as well as across the broader "Belt and Road" region.

Conclusion

As the Digital Silk Road moves forward and the regional digital economy expands at a rapid pace, collaborative activity in cross border e commerce between China and Kyrgyzstan grows ever deeper. That deepening cooperation generates a continuously rising demand for composite innovative management personnel. Drawing upon a survey of existing scholarly works and the broader developmental environment, the present study systematically examines the principal shortcomings affecting current practices in cultivating cross border e commerce talent across the two countries. Several interconnected factors emerge from that examination. An outdated curricular architecture, insufficient digital proficiencies among both students and instructors, and shallow integration between academic institutions and industry collectively produce a pronounced disconnect between the supply of graduates and what the market actually needs.

Proceeding from these findings, and taking into account the specific characteristics of cross border e commerce evolution, the study constructs a talent development trajectory. That trajectory rests upon three pillars: restructuring the curriculum, establishing cross border platforms for industry academic collaboration, and introducing diversified evaluation mechanisms. Practical viability of the proposed pathway is then tested through illustrative case studies.

The study indicates that the organic integration of digital technology, business logic, and cultural elements helps form a curriculum system better aligned with the development needs of cross-border e-commerce. Meanwhile, conducting practical teaching based on corporate resources and real-world business scenarios can significantly enhance students' comprehensive abilities and problem-solving skills. The introduction of a diversified evaluation mechanism further reinforces a competency-based approach, shifting talent development from the mere transmission of knowledge toward the cultivation of comprehensive competencies. This multidimensional, collaborative talent development model not only effectively alleviates the shortage of high-end talent in the cross-border e-commerce sector but also promotes the deep integration of the education system with the digital economy to a certain extent, providing sustained talent support for China-Kyrgyzstan cross-border e-commerce cooperation.

Nevertheless, this study primarily relies on literature analysis and case studies, lacking systematic empirical data to support its findings; the effectiveness of talent cultivation under different regional and institutional conditions remains to be further verified. In the future, questionnaire surveys and quantitative analysis methods could be integrated to conduct an in-depth evaluation of the implementation effectiveness of the training model. Concurrently, differentiated pathways should be explored within a broader context of international cooperation, with increased attention paid to the application mechanisms of emerging technologies, such as artificial intelligence, in talent development. By continuously refining theoretical and practical research, we can help drive the optimization and upgrading of the China-Kyrgyzstan cross-border e-commerce talent development system, thereby providing a more solid talent foundation for the construction of the Digital Silk Road.

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LEAPFROGGING DEVELOPMENT IN POST-CONFLICT TERRITORIES: SKIPPING TRADITIONAL STAGES THROUGH INNOVATIVE INVESTMENTS IN AZERBAIJAN'S LIBERATED AREAS

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Abstract

Post-conflict territories rarely have the luxury of rebuilding step by step through the same slow sequence that historically shaped stable regions. In the case of Azerbaijan's liberated territories, reconstruction is occurring under unusual conditions: infrastructure was heavily damaged, population return requires rapid service delivery, and the state has simultaneously framed these areas as laboratories for smart settlements, green energy, and digitally enabled governance. This article argues that the most productive framework for understanding this strategy is the leapfrogging model, in which destroyed or underdeveloped systems are not merely restored but redesigned around advanced technologies, new investment logics, and integrated territorial planning. Rather than reproducing outdated energy, housing, transport, and agricultural systems, Azerbaijan has the opportunity to bypass them through innovative investment, especially where reconstruction, resettlement, and economic diversification are being pursued together. The article develops a conceptual discussion of leapfrogging in post-conflict development, examines why this model is especially relevant to Azerbaijan's post-conflict territories, identifies priority sectors for innovative investment, and outlines the policy conditions required for a successful transition from recovery to competitive regional transformation.

Introduction

The reconstruction of post-conflict territories is often described as a process of restoration. Yet for Azerbaijan's liberated territories, restoration alone is too narrow a concept. The more strategic question is whether these regions should be rebuilt as replicas of what existed before occupation and destruction, or whether they should be transformed into economically modern, ecologically efficient, and digitally connected spaces that are better adapted to twenty-first century development dynamics. This distinction is central to the idea of leapfrogging.

Leapfrogging refers to a development pathway in which latecomer or disrupted regions avoid passing through every historical stage previously experienced by more advanced economies. Instead, they adopt advanced institutional, financial, and technological solutions that compress time, lower transition costs, and create new competitive advantages. For post-conflict territories, this model is especially appealing because war damage often eliminates both obsolete infrastructure and the political possibility of gradualism. Under such conditions, reconstruction can become a strategic reset.

Azerbaijan's post-conflict territories provide a particularly relevant setting for this approach. These areas are being rebuilt not only for humanitarian return and basic recovery, but also through the concepts of smart village, smart city, green energy zone, and modern logistics integration. In effect, the reconstruction agenda already contains the building blocks of a leapfrogging strategy; what remains is to articulate them within a coherent development model and align investment policy accordingly.

Leapfrogging as a Development Model

In development theory, leapfrogging challenges linear assumptions that countries or regions must pass through fixed historical stages before reaching higher productivity and technological sophistication. Burlamaqui and Kattel argue that development should be understood less as convergence toward a universal endpoint and more as innovation-driven leapfrogging supported by finance and institutional governance [1, p. 270]. Their argument is particularly valuable for post-conflict contexts because it shifts attention from imitation to strategic capability-building.

Recent scholarship also expands the concept beyond industrial upgrading alone. Yap and Truffer show that transformative leapfrogging requires not only knowledge accumulation but also the reshaping of legitimacy, markets, and finance around new socio-technical systems [2, p. 226]. This means that advanced development is not achieved simply by importing technology; it depends on whether policy can organize an ecosystem in which new technologies become investable, socially accepted, and institutionally embedded.

This broader understanding is highly relevant to post-conflict territories. In such environments, infrastructure, public trust, service delivery, and economic opportunity are rebuilt at the same time.

Therefore, leapfrogging should be seen not as a narrow technological shortcut but as a coordinated model linking governance, capital allocation, settlement planning, and productive transformation.

Why Post-Conflict Territories Can Leapfrog

Post-conflict reconstruction is often constrained by damaged infrastructure, weak investor confidence, institutional fragility, and the urgent need to deliver visible results. Yet these same constraints can create a unique opportunity. Because destroyed territories must rebuild foundational systems from the ground up, they are less locked into obsolete networks than mature regions. In this sense, the absence of legacy systems can become a developmental advantage if paired with strategic investment.

The World Bank's analysis of private participation in infrastructure in post-conflict settings emphasizes that where the right priorities and policies are established early, governments can mobilize financing and private expertise to break cycles of low investment and low productivity [3, p. 1]. This insight matters for Azerbaijan because reconstruction in the liberated territories is not only a fiscal exercise; it is also a question of how public investment can crowd in private and foreign capital over time.

A second reason leapfrogging is plausible in post-conflict settings is the possibility of institutional redesign. Rather than extending fragmented services into devastated spaces, governments can introduce integrated digital administration, resilient infrastructure standards, renewable energy systems, and new land-use models in one coordinated phase. Post-conflict territories thus allow not just rebuilding, but redesign.

Azerbaijan's Liberated Territories as a Leapfrogging Space

Azerbaijan has already articulated several strategic ideas that fit the leapfrogging paradigm. The first is the decision to rebuild liberated settlements through the smart city and smart village concepts. Official and semi-official accounts of the reconstruction agenda indicate that these settlements are intended to combine housing, social services, production systems, digital solutions, smart agriculture, and alternative energy within unified territorial projects. This directly departs from incremental reconstruction and instead points toward integrated modernization.

The second pillar is the designation of Karabakh and East Zangazur as a Green Energy Zone. According to the relevant official platform, the liberated territories are being developed around renewable energy potential and a long-term low-carbon transition agenda. In leapfrogging terms, this means that energy infrastructure is not being reconstructed as a fossil-fuel-heavy legacy system, but as a platform for future competitiveness, energy security, and environmental branding.

The third pillar is the broader strategic framing of reconstruction as modernization. Analytical accounts of post-war rebuilding in Karabakh stress that Azerbaijan's approach links security stabilization, large-scale public investment, transport connectivity, smart planning, and renewable energy development rather than treating reconstruction as a purely humanitarian or engineering task [4]. This framing is important because leapfrogging requires a forward-looking development narrative that attracts capital, technology partners, and skilled labor.

Priority Areas for Innovative Investment

Renewable Energy and Energy Systems

Renewable energy is one of the clearest sectors through which leapfrogging can occur. Since the liberated territories are being structured as a green energy zone, investments in solar, wind, storage, and intelligent grids can reduce dependence on older centralized energy models while improving long-term resilience [5]. Such investments are economically important not only for local supply, but also because low-carbon infrastructure can attract international strategic investors, climate finance, and technology partnerships.

Smart Settlements and Digital Public Services

Smart villages and smart cities should not be understood as branding exercises. Their real significance lies in combining housing construction, e-governance, utility management, education, health access, and digital service delivery in ways that reduce spatial disadvantage. For returnee populations, this can shorten the time between physical resettlement and actual socioeconomic reintegration.

Smart Agriculture and Rural Value Chains

Large parts of Azerbaijan's post-conflict territories possess agricultural potential. If reconstructed through conventional low-productivity models, these areas may remain dependent on subsidies and basic commodity production. But if investment supports precision irrigation, sensor-based farming, digital land management, renewable-powered cold storage, and agro-logistics platforms, agriculture can become a high-value, knowledge-intensive sector rather than a traditional fallback activity.

Logistics, Corridors, and Territorial Connectivity

Leapfrogging also depends on external connectivity. Reconstructed roads, rail links, logistics facilities, and digital trade systems can turn formerly peripheral territories into connected nodes within domestic and regional value chains [6]. This is especially relevant for Azerbaijan, whose liberated territories have strategic significance for internal integration and broader Eurasian transport geography.

Investment Logic and Institutional Conditions

Innovative investment is not defined only by the novelty of technology. It also depends on how risk is governed, how incentives are designed, and how public and private actors coordinate over time. Research on fragile and conflict-affected contexts by the OECD and EBRD underlines that private-sector recovery and growth can support broader development when investment strategies are linked to state-building, peacebuilding, and context-specific risk management [7, p. 1]. This principle is highly relevant for Azerbaijan's post-conflict territories, where investor decisions will depend on confidence in governance, infrastructure sequencing, land regulation, and long-term policy consistency.

For this reason, a leapfrogging model in the liberated territories should rest on several institutional conditions:

- predictable legal rules for domestic and foreign investors;
- phased use of blended finance, guarantees, and public-private partnership instruments;
- integration of reconstruction policy with industrial, agricultural, digital, and energy policy;
- transparent territorial planning that aligns resettlement with jobs and services;
- education and skills systems that prepare returnees and youth for technologically upgraded local economies.

Without such conditions, advanced projects may remain isolated showcases rather than drivers of structural transformation. Leapfrogging succeeds when infrastructure, institutions, and productive sectors evolve together.

Risks and Limits

Despite its promise, leapfrogging is not automatic. The first risk is technological overdesign: territories may receive highly visible smart solutions without sufficient maintenance capacity, local ownership, or economic integration. In that case, reconstruction becomes expensive symbolism rather than development.

The second risk is uneven inclusion. If advanced infrastructure is built but employment creation lags, returnees may encounter a modern physical environment without a sustainable local economy. Leapfrogging must therefore be measured not only by digital tools or energy projects, but by whether families can work, produce, learn, and remain in these territories over the long term.

The third risk is policy fragmentation. Smart villages, renewable energy, transport, agriculture, and investment promotion must be treated as interdependent systems. If they proceed separately, Azerbaijan may rebuild sectors, but not a functioning regional development model.

Conclusion

For Azerbaijan's post-conflict territories, leapfrogging is more than an academic concept; it is a rare historical opening. Regions that were once marked by destruction can become places where time itself is reorganized—where decades of delayed development are not merely recovered, but outpaced through bold combinations of green energy, digital governance, smart agriculture, and innovation-oriented investment. The real ambition, therefore, is not to rebuild yesterday with better materials. It is to design tomorrow so convincingly that return, productivity, sustainability, and dignity arrive together.

If this vision is pursued consistently, the liberated territories can emerge not as peripheral zones restored after war, but as frontier spaces of Azerbaijani modernization. Their success would demonstrate that post-conflict recovery need not move in a straight line. Sometimes the most resilient path forward is a jump: from ruins to smart systems, from disruption to design, and from reconstruction to reinvention.

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Journalism

VISUAL COMMUNICATION IN PR: WAYS OF INFLUENCING THE AUDIENCE

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PR-ДАҒЫ ВИЗУАЛДЫ КОММУНИКАЦИЯ: АУДИТОРИЯҒА ӘСЕР ЕТУ ТӘСІЛДЕРІ

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Abstract

This article examines how visual communication influences audiences in public relations. In the modern digital environment, brands actively use not only text but also corporate colors, logos, photos, videos, infographics, and human images to communicate with consumers. The purpose of the study is to identify how visual tools affect audience attention, brand recognition, trust, and emotional connection.

The research is based on literature review, content analysis, and comparative analysis. The visual materials of five international brands – Apple, Nike, Coca-Cola, Netflix, and McDonald's – were analyzed. In total, 50 visual materials were examined, including social media posts, advertising banners, short videos, product images, and campaign visuals.

The results show that visual communication plays an important role in strengthening brand image. Corporate color appeared in 70% of the analyzed materials, while logos and brand symbols were found in 54%. Each brand uses visual communication differently: Apple emphasizes minimalism and quality, Nike focuses on motivation, Coca-Cola creates positive emotions, Netflix builds intrigue, and McDonald's relies on bright colors and product visibility.

Overall, visual communication is not only a design element but also a strategic PR tool that helps attract attention, improve brand recognition, build trust, and create emotional connection with audiences.

Аңдатпа

Бұл мақалада PR саласындағы визуалды коммуникацияның аудиторияға әсер ету тәсілдері қарастырылады. Қазіргі цифрлық ортада брендтер тұтынушылармен байланыс орнату үшін мәтінмен қатар фирмалық түс, логотип, фото, видео, инфографика және адам бейнесі сияқты визуалды құралдарды белсенді қолданады. Зерттеудің мақсаты – визуалды құралдардың аудитория назарын аударуға, брендті тануға, сенім қалыптастыруға және эмоциялық байланыс орнатуға әсерін анықтау.

Зерттеу әдебиеттерге шолу, контент-талдау және салыстырмалы талдау әдістеріне негізделді. Apple, Nike, Coca-Cola, Netflix және McDonald's брендтерінің 50 визуалды материалы қарастырылды. Олардың ішінде әлеуметтік желідегі посттар, жарнамалық баннерлер, қысқа видеолар, өнімдік суреттер және брендтік кампания визуалдары болды.

Нәтижелер визуалды коммуникацияның бренд имиджін күшейтуде маңызды рөл атқаратынын көрсетті. Талдау бойынша материалдардың 70%-ында фирмалық түс, 54%-ында логотип немесе фирмалық белгі қолданылған. Әр бренд визуалды коммуникацияны әртүрлі мақсатта пайдаланады: Apple минимализм мен сапаға, Nike мотивацияға, Coca-Cola жағымды эмоцияға, Netflix қызығушылыққа, ал McDonald's ашық түс пен өнім бейнесіне басымдық береді.

Жалпы, визуалды коммуникация тек дизайн элементі емес, аудитория назарын аудартамын, брендті есте сақтататын, сенім мен эмоциялық байланыс қалыптастыратын стратегиялық PR құралы болып табылады.

Keywords: PR, visual communication, brand image, audience, visual content, logo, corporate color, digital marketing, social media, emotional impact.

Кілт сөздер: PR, визуалды коммуникация, бренд имиджі, аудитория, визуалды контент, логотип, фирмалық түс, digital-маркетинг, әлеуметтік желі, эмоциялық әсер.

Кіріспе

Қазіргі цифрлық қоғамда ақпарат ағымы өте жылдам. Адамдар ұзақ мәтін оқығаннан гөрі, қысқа әрі түсінікті визуалды контентті – сурет, видео, инфографиканы – тез қабылдайды. Осыған байланысты визуалды коммуникация PR-дың негізгі құралдарының біріне айналды. Бүгінде компаниялар мен брендтер аудиторияның назарын аудару үшін тек мәтінмен шектелмей, визуалды элементтерді белсенді қолданады [1]. Ғылыми зерттеулерде бұл үрдіс заманауи коммуникацияның табиғи дамуы ретінде түсіндіріледі. Визуалды бейнелер адамның эмоциясына тікелей әсер етіп, ақпаратты тез әрі тиімді жеткізеді [2]. Сонымен қатар визуалды коммуникация қазіргі қоғамда мағынаны жеткізудің негізгі формаларының бірі ретінде қарастырылады. Бұл визуалдың тек қосымша элемент емес, толыққанды коммуникация құралы екенін көрсетеді.

Әсіресе халықаралық брендтер бұл мүмкіндікті тиімді пайдаланады. Мысалы, Apple минималистік дизайн арқылы сапа мен премиум имидж қалыптастырса, Nike динамикалық визуалдар арқылы мотивация мен күш идеясын жеткізеді [3]. Ал Coca-Cola түс пен эмоцияға негізделген визуал арқылы қуаныш пен бірлік сезімін қалыптастырады. Бұл брендтердің тәжірибесі визуалды коммуникацияның аудиторияға әсер етудегі тиімділігін айқын көрсетеді [4]. Ресейлік және қазақстандық зерттеулерде де визуалды коммуникацияның маңызы кеңінен қарастырылады. Цифрлық ортада визуалды контенттің рөлі артып, аудиторияның ақпаратты қабылдау форматы өзгергені айтылады [5]. Сонымен қатар визуалды образдардың адамның санасында тез сақталатыны және бренд имиджін қалыптастыруда маңызды рөл атқаратыны көрсетіледі. Әлеуметтік желілер дәуірінде визуалды контент аудиториямен сенімді байланыс орнатудың негізгі құралына айналды.

Зерттеу мақсаты:

PR-дағы визуалды коммуникацияның аудиторияға әсер ету тәсілдерін шетелдік брендтер мысалында анықтау.

Зерттеу міндеттері:

1. Визуалды коммуникацияның теориялық негіздерін қарастыру
2. PR-дағы визуалды құралдарды жүйелеу
3. Әлемдік брендтердің визуалды стратегияларын талдау
4. Визуалды контенттің аудиторияға психологиялық әсерін анықтау

Зерттеу сұрағы:

Шетелдік брендтер визуалды коммуникация арқылы аудиторияға қалай әсер етеді?

Әдістер

Бұл зерттеуде сапалық әдістер қолданылады. Себебі мақалада визуалды коммуникацияның сандық көрсеткіштері емес, оның мазмұны, аудиторияға әсер ету ерекшелігі және бренд имиджін қалыптастырудағы рөлі қарастырылады.

Біріншіден, әдебиеттерге шолу әдісі пайдаланылды. Бұл әдіс арқылы PR, визуалды мәдениет, digital-маркетинг және бренд коммуникациясы туралы ғылыми еңбектер қарастырылды. Әдебиеттерге шолу визуалды коммуникацияның теориялық негізін түсінуге және зерттеу бағытын анықтауға мүмкіндік береді.

Екіншіден, контент-талдау әдісі қолданылды. Контент-талдау барысында әлемге танымал шетелдік брендтердің визуалды материалдары қарастырылды. Зерттеу нысаны ретінде Apple, Nike, Coca-Cola, Netflix және McDonald's брендтері таңдалды. Бұл брендтер визуалды коммуникацияны тұрақты әрі жүйелі қолданатындықтан, оларды талдау PR тәжірибесіндегі тиімді тәсілдерді анықтауға көмектеседі [6].

Үшіншіден, салыстырмалы талдау әдісі қолданылды. Бұл әдіс арқылы аталған брендтердің визуалды коммуникация ерекшеліктері бір-бірімен салыстырылды. Салыстыру брендтердің

аудиториямен байланыс орнатуда қандай визуалды құралдарға басымдық беретінін анықтауға мүмкіндік береді [7].

Талдау келесі критерийлер бойынша жүргізілді: визуалды стиль, түс палитрасы, фото мен видео қолдану, эмоциялық әсер, бренд сәйкестігі және аудиториямен байланыс. Осы критерийлер арқылы әр брендтің визуалды коммуникациядағы өзіндік ерекшелігі мен аудиторияға ықпал ету тәсілдері анықталды.

Нәтижелер

Бұл зерттеуде әдебиеттерге шолу әдісі PR-дағы визуалды коммуникацияның теориялық негіздерін терең түсіну үшін қолданылды. Қарастырылған еңбектер шетелдік, ресейлік және қазақстандық зерттеушілердің көзқарастарын қамтиды. Нәтижесінде визуалды коммуникацияның аудиторияға әсер ету механизмдері, оның PR жүйесіндегі рөлі және цифрлық ортадағы ерекшеліктері анықталды [8, 9].

Шетелдік ғылыми еңбектерде визуалды коммуникация адамның эмоциясына, алғашқы әсеріне және шешім қабылдауына ықпал ететін маңызды құрал ретінде сипатталады. Зерттеулерде түс, форма, дизайн, логотип және композиция сияқты визуалды элементтер аудиторияның брендті қабылдауына тікелей әсер ететіні көрсетіледі [10]. Сонымен қатар визуалды сәйкестік брендтің танымалдылығын арттырып, тұтынушы санасында тұрақты ассоциациялар қалыптастыратыны айтылады.

Кейбір зерттеулерде эмоция тудыратын визуалды контенттің тез таралу мүмкіндігі жоғары екені дәлелденеді. Қуаныш, шабыт, қызығушылық немесе таңғалу сезімін беретін визуалдар аудиторияның назарын күшейтіп, контенттің әлеуметтік желілерде белсенді таралуына ықпал етеді. Бұл PR-дағы визуалды материалдардың әсер ету күшін түсіндіреді [11]. Ресейлік ғылыми еңбектерде де визуалды коммуникацияның жарнама және PR саласындағы маңызы кеңінен қарастырылады. Зерттеулерде визуалды бейнелердің адамның назарын тез аударып, есте сақтау қабілетін күшейтетіні көрсетіледі. Сонымен қатар цифрлық коммуникация жағдайында аудиторияның мәтіннен гөрі визуалды ақпаратты жылдам қабылдайтыны және визуалды контентке көбірек сенім білдіретіні айтылады [12].

Қазақстандық зерттеулерде визуалды коммуникация заманауи медианың маңызды бөлігі ретінде қарастырылады. Әсіресе әлеуметтік желілер мен жаңа медиа кеңістігінде визуалды контенттің жастар аудиториясына әсері жоғары екені көрсетіледі [13]. Сонымен қатар визуалды коммуникацияның тиімділігі аудиторияның мәдени ерекшеліктеріне, ұлттық қабылдауына және әлеуметтік контекстіне байланысты екені атап өтіледі. Әдебиеттерге шолу нәтижелері бірнеше маңызды қорытынды жасауға мүмкіндік берді. Біріншіден, визуалды коммуникация адамның эмоциясына тікелей әсер етеді және ақпаратты жылдам қабылдауға мүмкіндік береді. Екіншіден, визуалды сәйкестік брендті танымал етудің негізгі құралдарының бірі болып табылады. Үшіншіден, әлеуметтік желілер жағдайында визуалды контенттің маңызы айтарлықтай артқан. Төртіншіден, визуалды коммуникацияның тиімділігі аудиторияның мәдени және психологиялық ерекшеліктеріне тәуелді.

Контент-талдау барысында Apple, Nike, Coca-Cola, Netflix және McDonald's брендтерінің визуалды материалдары қарастырылды. Әр брендтен 10 визуалды материалдан алынып, жалпы 50 визуалды контент талданды. Материалдарға жарнамалық баннерлер, әлеуметтік желідегі посттар, қысқа видеолар, өнімдік суреттер және брендтік кампания визуалдары кірді.

Талдауға алынған материалдар барлық брендке тең бөлінді. Бұл брендтерді салыстыруға ыңғайлы болды (1-кесте).

1-кесте. Контент-талдауға алынған материалдар саны

Бренд	Талданған визуалды материал саны	Үлес салмағы
Apple	10	20%
Nike	10	20%
Coca-Cola	10	20%
Netflix	10	20%
McDonald's	10	20%
Барлығы	50	100%

Кестеден көрініп тұрғандай, әр бренд бірдей көлемде қарастырылды. Бұл нәтижелердің біржақты болмауына және брендтердің визуалды тәсілдерін әділ салыстыруға мүмкіндік берді.

Келесі кезеңде әр брендтің визуалды стилі, негізгі түстері және аудиторияға әсер ету тәсілдері анықталды (2-кесте).

2-кесте. Брендтердің негізгі визуалды ерекшеліктері

Бренд	Негізгі визуалды стиль	Басым түс	Негізгі әсер ету тәсілі
Apple	Минимализм, таза фон	Ақ, қара, сұр	Сапа, технология, премиум имидж
Nike	Динамика, спорттық қозғалыс	Қара, ақ, қызыл	Мотивация, күш, жеңіске ұмтылу
Coca-Cola	Жылы эмоция, мерекелік атмосфера	Қызыл, ақ	Қуаныш, достық, бірігу
Netflix	Қою түстер, драмалық постерлер	Қара, қызыл	Қызығушылық, интрига, эмоция
McDonald's	Ашық түс, өнім бейнесі	Қызыл, сары	Тез танылу, тәбет ашу, қолжетімділік

Бұл кесте әр брендтің өзіндік визуалды “тілі” бар екенін көрсетеді. Мысалы, Apple қарапайымдылық арқылы сенім тудырса, Nike қозғалыс пен энергия арқылы аудиторияны шабыттандырады. Coca-Cola эмоцияға, Netflix қызығушылыққа, ал McDonald's өнімді тез танытуға басымдық береді.

Одан кейін визуалды құралдардың қаншалықты жиі қолданылатыны есептелді (1-сурет).



1-сурет. Визуалды құралдардың қолданылу жиілігі

Нәтижеге қарағанда, ең жиі қолданылған тәсіл – түс арқылы ерекшелену. Ол 50 материалдың 35-інде, яғни 70%-ында кездесті. Бұл фирмалық түстің брендті есте сақтауда маңызды рөл атқаратынын көрсетеді. Сонымен қатар материалдардың 54%-ында логотип немесе фирмалық белгі қолданылған. Бұл аудиторияға брендті тез тануға көмектеседі.

Соңғы кезеңде брендтердің визуалды коммуникация тиімділігі бірнеше критерий бойынша бағаланды (3-кесте).

3-кесте. Брендтердің визуалды коммуникация тиімділігі бойынша салыстырмасы

Бренд	Түс сәйкестігі	Визуалды стиль тұрақтылығы	Эмоциялық әсер	Брендті тану жеңілдігі	Жалпы баға
Apple	9/10	10/10	8/10	9/10	9.0
Nike	8/10	9/10	10/10	9/10	9.0
Coca-Cola	10/10	9/10	10/10	10/10	9.8
Netflix	8/10	8/10	9/10	9/10	8.5
McDonald's	10/10	9/10	8/10	10/10	9.3

Бұл салыстыру бойынша ең жоғары көрсеткіш Coca-Cola брендіне байқалды – 9,8 балл. Оның визуалды коммуникациясында түс, эмоция және брендті тану көрсеткіштері өте жоғары. McDonald's та жоғары нәтиже көрсетті, себебі оның қызыл-сары түсі мен өнім бейнесі аудиторияға бірден танылады. Apple мен Nike визуалды стилінің тұрақтылығымен ерекшеленеді, ал Netflix көрермен қызығушылығын оятатын драмалық визуалдарды тиімді қолданады.

Контент-талдау нәтижесінде визуалды коммуникация шетелдік брендтер үшін тек жарнама құралы емес, аудиториямен байланыс орнатудың маңызды PR тәсілі екені анықталды. Талдау бойынша 50 материалдың 70%-ында фирмалық түс негізгі рөл атқарды, 54%-ында логотип немесе бренд белгісі анық көрінді, 44%-ында өнім бейнесі қолданылды, ал 40%-ында адам бейнесі арқылы эмоциялық байланыс жасалды.

Бұл көрсеткіштер визуалды коммуникацияның аудитория назарын аудару, брендті есте сақтау және эмоциялық әсер қалыптастыру үшін маңызды екенін дәлелдейді.

Үшіншіден, зерттеуде салыстырмалы талдау әдісі қолданылды. Бұл әдіс арқылы Apple, Nike, Coca-Cola, Netflix және McDonald's брендтерінің визуалды коммуникация ерекшеліктері бір-бірімен салыстырылды. Салыстыру нәтижесінде әр брендтің аудиториямен байланыс орнатуда қандай визуалды құралдарға басымдық беретіні анықталды.

Салыстырмалы талдау көрсеткендей, әр бренд визуалды коммуникацияны өзіндік стратегия арқылы қолданады. Мысалы, Apple минималистік стильге сүйенеді: қарапайым фон, аз элемент, таза композиция. Бұл тәсіл аудиторияда сенім мен сапа туралы әсер қалыптастырады. Ал Nike керісінше, динамикалық визуалдарды, қозғалысты, спортшылар бейнесін қолдана отырып, мотивация мен энергияны жеткізеді.

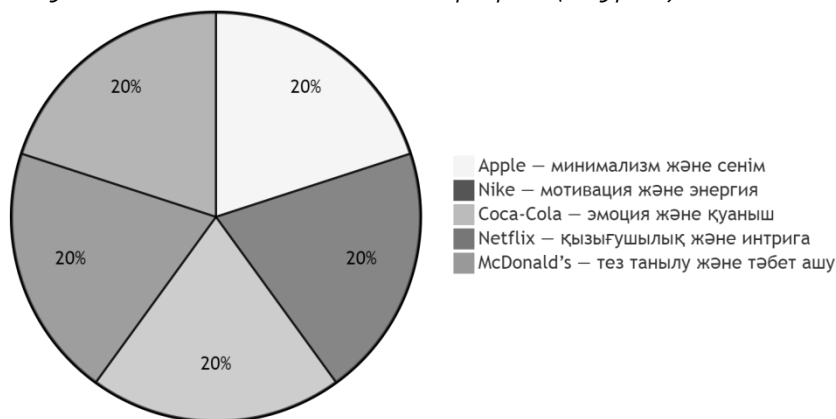
Coca-Cola визуалды коммуникацияда эмоцияға басымдық береді. Оның жарнамаларында адамдар, мерекелік сәттер, достық атмосфера жиі кездеседі. Бұл аудиторияда позитивті көңіл күй қалыптастырады. Ал Netflix визуалды контентте драмалық әсер мен интригаға назар аударады: қою түстер, контраст, кейіпкерлердің эмоциясы арқылы көрерменнің қызығушылығын арттырады.

McDonald's визуалды коммуникацияда қарапайымдылық пен тез танылуға мән береді. Өнімнің ірі бейнесі, ашық түстер және минималды мәтін арқылы аудиторияның назарын жылдам аударады.

Жалпы салыстырмалы талдау нәтижесінде бірнеше ортақ және айырмашылық белгілер анықталды. Барлық брендтерде фирмалық түсті тұрақты қолдану, логотипті визуалға енгізу және қысқа, түсінікті контент жасау ортақ сипат болып табылады. Ал айырмашылықтары олардың негізгі әсер ету стратегиясында көрінеді: біреуі эмоцияға, біреуі мотивацияға, енді бірі қарапайымдылық пен стильге басымдық береді.

Осылайша, салыстырмалы талдау визуалды коммуникацияның әр бренд үшін бірдей емес, аудитория мен бренд позициясына байланысты әртүрлі қолданылатынын көрсетті. Бұл PR-дағы визуалды стратегияны таңдауда брендтің мақсаты мен аудитория ерекшеліктері шешуші рөл атқаратынын дәлелдейді.

Салыстырмалы талдау нәтижесінде әр брендтің визуалды коммуникацияда өзіндік басым бағыты бар екені анықталды. Apple минимализм арқылы сенім қалыптастырса, Nike мотивация мен энергияға сүйенеді. Coca-Cola эмоциялық әсерге, Netflix қызығушылық пен интригаға, ал McDonald's тез танылу мен өнім бейнесіне басымдық береді (2-сурет).



2-сурет. Брендтердің визуалды коммуникациядағы негізгі басымдығы

Диаграммада көрсетілгендей, барлық брендтер визуалды коммуникацияны белсенді қолданады, бірақ олардың аудиторияға әсер ету тәсілдері әртүрлі. Бұл PR саласында визуалды стратегияны таңдағанда брендтің мақсаты, аудиториясы және нарықтағы орны ескерілуі керек екенін көрсетеді.

Талқылау

Зерттеу нәтижелері PR саласында визуалды коммуникацияның стратегиялық маңызы жоғары екенін көрсетті. Әдебиеттерге шолу, контент-талдау және салыстырмалы талдау нәтижелері өзара үйлесіп, визуалды контенттің аудиторияға әсер ету механизмдерін нақтылай түсті. Алынған деректер визуалды элементтердің ішінде түстің ықпалы ерекше екенін

дәлелдейді. Контент-талдау бойынша материалдардың 70%-ында фирмалық түстер қолданылған. Бұл түстің тек эстетикалық безендіру құралы емес, брендтің мағыналық коды екенін көрсетеді. Ғылыми еңбектерде де визуалды шешімдер адамның алғашқы әсерін қалыптастырып, кейінгі қабылдауына ықпал ететіні айтылады [14].

Сонымен қатар зерттеу барысында логотип пен визуалды сәйкестіктің де маңызы айқындалды. Материалдардың 54%-ында фирмалық белгі анық көрінген. Бұл тұрақты визуалды элементтердің тұтынушы санасында бренд туралы нақты әрі ұзақ сақталатын ассоциациялар қалыптастыратынын көрсетеді.

Зерттеу барысында әр брендтің визуалды коммуникацияны әртүрлі мақсатта қолданатыны анықталды. Мысалы, Apple қарапайымдылық пен минимализм арқылы сенімділік пен сапаны көрсетсе, Nike қозғалыс пен эмоцияға негізделген визуалдар арқылы мотивациялық әсер береді. Бұл эмоция тудыратын контенттің аудиторияға күшті әсер етіп, оның таралу ықтималдығын арттыратынын дәлелдейді.

Эмоциялық әсер әсіресе Coca-Cola мысалында айқын байқалады. Бұл бренд визуалды коммуникацияда қуаныш, достық, мерекелік көңіл күйді көрсетеді. Ал Netflix визуал арқылы қызығушылық пен интрига қалыптастырады. Мұндай тәсілдер аудиторияны әрекетке, яғни көруге, сатып алуға немесе бөлісуге итермелейді. McDonald's тәжірибесі визуалды қарапайымдылықтың тиімділігін көрсетеді. Ашық түстер, ірі өнім бейнесі және қысқа мәтін аудиторияға ақпаратты бірден жеткізеді [15]. Бұл қазіргі цифрлық ортадағы тұтынушы мінез-құлқымен тығыз байланысты, себебі әлеуметтік желі қолданушылары ақпаратты тез қабылдап, визуалды контентке көбірек назар аударады.

Қазақстандық зерттеулерде де визуалды коммуникацияның, әсіресе жастар аудиториясына әсері жоғары екені айтылады. Бұл зерттеуде қарастырылған брендтердің негізгі аудиториясы да цифрлық ортада белсенді жастармен байланысты. Сонымен қатар визуалды контенттің тиімділігі оның мәдени сәйкестігіне де тәуелді. Яғни бір визуалды шешім барлық аудиторияға бірдей әсер етпеуі мүмкін [16]. Жалпы талдау нәтижелері визуалды коммуникацияның үш негізгі қызметін айқындады. Біріншіден, ол аудитория назарын тез аударады. Екіншіден, брендті есте сақтауды жеңілдетеді. Үшіншіден, эмоциялық әсер арқылы аудиториямен байланыс орнатады. Осы қасиеттердің үйлесуі визуалды коммуникацияны PR-дағы ең тиімді құралдардың біріне айналдырады.

Қорытынды

Қорытындылай келе, жүргізілген зерттеу PR саласындағы визуалды коммуникацияның қазіргі цифрлық қоғамда аса маңызды рөл атқаратынын көрсетті. Бүгінгі аудитория ақпаратты өте жылдам қабылдайды, сондықтан компаниялар мен брендтер өз хабарламасын қысқа, түсінікті және әсерлі түрде жеткізуге ұмтылады. Осы жағдайда визуалды коммуникация PR-дың ең тиімді құралдарының біріне айналады. Себебі сурет, түс, видео, логотип, шрифт, композиция сияқты элементтер аудиторияға бірден әсер етеді және бренд туралы алғашқы пікір қалыптастырады.

Зерттеу барысында визуалды коммуникацияның тек ақпарат жеткізу құралы емес, аудиториямен эмоционалды байланыс орнататын стратегиялық механизм екені анықталды. PR-да визуал брендтің сыртқы бейнесін ғана емес, оның құндылықтарын, мінезін, нарықтағы орнын және аудиториямен қарым-қатынас стилін көрсетеді. Яғни визуалды коммуникация арқылы бренд өзін қалай танытатынын, қандай эмоция бергісі келетінін және аудитория санасында қандай бейне қалдырғысы келетінін білдіреді.

Әдебиеттерге шолу нәтижелері визуалды элементтердің адамның қабылдауына, эмоциясына және есте сақтауына тікелей әсер ететінін дәлелдеді. Шетелдік, ресейлік және қазақстандық зерттеушілер визуалды контенттің қазіргі медиа кеңістікте маңызы артқанын атап өтеді. Бұл теориялық тұжырымдар зерттеу барысында алынған практикалық нәтижелермен сәйкес келді. Яғни визуалды коммуникация адамның назарын аударып қана қоймай, белгілі бір сезім тудырып, брендке деген көзқарасты қалыптастырады.

Контент-талдау барысында Apple, Nike, Coca-Cola, Netflix және McDonald's брендтерінің визуалды материалдары қарастырылды. Жалпы 50 визуалды контент талданды. Нәтижесінде материалдардың 70%-ында фирмалық түс негізгі рөл атқарғаны анықталды. Бұл түс палитрасының брендті танытудағы маңызы өте жоғары екенін көрсетеді. Мысалы, Coca-Cola қызыл түс арқылы қуаныш пен мерекелік көңіл күйді жеткізсе, McDonald's қызыл-сары түстер арқылы жылдамдық, қолжетімділік және тәбет ашу әсерін береді. Ал Apple бейтарап түстер арқылы сапа, тазалық және заманауи стильді көрсетеді.

Сонымен қатар талданған материалдардың 54%-ында логотип немесе фирмалық белгі қолданылғаны анықталды. Бұл визуалды сәйкестіктің брендті есте сақтаудағы рөлін көрсетеді. Қазіргі әлеуметтік желі жағдайында қолданушылар контентті ұзақ қарап отырмайды. Сондықтан логотип, түс немесе өнім бейнесі сияқты элементтер брендті бірнеше секунд ішінде танытуға мүмкіндік береді. Осы тұрғыдан алғанда, визуалды коммуникация аудиторияның назарын ұстап қалу үшін ғана емес, брендтің есте сақталуы үшін де қажет.

Салыстырмалы талдау нәтижесінде әр брендтің визуалды коммуникацияны өзіндік мақсатпен қолданатыны байқалды. Apple минимализм арқылы сенім мен премиум имидж қалыптастырады. Оның визуалдарында артық элементтер аз, дизайн таза әрі қарапайым. Бұл аудиторияға сапа мен сенімділік әсерін береді. Nike қозғалыс, спортшы бейнесі және күшті эмоция арқылы мотивация тудырады. Бұл бренд аудиторияны белсенділікке, жеңіске және өзін дамытуға шақырады.

Coca-Cola визуалды коммуникацияда эмоциялық жақындыққа басымдық береді. Оның визуалдарында қуаныш, достық, отбасы, мереке сияқты образдар жиі кездеседі. Бұл брендтің өнімді ғана емес, жағымды көңіл күй мен өмір салтын ұсынатынын көрсетеді. Netflix визуалды стратегиясында драмалық әсер, интрига және қызығушылық маңызды орын алады. Қою түстер, кейіпкерлердің эмоциясы, тартымды постерлер көрерменді контентті көруге ынталандырады. McDonald's болса қарапайым, ашық әрі тез қабылданатын визуалдарды қолданады. Өнімнің ірі бейнесі, қысқа мәтін және фирмалық түстер аудитория назарын тез аударады.

Зерттеу нәтижелері визуалды коммуникацияның PR-дағы бірнеше негізгі қызметін анықтады. Біріншіден, визуалды контент аудитория назарын тез аударады. Екіншіден, ол брендті есте сақтауға көмектеседі. Үшіншіден, визуал эмоциялық әсер арқылы аудиториямен байланыс орнатады. Төртіншіден, визуалды стиль бренд имиджін қалыптастырады және оны тұрақты түрде қолдап отырады. Бесіншіден, визуалды коммуникация брендтің бәсекелестерден ерекшеленуіне мүмкіндік береді.

Осы нәтижелерден визуалды коммуникацияны тек дизайн немесе жарнамалық безендіру деп қарастыру жеткіліксіз екені байқалады. Ол PR стратегиясының маңызды бөлігі болып табылады. Егер визуалды контент брендтің құндылықтарымен, мақсатымен және аудитория ерекшелігімен сәйкес келсе, оның әсері күшейеді. Ал егер визуал кездейсоқ немесе бірізділіксіз жасалса, аудитория брендті дұрыс қабылдамауы мүмкін. Сондықтан PR мамандары визуалды коммуникацияны жоспарлағанда түс, логотип, композиция, мәтін, эмоция және мәдени ерекшеліктерді ескеруі қажет.

Жалпы алғанда, Apple, Nike, Coca-Cola, Netflix және McDonald's мысалдары визуалды коммуникацияның халықаралық брендтер үшін маңызды PR құралы екенін дәлелдейді. Бұл брендтер визуалды стильді жүйелі қолдану арқылы аудиториямен тұрақты байланыс орнатып, өз имиджін күшейтіп келеді. Олардың тәжірибесі визуалды коммуникацияны дұрыс қолдану брендтің танымалдылығын арттыруға, тұтынушы сенімін қалыптастыруға және қоғаммен байланыс сапасын жақсартуға мүмкіндік беретінін көрсетеді.

Осылайша, зерттеу мақсаты орындалды: PR-дағы визуалды коммуникацияның аудиторияға әсер ету тәсілдері шетелдік брендтер мысалында анықталды. Зерттеу сұрағына жауап ретінде, шетелдік брендтер аудиторияға түс, логотип, визуалды стиль, эмоциялық образдар, фото және видео арқылы әсер ететіні анықталды. Бұл құралдар аудиторияның назарын аударып, брендті есте сақтауға және оған жағымды көзқарас қалыптастыруға көмектеседі.

Болашақта визуалды коммуникацияның маңызы одан әрі арта түседі. Себебі әлеуметтік желілер, қысқа видеолар, сторис, reels және интерактивті контент аудиториямен байланыс жасаудың негізгі алаңына айналып отыр. Сондықтан PR саласында жұмыс істейтін мамандар визуалды контенттің сапасына, шынайылығына, тұрақтылығына және аудиторияға түсінікті болуына ерекше көңіл бөлуі керек. Дұрыс құрылған визуалды коммуникация бренд пен қоғам арасындағы сенімді байланысты нығайтады және PR қызметінің тиімділігін арттырады.

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Jurisprudence

CORRUPTION AS AN ECONOMIC AND LEGAL PROBLEM

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КОРУПЦІЯ ЯК ЕКОНОМІЧНА ТА ПРАВОВА ПРОБЛЕМА

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Вступ. Корупція, як негативне явище, розповсюджується на всі сфери життя суспільства і постає постійною проблемою. Вона загрожує існуванню держави в тих формах, які визначені Конституцією. Корупція виникає там, де є державна влада, вона здатна зруйнувати економіку будь-якої країни. Крім того, корупція є індикатором того, наскільки здоровим є суспільство. Наприклад, за Індексом сприйняття корупції (CPI) у 2020 році Україна посіла 117 місце з 180 країн, отримавши 33 бали зі 100 можливих. У порівнянні з 2019 роком цей показник зріс на 3 бали, порівнявши з 2018 роком - лише на 1 бал, що явно не є позитивним результатом ефективного механізму подолання корупції [1]. Ця теза підсумовує усі негативні наслідки корупції у сферах діяльності країни, а також її правові аспекти.

Сутність корупції. На сторінках юридичної наукової літератури корупцію визначають як соціально-правове або кримінологічне явище, яке охоплює сукупність суспільно-небезпечних діянь, як криміналізованих, так і не криміналізованих у державі, але визнаних протиправними у світовій практиці. Корупція не лише має незаконний характер, але й створює складну низку проблем, які знижують здатність державного сектору ефективно функціонувати, спотворюють основні ринкові принципи та викликають сумніви серед населення щодо свого уряду. Корупція може набувати багатьох форм, дві найпоширеніші з яких - це непряме лобювання від імені великих організацій та хабарі «готівкою в руках» та/або зловживання владою [2]. Корупція створює економічну нестабільність для уряду, оскільки вона зменшує наявні ресурси, створює нерівні конкурентні умови та знижує загальну стабільність економіки.

Економічні наслідки. Корупція є одним із ключових чинників, що стримує економічний розвиток держави, оскільки негативно впливає на функціонування різних сфер суспільного життя. Вона призводить до викривлення ринкових механізмів, зниження ефективності використання ресурсів та погіршення інвестиційного клімату. Особливо помітними є її наслідки у міжнародній діяльності, зовнішній торгівлі, освіті та сфері державних закупівель, де корупційні практики формують системні економічні втрати. Для кращого розуміння наслідків в таблиці 1 представлено економічні наслідки корупції у вибіркових сферах діяльності.

Таблиця 1

Сфера	Економічний наслідок
Міжнародна діяльність	-корупція постає як країна з високою ризикованістю для можливих інвестицій та партнерства. Відповідно менше іноземних інвестицій та можливих договорів, важливих для економічного зростання, надходять до країни. -корупція є перешкодою для інтеграції в міжнародні економічні та воєнно-політичні структури, такі як Європейський Союз та НАТО, що також не дає змогу розкрити максимальний економічний потенціал.
Експорт/імпорт	Корупція погіршує торгівлю між країнами у експортно-імпортних справах, оскільки створює бар'єри у вигляді вимагання хабарів та непрозорих вимог. Це шкодить експорту вітчизняних товарів на ринках світу, тому що вони не можуть конкурувати з товарами інших країн, що власне обмежує розвиток торгівлі з іншими країнами.
Освіта	Проявляється у вигляді "купівлі сесії" та видачі дипломів, що не відповідають рівню знань майбутнього спеціаліста, що у подальшому призведе до втрати компетентного фахівця.
Державні закупівлі	Корупційні змови під час державних закупівель призводять до штучного завищення вартості товарів і послуг, що, у свою чергу, спричиняє неефективне використання бюджетних коштів. Унаслідок цього зменшується рівень конкуренції між постачальниками, оскільки перевагу отримують наближені до корупційних схем суб'єкти господарювання. Це створює нерівні умови на ринку та поступово витісняє добросовісний бізнес, що негативно впливає на розвиток економіки загалом.

Джерело: розроблено авторами.

Правові аспекти. Корупція має глибокі корені в історії і суспільстві. Вона виникає через багато причин. Однією з яких виступає недосконалість законів і правил, тому важливо, щоб уряд діяв прозоро, для довіри суспільства до влади, якої на сьогодні бракує. Крім того, низькі зарплати в державному секторі часто приводять до хабарництва, оскільки робітники бачать хабарництво як спосіб заробити додаткові гроші.

Коли громадяни бачать, що корупціонери уникають покарання за свої дії, то це призводить до зниження їхнього бажання дотримуватися законів. Вони можуть вважати, що їхні сплатені в бюджет країни податки не використовуються належним чином, що робить їх більш схильними до ухилення від сплати податків і нехтування законами.

Висновки. Корупція - це складне питання, що має як економічні, так і юридичні аспекти. Корупція створює системну шкоду для здатності держави ефективно функціонувати, водночас спотворюючи ринкові механізми. Уряди знижують довіру громадськості, коли вони виглядають корумпованими. Корупція негативно впливає на багато сфер економіки, обмежує обсяг інвестицій, можливості інтеграції країни у світову економіку та свідчить про погані правові системи та погано впроваджені закони. Боротьба з корупцією здійснюється шляхом удосконалення законів, підвищення прозорості уряду та підвищення правових знань широкої громадськості.

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Mathematical sciences

SUBOPTIMAL CONTROL OF A SINGULARLY PERTURBED SYSTEM WITH DISTRIBUTED PARAMETERS

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СУБОПТИМАЛЬНЕ КЕРУВАННЯ СИНГУЛЯРНО-ЗБУРЕНОЮ СИСТЕМОЮ З РОЗПОДІЛЕНИМИ ПАРАМЕТРАМИ

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Запропоновано метод наближеного розв'язання сингулярно збуреної задачі оптимального керування інтенсивним процесом електролізу. Будуються субоптимальне керування і критерій якості з використанням асимптотики нульового порядку, а також оцінюється близькість отриманих наближених рішень до точних.

Процес електролізу в при катодному шарі описується функцією $c(x, t)$, яка всередині області $Q = \{[0, \delta] \times [0, T]\}$ задовольняє рівнянню

$$\tau_r c_{tt} + c_t = D c_{xx} \quad (1)$$

з початковими умовами

$$c(x, 0) = c_0(x), \quad c_t(x, 0) = \varphi(x), \quad (2)$$

і крайовими умовами

$$c_x(0, t) = \frac{p(t)}{a}, \quad c(\delta, t) = \psi(t), \quad (3)$$

де τ_r – час релаксації, $p(t)$ – катодна густина розрядного струму іонів металу, $a = Z \cdot F \cdot D$ – електрохімічна константа, $c(x, t)$ – концентрація металевих іонів у об'ємі електролізера, δ – товщина катодного шару.

Необхідно знайти такий керування $p(t)$, яке задовольняє умову

$$\int_0^T p^2(t) dt < \infty$$

Щоб в кінці процесу електролізу виконувалась умова

$$c(x, T) = \theta(x)$$

а функціонал енергії

$$I[p(t)] = \int_0^T p^2(t) dt$$

Набував найменшого значення.

Використовуючи [1], можна було довести, що ця задача еквівалентна задачі з мінімальною енергією з функціоналом якості

$$I[p(t)] = \int_0^T p^2(t) dt + \frac{1}{\beta} \int_0^\delta [c(x, T) - \theta(x)]^2 dx, \quad (5)$$

$$\|p(t, \beta) - p(t)\|_{L_2(0, T)} \rightarrow 0 \quad \text{на} \quad \beta \rightarrow 0.$$

Застосовуючи принцип максимуму Понтрягіна для розв'язання цієї задачі, отримуємо, що цей контроль $p(t)$ визначається формулою

$$p(t) = -\frac{D}{2a\beta} V(0, t), \quad (6)$$

де $V(x, t)$ — єдиний розв'язок крайової задачі (7) – (9)

$$\tau_r V_t'' - V_t' = D V_{xx}''; \quad (7)$$

$$\begin{cases} V(x, T) = -2c_t(x, T); \\ \tau_r V_t(x, T) = -2c_t(x, T) + 2[c(x, T) - \theta(x)]; \end{cases} \quad (8)$$

$$\begin{cases} V_x(0, t) = 0; \\ V(\delta, t) = 0. \end{cases} \quad (9)$$

Оскільки час релаксації τ_r є малим параметром, а задача (1) – (3), (7 – 9) є сингулярно збуреною, то шукаємо її розв'язок у вигляді суми регулярної компоненти та функції граничного шару, кожна з яких представлена як сума рядів за степенями τ_r

$$c(x, t) = \bar{c}(x, t) + \Pi c(x, \tau), \quad V(x, t) = \bar{V}(x, t) + QV(x, \bar{\tau}), \quad (10)$$

$$\bar{c}(x, t) = \sum_{i=0}^{\infty} \tau_r^i \bar{c}_i(x, t); \quad \Pi c(x, \tau) = \sum_{i=0}^{\infty} \tau_r^i \Pi c_i(x, \tau) \quad (11)$$

$$\bar{V}(x, t) = \sum_{i=0}^{\infty} \tau_r^i \bar{V}_i(x, t); \quad QV(x, \bar{\tau}) = \sum_{i=0}^{\infty} \tau_r^i QV_i(x, \bar{\tau}) \quad (12)$$

де $\tau = t / \tau_r$; $\bar{\tau} = (T - t) / \tau_r$ – швидкі змінні поблизу точок $t = 0$ і $t = T$ відповідно.

Підставляючи ряди (11) і (12) у рівняння (1) і (7), граничні умови (3) і (9) та прирівнюючи коефіцієнти при рівних степенях τ_r , які окремо залежать від $t, \tau, \bar{\tau}$, ми отримуємо задачі для регулярних складових порядку τ_r^0 і приграничних функцій

$$\begin{cases} \bar{c}_{0t} = D\bar{c}_{0xx} \\ \bar{c}_0(x, 0) = \bar{c}_0(x) \end{cases} \quad \begin{cases} -\bar{V}_{0t} = D\bar{V}_{0xx} \\ \bar{V}_0(x, T) = -2[\bar{c}_0(x, T) - \theta(x)] \end{cases} \quad (13)$$

$$\begin{cases} \bar{c}_{0x} = -\frac{D}{2a\beta} \bar{V}_0(0, t) \\ \bar{c}_0(\delta, t) = \psi(t) \end{cases} \quad \begin{cases} V_{0x}(0, t) = 0 \\ V_0(\delta, t) = 0 \end{cases} \quad (14)$$

$$\begin{cases} \Pi c_{0\tau\tau} + \Pi c_{0\tau} = 0, \quad i = 0 \\ \Pi c_{i\tau\tau} + \Pi c_{i\tau} = D\Pi c_{i-1xx}, \quad i \geq 1 \end{cases} \quad \begin{cases} QV_{0\bar{\tau}\bar{\tau}} + QV_{0\bar{\tau}} = 0, \quad i = 0 \\ QV_{i\bar{\tau}\bar{\tau}} + QV_{i\bar{\tau}} = DQV_{i-1xx}, \quad i \geq 1 \end{cases} \quad (15)$$

Щоб визначити члени розкладів (11) і (12) з отриманих рівнянь, необхідно зазначити початкові умови. Ми отримуємо їх, підставляючи (11), (12) у початкові умови (2) і (8) і прирівнюючи коефіцієнти при однакових степенях τ_r .

$$\begin{aligned} \Pi c_0(x, 0) &= c_0 - \bar{c}_0(x, 0); \quad \Pi c_{0\tau}(x, 0) = 0 \\ QV_0(x, 0) &= -2\bar{c}_t(x, T) - V_0(x, T); \quad QV_{0\bar{\tau}}(x, 0) = 2\bar{c}_t(x, T) + \bar{V}_0(x, T) \end{aligned} \quad (16)$$

Співвідношення для визначення коефіцієнтів i -го порядку ряду (11), (12) можна формально записати для $i \geq 1$. Оскільки маємо справу з розподіленою системою, використання кожної наступної компоненти розкладів (11), (12) вимагає дослідження розв'язності та підвищення гладкості функцій, включених у задачу.

Щоб побудувати наближене керування найпростішого типу, ми обмежимося вивченням систем (13), (14) та (15), (16).

Використовуючи [2], доведено наступне:

Теорема 1. Субоптимальне керування $p^0(t)$ — це розв'язок інтегрального рівняння

$$\beta p^0(t) = f(t) - \int_0^T k(t, \tau) p^0(\tau) d\tau, \quad (17)$$

де

$$f(t) = \frac{bD}{a} \sum_{n=1}^{\infty} e^{\lambda_n^2 D(t-T)} \gamma_n, \quad b = \sqrt{\frac{2}{\delta}}$$

$$k(t, \tau) = \frac{D^2 b^2}{a^2} \sum_{n=1}^{\infty} e^{\lambda_n^2 D(t+\tau-2T)}$$

$$\gamma_n = \int_0^{\delta} \left(1 - \frac{x}{\delta}\right) x_n(x) dx + \frac{bSI_0}{VzF} \frac{(-1)^{n+1}}{\lambda_n^3 D} (1 - e^{-\lambda_n^2 DT})$$

Єдиність розв'язку рівняння (17) випливає з того факту, що $f(t) \in L_2(0, T)$ та додатної визначеності ядра $k(t, \tau)$. За допомогою методів розв'язання рівнянь із виродженим ядром [2] ми отримуємо розв'язок рівняння (17). Субоптимальне керування має вигляд

$$p_0(t) = \frac{b}{a} \sum_{n=1}^{\infty} (\gamma_n - g_n) e^{\lambda_n^2 D(t-T)} - \frac{D}{2a\beta} QV^0(0, t), \quad (18)$$

В якому константи g_n визначаються з нескінченної системи лінійних неоднорідних алгебраїчних рівнянь.

Наступні теореми оцінюють близькість субоптимального керування задачі до оптимального.

Теорема 2. Оптимальне керування задачі (1) – (5) $p(t)$ збігається до субоптимального $p^0(t)$, якщо $\tau_r \rightarrow 0$, та існують такі константи τ_r^0, c , що коли $0 \leq \tau_r \leq \tau_r^0$, то

$$|p(t) - p^0(t)| \leq c \tau_r \quad \forall \quad 0 \leq t \leq T$$

Теорема 3. Якщо початкові умови задачі (1) – (5) задовольняють умови $c_0(x) \in W_2^1(0, 1)$, $\theta(x) \in L_2(0, 1)$, то існує таке $0 < \tau_n \leq \tau_r^0$, що

$$|I[p] - I[p^0]| \leq c \tau_r^2.$$

$$I[p^0] = \frac{1}{\beta} \sum_{n=1}^{\infty} (\gamma_n - g_n) \gamma_n$$

Тут

відповідне субоптимальне значення функціоналу задачі.

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Medical sciences

PSYCHOSOCIAL DETERMINANTS OF THE RISK OF PREMATURE BIRTH: DATA FROM A SURVEY IN KAZAKHSTAN

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Abstract

Premature birth (PR) continues to occupy a leading place among the causes of neonatal mortality and long-term morbidity. Despite well-studied medical causes, psychosocial determinants of PR risk are still understudied. To reveal the psychosocial factors of the risk of premature birth in pregnant women who are under dispensary supervision in the city polyclinics of Almaty.

Materials and methods. A survey of 400 pregnant women in the I-II trimesters was conducted using a structured questionnaire that includes elements of the PRAQ-R2 scale. Anxiety, stress, availability of social support, family violence and living conditions were evaluated.

Results. A significant association was established between high level of anxiety (OR=4.75), low level of education, lack of employment and risk of PR. Special attention is paid to the role of family violence (OR=5.20) as an independent predictor.

Conclusion. Psychosocial factors have a pronounced influence on the risk of PR and require mandatory integration into the algorithm of screening and prevention within the framework of antenatal care.

Keywords: *Pregnancy, preterm birth, perinatal risks, psychosocial factors*

Introduction

Preterm birth directly affects the incidence of morbidity and mortality of newborns, making this problem one of the most urgent in the field of obstetrics and perinatology [1]. Also, in women with preterm labor, postpartum complications are significantly more common than in women who gave birth on time. This is due to the presence of foci of chronic infection of the genitourinary system and infection with pathogens of perinatal infection, the presence of extragenital diseases, as well as the duration of anhydrous interval and other complications of the course of labor [2, 3]. In recent years, the percentage of PR has not decreased in many countries. For example, in Russia, the rate of preterm birth remains in the range of 7-12%, in Kazakhstan - according to official data-6-12% (for the city of Almaty-11% for 2020), in Europe-5-9%, and in the USA it even increased to 12-13% [4, 5]. In premature infants, perinatal mortality is 33 times more frequent than in full-fledged newborns, and approximately 70% of early neonatal mortality is associated with prematurity [6]. Currently, the main focus is on timely diagnosis and subsequent prevention of PR [7]. Preterm labor is considered to be labor that occurs from 22 to 37 weeks of pregnancy, with a fetal weight of 500 grams or more [8]. At the same time, 40-45% of cases are spontaneous PR, of which 25-30% of cases are preceded by premature rupture of the fetal membranes (PRP). The remaining 30-35% are induced preterm labor performed prematurely due to a threat to the health of the mother or fetus [9].

The fact of preterm birth is a special life situation for a woman, which acts as a determinant of specific indicators of self-esteem, anxiety and depression, which in turn provoke changes in the emotional and personal sphere, manifest themselves in the features of socio-psychological adaptation [10]. Every year, about 15 million children are born prematurely in the world, which, of course, is the most common cause of infant mortality [14, p. 390]. Preterm birth interrupts the process of full-fledged fetal

development in the last weeks of pregnancy, and is the main cause of long-term neurological disability in children [11]. Combining the above, preterm birth is a complex problem, both medical and socio-economic, associated with solving problems to improve the quality of subsequent life of children born prematurely, and associated with material and economic costs [12]. It just so happens that all the measures taken in PR are aimed at improving the survival and health indicators of premature babies. But even these efforts do not reduce the frequency of preterm birth. The literature contains many works on the study of perinatal care in the Republic of Kazakhstan, in particular, the determination of risk factors for preterm birth (birth parity, the presence of ICN, EGZ, etc.), [13, 14, 15]. However, the in-depth analysis of individual medico-social risk factors for PR is not fully disclosed. Psychosocial stressors - anxiety, insufficient support, domestic violence - often remain outside the scope of clinical practice. In conditions of increasing urban pressure, social inequality and emotional instability of pregnant women, the study of these factors is of paramount importance. The purpose of the study was to identify psychosocial risk factors for PR and assess their contribution to the deterioration of perinatal outcomes.

Materials and methods

The study had a cross-sectional nature and was based on a survey of 400 pregnant women in the I-II trimester, who were under observation in women's clinics in Almaty. The instrument included elements of the PRAQ-R2 scale, supplemented by blocks on social support, professional workload, presence of family violence, anxiety level, as well as assessment of educational and economic status.

The results of childbirth were obtained from the history of childbirth and compared to the level of psycho-emotional stress. The analysis was carried out using SPSS 26.

Results

The analysis of psychosocial determinants showed a statistically significant relationship between a high level of anxiety and the risk of premature birth. Among women who gave birth prematurely ($n=29$), 48.3% ($n=14$) demonstrated a high level of anxiety, while in the general sample this indicator was 34.4% ($n=138$), $\chi^2 = 4.32$, $p = 0.038$. Logistic regression showed that anxiety increases the risk of premature birth by 4.75 times ($OR = 4.75$). The presence of domestic violence was noted in 5.2% ($n=21$) of women in the general group, however, no such cases were registered in the group with PR ($n=29$). Despite this, the regression analysis confirmed its significant influence on the probability of premature births ($OR = 5.20$; $p = 0.023$), which may be related to insufficient openness of women to discuss the topic of violence or cultural peculiarities of self-disclosure. Insufficient social support was found in 31.0% ($n=9$) of women with PR and in 23.5% ($n=94$) in the control group, however, the differences did not reach statistical significance ($\chi^2 = 1.16$, $p = 0.281$). Emotional stress, including night shifts and work with increased load, was revealed in 13.8% ($n=4$) of women with PR and in 17.5% ($n=70$) in the general group, $p = 0.452$.

Socio-demographic parameters also demonstrated a connection with psycho-emotional vulnerability. In the group with PR, the share of women with only secondary education was 44.8% against 20.5% in the control group ($p = 0.0004$), and only 13.8% of unemployed women, while in the general sample there were 31.9% of them ($p = 0.002$). This indicates the potential role of professional employment as a buffer against stress, as well as the relationship between the level of education and susceptibility to anxiety states.

Conclusion

Psychoemotional conditions, especially anxiety and unfavorable family situation, have a significant impact on the risk of premature birth. Social vulnerability, lack of support and emotional stress aggravate this effect, even in the absence of pronounced medical complications. In order to reduce the frequency of premature births, it is necessary to include psychosocial assessment in the standard prenatal care. Future prospects include the development of programs for early psychological support, training of nurses in the skills of identifying hidden stressors, and the introduction of interdisciplinary models of support for pregnant women with a high level of psycho-emotional risk.

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CLINICAL SIGNIFICANCE OF ULTRASOUND IN INFLAMMATORY, PRECANCEROUS DISEASES AND THYROID CANCER

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Abstract

This scientific and analytical work systematizes the clinical applications of ultrasound diagnostics for various thyroid diseases. Diffuse and focal changes, echogenicity variations, nodular and cystic lesions, inflammatory changes, and neoplastic processes in this organ are covered in detail. It is emphasized that ultrasound examination occupies a leading place both in the initial diagnosis and as part of a comprehensive patient examination. The article presents a detailed and comprehensive review of modern ultrasound diagnostic methods using various modes: B-mode only, Doppler techniques, microangiographic technologies, elastography, contrast-enhanced ultrasound, and digital analysis algorithms using artificial intelligence, as well as their features and informative value in the differential and early diagnosis of thyroid pathological conditions. Current recommendations for ultrasound diagnostic specialists in accordance with the TI-RADS standard are presented. The article presents clinical protocols for the diagnosis and treatment of various thyroid pathologies, and also describes in detail current international practices and trends in the field of oncological surveillance and early diagnosis of thyroid cancer using ultrasound examination.

Keywords: thyroid gland, thyroid, thyroid lesions, ultrasound, ultrasound diagnostics, region of interest, B-mode, color Doppler, ultra-microangiography, ultra-microvascular imaging technology, elastography, contrast ultrasonography, computer-assisted diagnosis, artificial intelligence, fine needle aspiration biopsy, oncology, thyroid cancer.

Today, ultrasound diagnostics of various thyroid gland pathologies, including diffuse changes, decreased and increased echogenicity, nodular and cystic lesions, inflammatory changes, and thyroid cancer, is a leading method for both primary diagnosis and comprehensive examination. According to current protocols for the diagnosis and treatment of thyroid pathology in the Republic of Kazakhstan, ultrasound diagnostics occupies a leading position both in diagnostics and for monitoring [1-4].

As noted by Zhou H. et al. [5] thyroid cancer is one of the most common malignant tumors of the endocrine system. Thyroid nodules in 5% ~ 15% thyroid cancer are malignant. The incidence rate of

thyroid cancer is increasing year by year. The incidence rate in women is generally higher than that in men. Papillary thyroid carcinoma is the most common clinical feature of thyroid cancer. It has the characteristics of high differentiation, low malignancy, good prognosis, and long survival. However, local metastasis and distant metastasis can also occur. Studies have shown that the rate of lymph node metastasis in papillary thyroid carcinoma is 84.7%, of which two-thirds have 70% lymph node metastases to thyroid cancer, and the incidence rate of thyroid cancer ranges from 70% to 85%. Local invasion or distant metastasis of thyroid cancer may increase the chance of postoperative recurrence. Therefore, metastasis of thyroid cancer is one of the important factors affecting the prognosis of patients. Early detection of thyroid cancer metastasis can help clinicians to estimate the surgical conditions. Ultrasound is the most important imaging method for the diagnosis of thyroid cancer metastasis, which is not only convenient but also accurate and reliable. With the continuous improvement of instrument performance, high-frequency ultrasound can not only sensitively display the internal structure of lesions but also provide blood flow information or judge the quality of lesions. In 2009, the American Thyroid Association emphasized the significance of ultrasound in thyroid nodules in the diagnosis and treatment manual of thyroid nodules and differentiated thyroid cancer and evaluated the ultrasonic thyroid examination as Grade A. Ultrasound examination is of great significance for early detection of thyroid cancer metastasis, early treatment, and improving the survival rate and quality of life of patients and has an important impact on the prognosis of patients.

A very interesting study was conducted by Kennedy E. et al. [6]. Our colleagues investigated which indications most commonly prompt referral for thyroid ultrasound and the diagnostic utility by indication. Extractors categorized referral reasons into (1) suspected palpable nodule (SPN) on physical examination; (2) chronic symptoms (CS) - e.g., globus sensation and dysphagia; (3) metabolic symptoms (MS; e.g., fatigue, weight change, and heat intolerance); (4) screening due to high risk for thyroid cancer (e.g., multiple endocrine neoplasia, Pendred syndrome, and family history of thyroid cancer); (5) follow-up of incidental thyroid nodule detected on another imaging study; or (6) combination of aforementioned factors. Suspected cases of goiter were included in the physical examination findings of a palpable thyroid nodule or mass. Additional variables extracted included the date of ultrasound, maximum diameter of largest nodule identified, if a biopsy was recommended by the interpreting radiologist, and if fine needle aspiration biopsy (FNAB) was performed. Demographic variables extracted included patient age, sex, race/ethnicity (White, Black, Asian, and Hispanic), insurance status (Medicaid, Medicare, private insurance, and uninsured), and Charlson Comorbidity Index (CCI) - 0, 1, and 2+. The primary outcome of interest was the percentage of thyroid ultrasounds performed that had an identifiable nodule for each referral indication. The secondary outcome evaluated "biopsy-recommended" nodules specifically, which were defined as nodules that the radiologist recommended for biopsy. Radiologists at institution routinely utilize the Thyroid Imaging Reporting and Data System (TI-RADS), and recommendations for biopsy are based on nodule size and TI-RADS category; however, specific TI-RADS scores were not abstracted. The percentage of biopsy-recommended nodules among all ultrasounds performed was compared among each referral indication.

In all, 3459 discrete neck ultrasounds were identified between 2017 and 2019. Of these, 1739 (50%) met inclusion criteria. The majority of patients were female (76%), White (86%), privately insured (62%), and healthy (76% with CCI 0); the mean age was 53 years standard deviation (SD). The most common indication for thyroid ultrasound referral was an SPN on physical examination (40% of all ultrasounds performed). The next leading referral indication was follow-up of a nodule identified on incidental imaging (28%). Referral for CS and MS made up 13% and 6% of ultrasounds, respectively. Only 2% of patients were referred for thyroid ultrasound due to high-risk factors. Patients referred for a combined indications accounted for 11% of thyroid ultrasounds. The combined indication was most often (45%) due to a patient presenting with CS and an SPN on examination. Among all ultrasounds performed, 62% identified a thyroid nodule. Patients referred for incidental findings had the highest percentage of ultrasounds with thyroid nodules present at 94%. Several possible reasons exist for the 6% of incidental findings that lacked a thyroid ultrasound correlate. For example, some were imaging "suggestive" of a nodule, but not definitively a nodule. These findings typically derived from imaging that was not optimal for the thyroid (e.g., chest or cervical spine computed tomography scan and nuclear imaging); and the suggestive nodule was ultimately not detectable on dedicated thyroid ultrasound [6].

In comparison, patients referred because of an solid pseudopapillary neoplasm (SPN) on examination and for CS identified nodules on 55% and 39% of ultrasounds, respectively. Patients with MS had a nodule on ultrasound 43% of the time. Among those referred for high-risk factors, 57% had a nodule present. Patients referred for combined indications had nodules on 42% of ultrasounds. Analysis of

variance (ANOVA) indicated the difference in nodule detection rate between indications was statistically significant ($p < 0.05$). Only 27% of ultrasounds identified a thyroid nodule that was recommended for biopsy. Those referred from incidental imaging had the highest percentage of biopsy-recommended nodules (55%). This was followed, in order, by patients referred for physical examination of a palpable thyroid nodule (21%), high-risk factors (20%), combined indications (16%), MS (10%), and CS (6%). The overall mean maximum diameter of identified thyroid nodules was 1.9 cm (SD 1.3 cm). Of note, 32 radiology reports identified a thyroid nodule but did not record size and were, therefore, excluded from this specific analysis. Patients referred for incidentally found thyroid nodules had the largest mean nodule size at 2.4 cm (SD 1.2 cm). All other groups had a mean nodule size between 1.2 and 1.8 cm. The difference in average size of nodule was statistically significant ($p < 0.05$). A logistic regression model evaluated the association of patient age, sex, ethnicity, CCI, insurance status, and referral indication with identification of a nodule on ultrasound. Compared with patients referred for an SPN on examination, those with incidental nodules were over 10 times more likely to have a nodule found on ultrasound (odds ratio [OR] = 10.6 [confidence interval (CI) 7.0–16.0]). Conversely, patients referred for CS were half as likely to have an identifiable nodule compared with those referred for physical examination findings (OR = 0.5 [CI 0.4–0.7]). In addition, the odds of finding a nodule increased with age, especially for those aged 65 years and above (vs. age <45 OR = 3.6 [CI 2.2–5.9]). Finally, females were twice as likely to have a nodule found on thyroid ultrasound (OR = 2.0 [CI 1.5–2.6]). Results were similar when evaluating only biopsy-recommended nodules. Compared with patients referred for an SPN on examination, those referred for incidental findings were significantly more likely to have a biopsy-recommended nodule (OR = 4.7 [CI 3.5–6.3]), while those referred for CS were significantly less likely to have a biopsy-recommended nodule on ultrasound (OR = 0.3 [CI 0.1–0.5]). There was no difference in identifying biopsy-recommended nodules between sexes (female vs. male OR = 1.2 [CI 0.9–1.6]). In conclusion, the authors emphasize that only a quarter of dedicated thyroid ultrasounds yielded a nodule recommended for biopsy, and 39% did not have a nodule present at all. Moreover, only half of ultrasounds performed to evaluate a suspected nodule on physical examination actually identified one. Ultrasound referrals for symptoms had the lowest diagnostic yield, with fewer than 10% identifying a biopsy-recommended nodule. These findings suggest that re-evaluation of guidelines on thyroid ultrasound referral may be necessary to decrease the overutilization of thyroid ultrasound and the downstream consequences of detection of small potentially irrelevant nodules [6].

Wu J. et al. [7] to study the application value of SMI technology (ultra-microvascular imaging technology) and contrast-enhanced ultrasound in the differential diagnosis of thyroid benign and malignant nodules. According to the authors, thyroid disease has always been a common and frequent disease in clinical medicine, and its disease detection rate has been increasing year by year. Thyroid diseases are mainly divided into two categories: thyroid diseases treated by medical treatment and thyroid diseases treated by surgery. Thyroid cancer has also become one of the most common malignant secretory tumor diseases today. Ultrasound examination is a commonly used method for diagnosing thyroid diseases. During the diagnosis process, doctors need to observe the characteristics of ultrasound images and combine professional knowledge and clinical experience to give the patient's disease status.

The thyroid is an important organ of the human body, and it plays an important role in maintaining the health of the human endocrine system and the physical and mental health of the human body. With the advancement of medical ultrasound technology, ultrasound examination has become one of the most commonly used early detection methods for diseases due to its advantages such as low price, safety, noninvasiveness, convenient use, and ability to reflect the actual situation of tissues. A thyroid nodule refers to a mass in normal thyroid tissue that is different from normal glandular tissue. Thyroid nodules can be divided into two categories according to their nature: benign nodules and malignant nodules. Among them, benign nodules can be divided into nodular goiter, thyroid adenoma, and Hashimoto's thyroiditis (HT); the main type of malignant nodules is thyroid papilloma, which is the most common pathological type with the highest incidence of malignant thyroid nodules, while other pathological types are relatively rare. Due to the superficial location of the thyroid, the boundary between the outer envelope and surrounding soft tissues is clear, which provides favorable conditions for ultrasound diagnosis. The self-regulation of thyroid function refers to the regulation of the secretion of thyroxine by the amount of iodine supplied by the thyroid itself in the absence of thyroid-stimulating hormone (TSH) or the concentration of TSH is unchanged. Therefore, for the identification and diagnosis of benign and malignant thyroid nodules, ultrasound has always been one of the preferred imaging methods. With the continuous improvement of the level of science and technology, ultrasound inspection technology has also improved. When using ultrasound to diagnose thyroid diseases, thyroid neoplastic lesions can be displayed more

clearly on the ultrasound images, and the lesions can be found in time and medical measures can be taken to control the condition. However, thyroid diseases are complex and changeable, especially malignant thyroid nodules, which are difficult to diagnose and control. During an ultrasound examination, benign and malignant nodules overlap on the two-dimensional sound image, which makes the diagnosis more difficult. Especially when some nodules have both benign and malignant characteristics, it is difficult to distinguish and qualitatively diagnose their nature based on the sonogram alone, which directly affects the choice of clinical treatment and surgical methods. This puts forward higher requirements for the initial qualitative diagnosis of lesion formation for ultrasound diagnosticians. Therefore, medicine urgently needs more advanced ultrasound diagnostic technology to overcome the difficulties encountered when using conventional ultrasound examination methods to diagnose thyroid diseases so as to help clinicians better diagnose and treat thyroid diseases and protect the health of patients. There is a clinical need for an intelligent diagnosis technology of thyroid diseases based on ultrasound images, which can provide objective and reliable auxiliary diagnosis opinions for thyroid diseases through the texture, shape, and other information of the images, freeing doctors from heavy work [7].

The study states that SMI technology is a new ultrasound diagnostic imaging method proposed by Canon in Japan in 2014. The principle basis of SMI technology is the motion suppression technology used to isolate and eliminate clutter but retain the vulgar blood flow signal. It includes ultrasound diagnostics, ultrasound therapy, and biomedical ultrasound engineering. Therefore, ultrasound medicine has the characteristics of combining medicine, science, and engineering. It involves a wide range of contents and has a high value in the prevention, diagnosis, and treatment of diseases. In the motion suppression technology, the ultrasonic detection image subtracts the change of the structure position from one frame to another, leaving only the color imaging part. SMI technology uses an adaptive wall wave to suppress clutter noise and minimize the flash artifacts of the image. Ultrasound technology is a high-tech developed in the 20th century. It is an emerging, interdisciplinary, and borderline science, which has attracted extensive attention of scientific and technological workers in countries such as the United States, Germany, Canada, Japan, and China. Contrast-enhanced ultrasound technology is a very prominent technological development in the field of ultrasound imaging diagnostics in recent years, and it can also be called the third leapfrogging revolution in the history of ultrasound imaging. Contrast-enhanced ultrasound uses low mechanical index (MI0.2) pulse contrast sequence imaging technology for ultrasound inspection, so it reduces the damage to microbubbles and greatly improves the signal-to-noise ratio of the image. In the project of acquiring a dynamic image by contrast-enhanced ultrasound, although the detected object can hold the breath for a short time, the slight movement of the organs cannot be completely eliminated, and the organ movement may be more serious after the breath-hold is over. In order to comprehensively use multiple imaging modes or co-modal changes to provide more complete information, the ultrasound contrast motion correction algorithm often integrates all effective information to make up for information deficiencies and better serve clinical diagnosis and treatment. In the work of our colleagues, the experimental methods of this study are as follows: first, 40 cases of benign and malignant thyroid nodules in China in 2018 were randomly selected. Among them, there were 20 cases of benign and malignant nodules. The maximum diameter of the nodules was 0.6~3.9 cm, with an average of 2.10.3 cm. The pathological results of all nodules were obtained through fine-needle aspiration biopsy or surgical treatment. Then, according to the standard blood flow distribution pattern of thyroid nodules, SMI technology and contrast-enhanced ultrasound were used to judge, and two different selected nodule cases composed of 20 nodules in each group (10 benign and malignant nodules) compared the distribution pattern of blood flow and the morphological characteristics of blood vessels. According to the standard blood flow distribution pattern of thyroid nodules, in this experiment, SMI technology was used to judge the blood flow distribution pattern of nodules 4 times. That the analysis of the blood flow distribution pattern of SMI technical nodules in 20 cases of benign and malignant thyroid nodules in this group showed that the number of central and mixed nodules was the same, and the number of peripheral nodules was the least. After evaluation, through 4 repeated judgments, the blood flow distribution pattern of the nodules under SMI technology is completely consistent with the actual case. It shows that SMI technology has a high accuracy rate for displaying the blood flow distribution pattern of thyroid nodules. SMI angiography showed that the vascular morphology of malignant nodules was stump type and crab foot type, with more tortuous and chaotic directions, and more irregular small branches, which was in line with the actual situation. This shows that SMI technology has a good imaging effect on nodular blood vessels [7].

In conclusion, the authors come to the conclusion that with the improvement of medical technology in today's society and the enhancement of people's health awareness, people's attention to thyroid

diseases continues to increase. However, thyroid diseases, such as malignant secretory tumor diseases, are more complex and changeable, especially for malignant thyroid nodules, which are difficult in clinical diagnosis and treatment. Conventional thyroid ultrasound examination methods also have certain limitations, such as: for benign and malignant thyroid lesions, two-dimensional detection images sometimes overlap, which can also lead to different images of the same disease, and the same frequency of different diseases; at the same time, the blood flow with a low flow rate will not be displayed. And usually, it can only clearly display the larger blood vessel images, but the new microvascular network of the tumor cannot show its full picture, which means that thyroid cancer with less blood supply is easy to be missed. These deficiencies in conventional ultrasound examinations will directly affect the clinical treatment of thyroid diseases. Therefore, the medical field of thyroid diseases urgently needs more advanced ultrasound diagnostic technology to overcome the difficulties encountered in the diagnosis of thyroid diseases so as to help clinicians better diagnose and treat thyroid diseases and protect the health of patients. With the improvement of science and technology, two more advanced ultrasound detection technologies, SMI technology and contrast-enhanced ultrasound, have emerged in medicine. SMI technology can detect very low blood flow in thyroid lesions and can noninvasively and truly reflect the blood perfusion state of the nodules; contrast-enhanced ultrasound can continuously and dynamically observe the vascular distribution and blood perfusion of thyroid nodules, showing that the possibility of tumor neovascularization has also been improved. Therefore, SMI technology and contrast-enhanced ultrasound technology can solve the current problems in the diagnosis and treatment of thyroid diseases to a certain extent by virtue of their own advantages and have begun to be used in the identification and diagnosis of thyroid benign and malignant nodules. The research in this article has proved through experiments that SMI technology and contrast-enhanced ultrasound have high diagnostic sensitivity for the identification and diagnosis of benign and malignant thyroid nodules, that is they have better diagnostic efficiency and application value. And from the comparison of sensitivity, the diagnostic sensitivity of SMI technology is slightly higher than that of contrast-enhanced ultrasound, which shows that SMI technology has slightly better diagnostic performance and application value than contrast-enhanced ultrasound. The findings of this article provide a meaningful reference for the medical community to better apply SMI technology and contrast-enhanced ultrasound in the diagnosis and treatment of thyroid diseases. The number of features extracted manually in the research of thyroid nodular disease in this article is relatively small. In the future, more features can be added to study the interaction between artificial features and neural network features to achieve better classification results [7].

Jacome C.S. et al. [8] провели познавательное исследование, посвященное эффективности пальпаторного выявления узлов в щитовидной железе и корреляции этих результатов с последующими ультразвуковыми исследованиями. The authors conducted a retrospective observational study and identified adult patients (>18 years old) who underwent thyroid or neck ultrasounds (TUS) for the first time between January 1, 2015, and September 30, 2017, from ultrasound database. An initial search identified 5,938 patients with a TUS, from which our colleagues randomly selected a cohort of 500 patients who had a TUS ordered for any reasons (e.g., screening, workup of thyroid dysfunction). Of these, 327 patients were found to have both a TUS ordered and documented physical examination of the thyroid, which was performed either as part of the thyroid-related workup (e.g., thyroid function test abnormalities, personal or family history of thyroid cancer) or as a routine neck examination. In all those instances, the TUS was ordered after the physical examination had been conducted.

The researchers piloted and applied an extraction form to collect patient demographics and the specialty of the clinician who conducted the physical exam. From the physical exam documentation, they extracted the types of findings (solitary nodule, multinodular goiter, enlargement without nodularity, normal thyroid, and an "other category" for patients with indeterminate findings such as thyroid asymmetry). Additionally, study's authors documented the precise locations (right lobe, left lobe, isthmus or bilateral) where these findings were encountered, whenever the data was accessible. In a similar fashion, researchers carefully extracted the TUS findings (solitary nodule, multinodular goiter, enlargement without nodularity, no finding, and "other category" to group patients who had thyroiditis without the presence of nodules or lymphadenopathy) and noted the corresponding locations of the described findings. When there was a nodular finding in the ultrasound, authors extracted the largest diameter from the largest nodule. Given that the accuracy of thyroid physical exam may be affected by previous knowledge of thyroid-related symptoms, our colleagues also documented whether there was presence of symptoms associated with thyroid nodules or masses (e.g., neck fullness, dysphagia, odynophagia, choking, etc). The authors summarized continuous variables using means and standard deviations, and categorical variables using frequencies and percentages. Using the TUS findings as the reference standard, they calculated

the accuracy of the findings noted from the thyroid palpation. First, our colleagues calculated the sensitivity, specificity, accuracy, and positive predictive value (PPV) and negative predictive value (NPV) of the thyroid palpation in the identification of any abnormal thyroid findings (any abnormality yes/no in thyroid palpation compared with any abnormality yes/no in thyroid ultrasound). Then, study's authors estimated the accuracy of the physical exam in detecting thyroid nodules (single thyroid nodule [yes/no] detected by thyroid palpation compared to thyroid nodule [yes/no] detected on confirmatory thyroid ultrasound), and multinodular goiters (multiple nodules [yes/no] found by thyroid palpation compared to multiple nodules [yes/no] identified on a thyroid ultrasound). Additionally, they calculated the accuracy and PPV of the thyroid physical exam to determine the location (e.g., right lobe, left lobe, isthmus or bilateral) of the thyroid findings when data was available in the medical records. Finally, authors calculated the proportion of additional findings derived from a positive thyroid palpation as 1) the number of patients who had a solitary nodule palpated and were found to have multiple nodules on the subsequent ultrasound, or 2) patients who had a thyroid enlargement in the physical exam and found to have one or more thyroid nodules on the subsequent ultrasound. When possible, researchers conducted subgroup analyses by patient sex, patient weight (obese or overweight vs. normal weight based on body mass index (BMI) categories), size of the thyroid nodule (≤ 2 cm or >2 cm), symptoms of nodular disease (yes and no), and by clinician specialty (primary care vs. specialties). Scientific researchers conducted a test interaction to evaluate for statistically significant subgroup differences [8].

Our colleagues included 327 patients, the majority were female (213/327, 65.1%) and white (275/327, 84.1%) with a mean age [standard deviation – (SD)] of 50.8 years old (16.9). Most patients were obese or overweight (225/327, 71.2%) and had the thyroid physical exam performed by a primary care clinician (178/327, 54.4%). Additionally, most patients did not present any symptoms of thyroid nodular disease (231/327, 70.6%). Regarding finding any thyroid abnormality, the thyroid physical exam had a sensitivity of 71.8% ($n=189/263$; 95% CI 66%-72.2%), specificity of 35.9% ($n=23/64$; 95% CI 24.2%-49.9%), accuracy of 64.8% (212/327; 95% CI 59.4%-70.0%), NPV 23.7% (23/97; 95% 17.5%-31.3%) and PPV 82.1% (189/230; 95% CI 79.1%-84.9%). When the diagnostic accuracy was estimated by an individual thyroid palpation finding (thyroid nodule or multinodular goitre), the physical exam had a sensitivity of 20.3% ($n=12/59$; 95% CI 12.3%-36.2%), specificity of 79.1% (212/268; 95% CI 73.7%-83.2%), accuracy of 68.5% ($n=224/327$; 95% CI 59.4%-70.0%), NPV 81.8% ($n=212/259$; 95% 81.5%-85.8%) and PPV 17.6% ($n=12/68$; 95% CI 11.1%-27.1%) in detecting a thyroid nodule; and a sensitivity of 10.8% ($n=17/157$; 95% CI 6.4%-16.7%), specificity of 96.5% ($n=164/170$; 95% CI 92.4%-98.7%), accuracy of 55.4% ($n=181/327$; 95% CI 49.78%-60.8%), NPV 53.9% ($n=164/304$; 95% 52.4%-55.4%) and PPV 73.9% ($n=17/23$; 95% CI 53.4%-87.5%) in finding a multinodular goiter. Out of 327 patients, 60 physical exams included the side of the thyroid nodule. Among these, the overall accuracy, and the PPV of the physical examination in identifying the location (e.g., right lobe, left lobe, isthmus, or bilateral) of the thyroid finding were 46.6% and 37.5%, respectively. Physical exams among symptomatic patients demonstrated superior performance than those conducted among asymptomatic patients, with higher specificity (100% vs. 62%; $p<0.01$), accuracy (83% vs. 62%; $p<0.01$), and NPV (87% vs. 79%; $p<0.01$) for detection of solitary nodules, as well as a higher NPV for detection of multinodular disease (61% vs. 51%; $p<0.01$). In addition, higher PPV for detecting multinodular disease was observed when a specialist conducted the physical exam compared to a primary care provider (100% vs. 60%; $p<0.01$) and when the nodule detected by physical examination was greater than 2 cm (100% vs. 73% for nodules ≤ 2 cm; $p=0.026$). The study's authors found that out of 68 solitary nodules palpated, 37 (54%) were found to have additional findings such as, multinodular goiter on a subsequent TUS; similarly, out of 88 patients for whom the physical exam identified an enlarged thyroid, 56 (64%) of these were subsequently found to have a solitary nodule (16 cases) or a multinodular goiter (40 cases) on the TUS. The authors emphasize that in this retrospective observational study, scientific researchers found that, while a thyroid physical exam can detect thyroid abnormalities, these findings were rarely concordant with findings identified on a subsequent thyroid ultrasound. Furthermore, the diagnostic accuracy of specific thyroid physical exam findings was low, particularly for the PPV of solitary thyroid nodules. For instance, out of every 100 patients with a physical exam consistent with a solitary thyroid nodule, approximately 18 had a thyroid nodule, while out of every 100 patients with a physical exam consistent with multinodular goiter, about 74 had the same finding in the ultrasound. In the course of the study, the authors state that thyroid physical exam has limited diagnostic performance and leads to additional findings when followed by a thyroid ultrasound. As such, thyroid physical exams in asymptomatic patients may play an important role in the overdiagnosis and overtreatment of thyroid cancer. To determine if any patient subgroups derive some benefit from thyroid physical exams beyond their use as a diagnostic approach, further research is

necessary. Additionally, potential interventions should be explored to improve the accuracy of thyroid physical exams [8].

Next, we consider a study aimed to examine the potential associations between Doppler parameters and clinical characteristics of hypothyroid patients, such as the autoimmune nature of the disease and adequacy of LT4 replacement [9]. Angelopoulos N. et al. in their work note that While hormonal assays are commonly used for thyroid function assessment, Doppler sonography provides valuable information on vascularization and blood flow.

A total of 400 consecutive patients with hypothyroidism attending an Endocrinology outpatient clinic for annual follow-up visit were evaluated for eligibility. Autoimmune thyroiditis was considered the underlying disease of hypothyroidism based on high serum concentrations of antithyroid antibodies [thyroid peroxidase (anti-TPO) and/or thyroglobulin (anti-Tg) antibodies]. Exclusion criteria were history of Graves' disease or subacute thyroiditis, malignancies, pregnancy, previous use of medications that can affect thyroid stiffness (amiodarone, tamoxifen, anti-neoplastic) and nodular abnormalities of the thyroid gland (nodules > 3 mm detected by conventional B-mode ultrasound. A total of 338 patients treated for hypothyroidism [females: $n = 292$ (86.4%); males: $n = 46$ (13.6%)] were enrolled in the study. Demographic characteristics (age, sex, BMI), treatment parameters (LT4 daily dose) were recorded and thyroid hormones [TSH, free thyroxine (fT4)] were measured. All included subjects were residents of a geographical area of low-prevalence iodine deficiency disorders. The study protocol was conducted by the tenets of the Declaration of Helsinki and all patients agreed to participate in the study, which was approved by the Bioethics Committee of the Aristotle University of Thessaloniki, Greece. Conventional B-mode thyroid ultrasound and strain elastography [(real-time elastography (RTE))] were performed on a General Electric P9 machine (LOGIQ-P9; GE Medical Systems, Milwaukee, WI, USA) with an 8–12 multifrequency linear probe. Conventional grey-scale ultrasound was initially performed to measure transverse (two dimensions) and longitudinal (one-dimension) diameters and thyroid volume. Three linear dimensions were measured for each lobe: the length (L) was assessed on the sagittal view and the anterior–posterior (A-P) and width (W) diameters of each lobe were assessed on the transverse view. Given that the normal thyroid shape is ellipsoid, the volume of each lobe was automatically calculated by recording the above-mentioned three linear dimensions (ellipsoid equation with a correction factor: $V \text{ (ml)} = L \text{ (cm)} \times A-P \text{ (cm)} \times W \text{ (cm)} \times 0.523$). Thyroid vascularity was examined with color Doppler and patients were classified into four patterns: Pattern I (normal thyroid vascularity, blood flow limited to the peripheral thyroid arteries, absent parenchymal flow); Pattern II (minimally increased thyroid vascularity, mildly increased parenchymal flow); Pattern III (increased blood flow with a diffuse homogenous distribution, increased parenchymal flow with a diffuse homogenous distribution pattern) and Pattern IV (markedly increased parenchymal flow with a homogenous distribution, including the “thyroid inferno”). The probe was placed perpendicularly to the skin for RTE examination, and repetitive light compression was applied in the longitudinal plane. The ideal pressure on the target lesion was confirmed based on the cine-memory data. A cine-memory stores data obtained through the transmission and reception of ultrasound. A cine-memory generally has a storage capacity allowing storage of multiple numbers of frames obtained in time sequence. In a cine-memory, the newest input data overwrites the oldest data which is already stored in the memory, and this process is repeated. The patients held their breath while the images were obtained to avoid respiratory motion artifacts. The strain index (elastography ratio, $E2/E1$) was used that represents the ratio of the strain of thyroid parenchyma (E2) to that of sternocleidomastoid muscles (E1). Region of interest (ROI) for E2 was free-handed and designed at the peripheral edge of the gland to include the whole longitudinal image of each lobe; ROI for E1 was the sternocleidomastoid muscle in front of the ipsilateral thyroid parenchyma [9].

An endocrinologist with twenty years of experience in sonography, who was blinded to the clinical status, performed all thyroid ultrasound examinations. The Doppler spectral analysis was of the right and left inferior thyroid arteries in the transverse scanning, in which the vessels crossed the common carotid arteries posteriorly, or in the longitudinal scanning of the ascending parts of the arteries, in which the vessels lie parallel to the common carotid arteries for the superior thyroid arteries. The superior thyroid artery was assessed with the probe positioned in the oblique sagittal plane, close to the superior thyroid pole. The inferior thyroid artery was assessed in the oblique transversal plane, close to the transition between the mid and inferior third of the thyroid. The cursor for evaluating the inferior thyroid artery was set close to the trachea to avoid artifacts from the common carotid artery and the internal jugular vein. Parameters for color Doppler are frequency 4.4–6.6 MHz, Gn 40%, pulse-repetition frequency (PRF) 2–8 kHz and Wall Filter (WF) 25–80 Hz. The angle correction cursor was parallel to the flow direction and the Doppler angle was kept at or below 60°. The sampling gate was set to 2 mm. The peak systolic

velocity (PSV), end-diastolic velocity (EDV), and pulsatility indices (PI) and the resistive index (RI) values in the superior and the inferior thyroid arteries were obtained in both thyroid lobes. The mean value of the right and left lobes was used as the outcome parameter. Serum TSH and fT4 concentrations were measured by the immunochemistry method with enzyme chemiluminescence immunoassay (reference range: 0.27–4.5 mIU/ml and 0.8–1.5 ng/dl, respectively). Measurements were performed on the Cobas 8000 platform by Roche (Basel, Switzerland). Data were presented as mean $\pm$ SD or range (min—max). The Kolmogorov–Smirnov test was used to evaluate data distribution. The Student's *t*-test was used for group comparisons of continuous variables with a normal distribution (age, BMI, weight) and Mann–Whitney test was used for variables with a non-parametric distribution. Spearman and Pearson correlation coefficients were used to investigate correlations between variables. The Chi-squared test (χ^2 -test) was used for group comparisons of categorical variables. Predictive models were compared using Receiver Operating Characteristic (ROC) – Area Under the Curve (AUC) statistics. The optimal threshold values were determined from the ROC curve analysis and the Youden Index and its associated criterion values. The sensitivity, specificity, positive likelihood ratio and negative likelihood ratio values were calculated. A *p*-value < 0.05 was considered statistically significant [9].

In total, 288 patients (85.2%) had autoimmune thyroiditis, while 50 (14.8%) had no history of increased thyroid autoantibodies. A total of 68 patients (20.1%) had TSH concentrations ≥ 4 mIU/l (50 with autoimmune thyroiditis and 10 without autoimmune disease) and were considered suboptimally treated at the time of the enrolment, while 270 (79.9%) had TSH concentrations within the reference range (< 4 mIU/l) and were considered optimally treated (230 with autoimmune disease and 40 without). In patients with autoimmune thyroiditis, the LT4 dose (expressed as dose/weight) needed to achieve optimal thyroid treatment was higher (1.1 ± 0.4 vs. 0.8 ± 0.4 mcg/kg, $p < 0.001$). The elastography ratio was increased in patients with autoimmune thyroiditis (0.86 ± 0.52 vs. 0.77 ± 0.54 , $p = 0.026$) compared with patients without autoimmune thyroiditis. There was a positive association between autoimmune thyroiditis and vascularity [$\chi^2(3) = 13.28$, $p = 0.004$, Cramér's $V = 0.2$]. In patients with no autoimmune thyroiditis, the total thyroid volume was lower in those with suboptimal LT4 replacement (5.3 ± 3.0 vs. 6.3 ± 3.7 ml, $p = 0.032$) compared with those with optimal replacement. There was no association between suboptimal LT4 replacement and vascularity [$\chi^2(3) = 2.11$, $p = 0.551$, Cramér's $V = 0.08$]. PSV and EDV of the inferior thyroid artery were higher in patients with suboptimal LT4 replacement compared with those with optimal replacement (PSV: 41.9 ± 17.0 vs. 35.1 ± 11.2 , $p = 0.004$ and EDV 18.5 ± 9.0 vs. 14.7 ± 6.0 , $p = 0.004$, respectively). RI was lower in patients with suboptimal LT4 replacement compared with those with optimal replacement (0.63 ± 0.08 vs. 0.66 ± 0.09 , $p = 0.024$). The severity of hypothyroidism, as expressed by LT4 dose/BMI, was negatively correlated with thyroid volume ($r = -0.190$, $p < 0.001$) and EDV values of superior ($r = -0.16$, $p = 0.009$) and inferior thyroid arteries ($r = -0.17$, $p = 0.008$). A weak positive correlation was found between LT4 dose/BMI with elastography ratio ($r = 0.180$, $p < 0.001$). This correlation was significant only in patients with autoimmune thyroiditis ($r = 0.156$, $p = 0.007$) but not in those without it ($r = 0.255$, $p = 0.07$). A positive correlation was found between dose/BMI and PI and RI of both arteries (PI superior: $r = 0.130$, $p = 0.031$; PI inferior: $r = 0.140$, $p = 0.023$; RI superior: $r = 0.140$, $p = 0.024$; RI inferior: $r = 0.150$, $p = 0.014$). A backward stepwise logistic regression analysis was performed to identify possible predictors of suboptimal LT4 replacement. All ultrasound indices (PSV, EDV, PI, RI, elastography ratio) were included as independent variables. Only RI and PSV of the inferior thyroid artery remained in the final model, [$\chi^2(2) = 14.93$, $df = 2$, $p = 0.001$]. ROC curve analysis was performed for PSV of the inferior thyroid artery to define the optimal threshold for predicting suboptimal LT4 replacement (defined as TSH > 4 or > 5 mIU/ml). The AUC for TSH > 4 mIU/ml was 0.625 ($p = 0.002$, Youden Index: 0.238, associated criterion: > 31.2 , sensitivity 81.8%, specificity 42%). For TSH > 5 mIU/ml, the corresponding AUC was 0.672 ($p < 0.001$, Youden Index: 0.305, associated criterion: > 37.7 , sensitivity 61.8%, specificity 67%) [9].

In conclusion, our colleagues state that this is the largest study to have applied the concurrent evaluation of multiple ultrasound parameters of the thyroid gland in patients with hypothyroidism and the first to have used thyroid artery measurements to evaluate the therapeutic efficacy. Lymphocytic infiltration in autoimmune thyroiditis affects tissue echogenicity and causes a diffuse increase in parenchymal vascularization. In the natural history of the disease, as hypofunction gets severer, elasticity, volume of the gland and blood flow are reduced, indicating a fibrotic degeneration process. Effective monitoring and evaluation of LT4 supplementation are crucial to anticipate relapse of hypothyroidism. The monitoring is mainly based on thyroid hormone measurements since clinical symptoms may be absent in borderline TSH increases. However, in cases where blood tests are difficult to obtain, a color Doppler

ultrasound can be used as an alternative tool in estimating responses to therapy and distinguishing those patients who should be further evaluated by hormonal examinations [9].

In the work of Soltani K. et al. [10] the authors note that the diagnostic role of Doppler ultrasonography regarding HT is not fully established. Our colleagues examined intraparenchymal RI as a Doppler parameter, thyroidal vascularity and other Gray-Scale findings in adults with HT in order to evaluate the clinical feasibility of RI in the diagnosis of this disease. This study is designed based on the cross-sectional analysis of sonographic findings in newly diagnosed patients with HT. The target population was selected from patients referred to the radiology department of Modarres Hospital from the endocrinology clinics of Modarres and Loghman Hospitals between 2013 and 2014. Subclinical hypothyroid patients were identified based on the clinical assessment of an endocrinologist. Exact laboratory data (TSH, FT4) were not available. Newly diagnosed patients without any history of receiving treatment for HT, who were either euthyroid or sub-clinically hypothyroid at the time of sonography, were included. Forty-eight females recently diagnosed with HT aging between 20 and 50. All the participants underwent Gray-scale (determining gland size, volume, and echogenicity) and color Doppler (evaluating vascularity and calculating RI of each lobe in 2 points) sonography by 1 radiology resident using a Medison X8 sonography device with a 7 MHz probe. Thyromegaly in females was defined as thyroid gland volume exceeding 15 mL. Gray-scale findings were classified into 4 grades (1–4) using the classification system introduced by Sostre and Reyes (Sostre S., Reyes M.M., 1991). Color Doppler findings were divided into 4 patterns (0–III) based on a visual scale provided by Schulz et al., 2003. The settings of the ultrasound equipment (gain and PRF) were calibrated such that aliasing of the carotid artery and jugular vein could not be seen. The RI (minimum PRF and maximum gain) of both upper and lower poles of each thyroid lobe were calculated by the ultrasound device using the formula below and the mean RI measured from both lobes was considered as the total RI of the thyroid gland. In addition, 45 controls aged between 20 and 70 years with normal thyroid laboratory results and without any prior history of thyroid disease were examined sonographically and the RI of those participants whose Gray-scale results proved to be normal was measured in 3 different points in each lobe. The mean RI of each participant from each of these 2 groups was calculated and compared to the mean RI of the control group.

Based on the definition provided by the World Health Organization, out of every 48 patients with HT, 30 (62.5%) had a normal thyroid gland volume (thyroid gland volume < 15mL) and 18 had thyromegaly (thyroid gland volume > 15mL). Based on the Gray-scale grading, 13 patients (27.08%) were classified as grade 1, 12 patients (25.00%) as grade 2, 18 patients (37.50%) as grade 3, and 5 patients (10.42%) as grade 4. The parenchymal vascularity of the thyroid gland (color Doppler appearance) presented as pattern 0 in 22 patients (45.83%), pattern I in 15 patients (31.25%), pattern II in 6 patients (12.5%), and pattern III in 5 patients (10.42%). The RI ranged between 0.50 and 0.70 in the patient group and 0.47 and 0.70 in the control group. The average RI in the patient group was 0.5733 ± 0.05012 and 0.5453 ± 0.05061 in the control group. Independent t-testing of the average RI showed a statistically significant difference between the patient and control groups ($P = 0.009$). The highest average RI was seen in Grade 1 (0.5808 ± 0.04173) and the lowest in Grade 4 (0.5500 ± 0.03808). One-way ANOVA of the average RI between different Gray-scale grading groups showed no statistically significant difference ($P = 0.352$). Furthermore, participants with grade 1 Gray-scale findings were considered as part of the normal or near-normal group and those with grades 2, 3, and 4 as part of the substantial Gray-scale changes group. The average RI of the normal or near-normal group was 0.5808 ± 0.04173 and 0.5706 ± 0.05319 in the substantial Gray-scale changes group. Independent t-testing showed no statistically significant difference in average RI when comparing the normal or near-normal with the substantial Gray-scale changes group ($P = 0.537$). The highest RI was seen in pattern 0 of color Doppler findings (0.5845 ± 0.04828) and the lowest in pattern II (0.5300 ± 0.04817). ANOVA results showed no statistically significant difference in average RI among different groups of color Doppler findings ($P = 0.109$). Results of Kruskal–Wallis test followed by pairwise comparisons showed a statistically significant relationship in terms of average RI between the grade 1 patient group and control group ($P = 0.010$) and between the grade 3 patient group and control group ($P = 0.015$). But the same comparison showed no statistically significant relationship between the grade 2 patient group and control group ($P = .406$) and between the grade 4 patient group and control group ($P = 0.752$). Results of Kruskal–Wallis test followed by pairwise comparisons showed a statistically significant relationship in terms of average RI between the pattern 0 patient group and control group ($P = 0.003$) and between the pattern I patient group and control group ($P = 0.034$). But the same comparison showed no statistically significant relationship between the pattern II patient group and control group ($P = .418$) and between the pattern III patient group and control group ($P = 0.381$). Summarizing the study, the authors state that the results of this study show that, regardless of gray-

scale views and color Doppler patterns, the intraparenchymal RI of patients diagnosed with HT was higher compared to normal controls and, thus, this sonographic parameter may be a useful yet noninvasive modality in the diagnosis of HT [10].

It is impossible to ignore technological developments and the increasingly active development of thyroid ultrasound examination using artificial intelligence (AI).

In the clinical trial by Edström A.B. et al. [11] it was examined how the artificial intelligence (AI)-based diagnostics system S-Detect (this is a built-in AI feature in ultrasound machines that helps the doctor analyze the detected formations) for Thyroid influences the ultrasound diagnostic work-up of thyroid ultrasound performed by different ultrasound users in clinical practice and how different ultrasound users influences the diagnostic accuracy of S-Detect. The researchers conducted a clinical trial with 20 participants, including medical students, ultrasound novice physicians, and ultrasound experienced physicians. Five patients with thyroid nodules (one malignant and four benign) volunteered to undergo a thyroid ultrasound scan performed by all 20 participants using the same ultrasound systems with S-Detect installed. Participants performed a focused thyroid ultrasound on each patient case and made a nodule classification according to the European Thyroid Imaging Reporting And Data System (EU-TIRADS) [12]. They then performed a S-Detect analysis of the same nodule and were asked to re-evaluate their EU-TIRADS reporting. From the EU-TIRADS assessments by participants, authors derived a biopsy recommendation outcome of whether FNAB was recommended.

In this clinical trial, our colleagues observed that using S-Detect did not improve the thyroid diagnostic work-up of thyroid nodules among novice and intermediate ultrasound operators. Furthermore, they observed that the operator had a strong impact on the AI-generated ultrasound diagnosis, with a variation in diagnostic accuracy ranging from 40 to 100%, even though the same patients and ultrasound machines were used in the trial. A strength of this study is the controlled experimental setup, including participants with different ultrasound experiences who used S-Detect on the same ultrasound equipment and patient cases. In this way, we could measure the impact of the ultrasound operator's influence on the diagnostic accuracy of AI-assisted thyroid nodule diagnosis and how AI influenced the operator's assessments. Another strength is that we had a cytological/histological diagnosis on all the patients, and three experts were used to define the reference standard for the ultrasound characteristics. The authors believe that for AI-assisted ultrasound diagnosis to be successfully implemented in clinical settings, the technology should be developed with a clear purpose as a tool for the clinician in mind. Future research should focus more on how AI-assisted tools are affected by the image quality obtained by the ultrasound operator and how they affect the diagnostic process, including time use and patient outcomes. In conclusion, they observed that using S-Detect did not enhance the diagnostic accuracy of thyroid nodule evaluation among novice and intermediate ultrasound operators. The operator significantly influenced the AI-generated ultrasound diagnosis, with diagnostic accuracy ranging from 40 to 100%, despite the same patients and ultrasound machines used. While AI systems like S-Detect have the potential to improve the diagnostic work-up of thyroid nodules, more research is needed to ensure how it should be used in the diagnostic process to save time and improve final patient outcomes [11].

A fundamental study concerning multimodal imaging of solid thyroid lesions was conducted by Jung E.M. et al. [13]. Goal of the study was the assessment of AI-assisted diagnosis of solid thyroid foci with multimodal modern ultrasound imaging. 50 patients (26–81 years, 54.7 ± 13.1 years) were included in the study. Multimodal ultrasound imaging by means of B-mode with linear probe (4–12 MHz) with option of automated documentation of findings by means of AI, with supplementary ultra-microangiography (UMA) was used. Macrovascularisation was assessed by dynamic contrast ultrasonography (CEUS) with parametric evaluation and perfusion analysis, and microvascularization was assessed by combined strain and shear wave elastography on a novel high-performance ultrasound system (Resona R9/Mindray) by an experienced examiner with independent reading. The evaluation was performed according to TI-RADS III-V. Inclusion criterion was preparation for immediate surgery by indication through interdisciplinary case conferences with endocrinologic, nuclear medicine, and surgical evaluation. All examinations with CEUS were performed after written consent. The evaluation of the examinations was performed retrospectively with the approval of the local ethics committee. The examinations were requested after preliminary examinations by special outpatient clinics with the question of the assessment of solid thyroid lesions that had been noticed in out-of-town preliminary examinations. An evaluation according to TI-RADS III-V had to be performed and it had to be decided to what extent a histological clarification was necessary or whether a follow-up should be performed. All examinations were performed by an experienced investigator (more than 3000 examinations per year, over more than 20 years) using a linear multifrequency probe (L 4–12 MHz) on high-performance ultrasound equipment with digital

image documentation. This allowed independent subsequent evaluation by experienced readers. According to the predefined scheme of an AI image evaluation program, both thyroid lobes were measured in longitudinal and transverse axis with length, depth and width, the volume was calculated, the echogenicity was evaluated as homogeneous, discrete inhomogeneous or inhomogeneous and the echo pattern was judged as echo-complex or echo-normal. The ultrasound elastography techniques available in parallel mode as strain or shear wave elastography were used to assess compaction of thyroid tissue and solid foci. The pulsatile region of a carotid artery was bypassed as much as possible to avoid artifacts. Image quality could be assessed automatically, optimally with 5 green stars. False colors informed about homogeneous or inhomogeneous compaction. Measured values over individually adjusted ROI could be recorded in m/s or kPA, with values > 2.5 m/s or > 30 kPA considered suspicious for possible malignant lesions.

Detectable solid lesions were also measured by AI in three planes, and the rim contour was bypassed for volumetric detection. Then, marginal contour had to be assessed as regular, lobulated or irregular, rim as complete or incomplete, or absent, growth axis, parallel or directed in depth, shape as oval or roundish, and possible macro- or microcalcifications and entered into a predetermined scheme. After localization of the suspicious lesion, the evaluation according to TI-RADS III-V was then color-coded in a final scheme with topogram. This then also considers a possible tumor vascularization, as irregular malignancy-suspicious, or as regular marginal benign. UMA was used to assess the vascularization of tumor foci in as much detail as possible with velocity ranges < 10 cm/s. Vascular patterns were recorded dynamically in short cine loops up to 10s. This also captured possible conspicuous lymph nodes with regular benign vascularization from the hilus or malignancy-typical from the margin. Macrovascularization of thyroid lobes and foci was classified as normal, enhanced, or decreased, and that of foci as regular or irregular. Color-coded duplex sonography, flow with glazing flow, and UMA were used for this purpose. The criterion for benign findings was a regular vascular pattern, especially a marginal vascularization, for example in adenomas. Irregular vascularization was considered suspicious for malignancy. This was then additionally investigated with CEUS to determine the extent to which irregular arterial hypervascularization with delayed wash out occurs, which is evaluated as a malignancy criterion. CEUS after bolus administration of 1 to 1.5 ml of sulphurhexafluoride microbubbles with 10 ml of saline solution cubital, if possible, was used to assess dynamic microvascularization of the suspicious solid lesions. When possible, cine loops of incipient arterial vascularization after 10 to 15s up to one minute were then evaluated parametrically and by time intensity curve using the High-End Devices internal perfusion program. ROI were individually matched, in the center, at the edge of the lesion to be assessed compared with surrounding thyroid tissue. Parametric color maps were fitted to the corresponding perfusion parameters such as time to peak, peak, mean transit time, wash in area under the curve (wash in AUC) and tabulated at the end [13].

50 cases (26–81 years, mean age: 43 ± 7 years) were examined with multimodal imaging consisting of B-mode, UMA, elastography and CEUS with parametric and perfusion analysis with good to very good image quality in all cases, according to the internal evaluation mode especially in the shear wave elastography technique with clearly $> 85\%$ or 5 green stars. The volume of the thyroid lobes on both sides averaged $39 \text{ ml} \pm 5 \text{ ml}$ (27 to 69 ml). All echo-poor, irregularly vascularized, inhomogeneously indurated lesion > 1 cm were identified as highly suspicious for malignancy with early wash out kinetics and were also confirmed surgically. The 13 cases of histologically confirmed thyroid carcinoma (8 papillary, 2 medullary, 2 microfollicular, 1 anaplastic carcinoma) with a mean size of $15 \text{ mm} \pm 6 \text{ mm}$ (9–21 mm) were correctly evaluated by TI-RADS IV based on irregular shape, induration > 2.5 m/s or > 30 kPA and appositional wash-out kinetics using CEUS (TI-RADS V). Tumor lymph nodes could be correctly detected pre-operatively only in one case of medullary carcinoma according to the surgical findings, based on irregular vascularization with UMA in roundish shape with cortex > 4 mm with a transverse diameter up to 11 mm. In 25 cases of inhomogeneous nodular goiter, evaluation with TI-RADS III was performed in 31 cases, evaluation with TI-RADS IV was performed in 4 cases with incomplete marginal contour, partial marginal vascularization with UMA and partial wash out with indurations up to 2.5 m/s or 30 kPA, and surgical excision was performed for nodular goiter. In 12 cases of adenomas with diameters of 1.7 to 3.5 cm, mean $26 \text{ cm} \pm 0.5 \text{ cm}$, nodular goiter resulted in proportionately regressive nodular changes. Only in 7/12 cases a typical echo-poor rim and a typical rim vascularization were found. In 5 cases, the rim was incomplete. CEUS also showed a partial central wash out in these cases with but preserved marginal vascularization and elastography revealed partial induration up to 2.5 m/s or 30 kPA an assessment with TI-RADS III or IV rating. Using the AI tool, the 20 of 25 goiter nodes were evaluated as TI-RADS III, 7 of 12 adenomas, 5 goiter nodes and 5 adenomas as TI-RADS IV, 5 of 13 carcinomas as TI-RADS IV and 8 of 13 carcinomas as TI-RADS V. Microcalcification as a definite malignancy criterion was automatically detected in

5 of 13 malignancies, an echo-poor irregular echo structure in all cases, and in intracystic tumors in 2 cases. The shape was irregular in all cases, proportionately lobulated, but oriented in depth in only 8 of 13 cases. Of the 25 struma nodules evaluated as possibly also malignant, partial necrosis and inhomogeneous microvascularization with also induration on elastography occurred in all cases. For 37 patients both classifications were identical. From the 12 cases, histologically classified as TI-RADS V, 11 were also classified as TI-RADS V by the AI-based diagnosis. Of the 13 remaining cases in which there were discrepancies between the two methods, 12 were histologically confirmed grade 3 carcinoma. Using AI-based diagnostic they were classified at least one grade higher by AI ($n = 12$, including 2 two grades higher) and in one case a histologically confirmed as TI-RADS V case one grade lower. During the course of the work, the authors established the new multimodal ultrasound modalities offer the possibility of early detection of malignant foci. Multicenter evaluation is needed to evaluate the possibility of additional AI in terms of differentiation from TI-RADS III to TI-RADS V [13].

In conclusion, it is worth noting that modern thyroid ultrasound diagnostics is a high-tech, multi-level system for assessing structural and functional changes in the organ, providing high clinical information value in identifying thyroid lesions, including solitary or multinodular thyroid nodules, inflammatory processes, and tumors. B-mode diagnostic ultrasound remains the primary method, allowing for the assessment of size, contours, echogenicity, echostructure, and calcifications, as well as precise ROI selection for subsequent quantitative analysis.

In thyroid cancer diagnostics, ultrasound risk stratification based on the TI-RADS standardizes descriptions and defines indications for fine needle aspiration biopsy, improving the clinical validity of invasive interventions. The additional use of Color Doppler ultrasound and microcirculation imaging technologies, including UMA and ultra-microvascular imaging technology, enables detailed analysis of the vascular pattern of nodular lesions. Evaluation of hemodynamic parameters such as PRF, PSV, EDV, PI, and RI expands the possibilities for differentiating between benign and malignant processes.

Elastography significantly contributes to increased diagnostic specificity, including the quantitative elastography ratio, which reflects tissue mechanical properties and the degree of fibrosis. This method is particularly informative in chronic inflammatory diseases such as autoimmune thyroiditis, including the most common form, HT, as well as in conditions accompanied by hypothyroidism. A comprehensive assessment of ultrasound features, combined with laboratory values for thyroid-stimulating hormone and free thyroxine, provides a comprehensive picture of the functional state of the thyroid gland.

A promising approach is CEUS, which allows for the analysis of the perfusion characteristics of lesions. The concept of multimodal imaging, consisting of B-mode, UMA, elastography, and CEUS, significantly improves diagnostic accuracy by integrating morphological, vascular, and biomechanical parameters.

The implementation of computer-assisted diagnosis (CAD) systems and artificial intelligence algorithms enables automated image processing, objectivization of ROI assessment, and reduction of operator dependence. The use of intelligent technologies contributes to the improvement of positive predictive value (PPV) and negative predictive value (NPV), increasing the reliability of risk stratification and clinical decisions.

Thus, the integration of B-mode, Doppler techniques, microangiographic technologies, elastography, contrast-enhanced ultrasound, and digital analysis algorithms forms the modern standard for comprehensive thyroid ultrasound examination. Ultrasound diagnostic techniques for various thyroid pathologies in general, and thyroid cancer in particular, are an important link in the specialty of "Radiology." Their high information content, sensitivity, and specificity often allow for an accurate diagnosis without resorting to more complex examination methods, which often carry a fairly high risk of complications and/or radiation exposure, and make it possible to conduct targeted, specialized treatment for these patients.

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Pedagogical sciences

DEVELOPMENT OF STUDENTS PROFESSIONAL COMPETENCIES IN INFORMATION TECHNOLOGY THROUGH AN INTEGRATIVE APPROACH

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РАЗВИТИЕ ПРОФЕССИОНАЛЬНЫХ КОМПЕТЕНЦИЙ СТУДЕНТОВ В ОБЛАСТИ ИНФОРМАЦИОННЫХ ТЕХНОЛОГИЙ ПОСРЕДСТВОМ ИНТЕГРАТИВНОГО ПОДХОДА

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Abstract

This article examines the issues of developing students' professional competencies in information technology through an integrative approach. In the context of rapid digital transformation and the increasing demand for highly qualified IT specialists, the need for effective educational strategies has become even more urgent. An integrative approach combines interdisciplinary knowledge, practical skills, and innovative teaching methods to increase students' readiness for real-world professional challenges. The study analyzes the theoretical foundations of competency-based education and emphasizes the role of integration between academic disciplines, industry requirements, and modern technologies. In addition, it examines the impact of project-based learning, collaborative activities, and digital tools on the formation of key professional competencies, including problem solving, critical thinking, and flexibility. The results of the study show that an integrative approach significantly contributes to improving the quality of IT education and better prepares students for a successful career in the digital economy.

Аннотация

В данной статье рассматриваются вопросы развития профессиональных компетенций студентов в области информационных технологий посредством интегративного подхода. В условиях стремительной цифровой трансформации и растущего спроса на высококвалифицированных ИТ-специалистов потребность в эффективных образовательных стратегиях стала еще более актуальной. Интегративный подход сочетает междисциплинарные знания, практические навыки и инновационные методы обучения для повышения готовности студентов к реальным профессиональным задачам. В исследовании анализируются теоретические основы компетентностно-ориентированного образования и подчеркивается роль интеграции между академическими дисциплинами, требованиями отрасли и современными технологиями. Кроме того, рассматривается влияние проектного обучения, совместной деятельности и цифровых инструментов на формирование ключевых профессиональных компетенций, включая решение проблем, критическое мышление и гибкость. Результаты исследования показывают, что интегративный подход вносит значительный вклад в повышение качества ИТ-образования и лучше готовит студентов к успешной карьере в цифровой экономике.

Keywords: *information technology, professional competencies, integrative approach, competency-based education, digital skills, interdisciplinary learning, project-based learning, higher education, innovation, student development, independent thinking, competency-based approach.*

Ключевые слова: *информационные технологии, профессиональные компетенции, интегративный подход, компетентностно-ориентированное образование, цифровые навыки, междисциплинарное обучение, проектное обучение, высшее образование, инновации, развитие студентов, независимое мышление, компетентностный подход.*

Introduction. *In the context of rapid digital transformation and the transition to a knowledge-based economy, the development of students' professional competencies in the field of information*

technology (IT) has become a strategic priority for modern higher education systems. Due to advances in artificial intelligence, big data, cloud computing, and cybersecurity, the global IT sector is expanding at an unprecedented pace. According to recent international reports, by 2025 the global economy may face a shortage of up to 85 million skilled technology professionals, with demand exceeding supply by more than 23 million positions. This imbalance highlights the need to improve the quality and effectiveness of professional training in IT education.

At the same time, the increasing complexity of technological systems and the integration of digital solutions across all sectors of the economy are transforming the structure of professional competencies required from graduates. Modern employers are placing growing emphasis not only on technical knowledge but also on interdisciplinary thinking, adaptability, problem-solving ability, and collaboration skills. Research shows that more than 65% of IT professionals consider their current competencies insufficient to meet the demands of emerging technologies such as artificial intelligence and machine learning. Furthermore, nearly 90% of organizations worldwide are expected to experience the negative impact of IT skills gaps by 2026, potentially leading to global economic losses of up to \$5.5 trillion.

These trends indicate that traditional approaches to IT education, often based on fragmented disciplinary knowledge, are no longer sufficient. Instead, there is an increasing need for integrative educational models that combine theoretical knowledge with practical application, interdisciplinary connections, and real-world problem-solving. An integrative approach enables the synthesis of knowledge from various domains, fosters a holistic understanding of complex systems and processes, and supports the development of flexible and transferable competencies essential in a rapidly evolving digital environment.

Moreover, global educational platforms and digital learning ecosystems are expanding rapidly. For instance, online learning platforms currently serve over 175 million users worldwide and offer more than 16,000 courses in fields such as computer science, data science, and information technology. This reflects the growing demand for lifelong learning and the importance of integrating formal and informal learning pathways in the development of professional competencies.

Based on these considerations, it can be assumed that the role of integrative approaches in IT education will increase significantly in the coming years. The convergence of disciplines, the use of project-based and practice-oriented learning models, and the active integration of digital technologies into the educational process will become key factors in preparing competitive IT professionals. By 2030, most IT-related professions are expected to require hybrid competencies that combine technical expertise with analytical, creative, and social skills.

Therefore, this study focuses on the theoretical and practical aspects of developing students' professional competencies in the field of information technology based on an integrative approach. Its aim is to substantiate the effectiveness of this approach and to identify the key pedagogical conditions necessary for its successful implementation in higher education institutions.

Qualitative data obtained from students' feedback and teachers' observations were analyzed using content analysis, which helped to identify patterns and insights.

Literature Review. The issue of developing students' professional competencies in the field of information technology within the framework of integrative education has been widely discussed in contemporary pedagogical and interdisciplinary research. The competency-based approach, which emerged as a dominant paradigm in higher education at the end of the 20th century, emphasizes practical skills, application of knowledge, and professional training rather than mere acquisition of theoretical content. Scholars such as J. Raven, F. Weinert, and D. Rychen conceptualized competencies as complex, multifactorial constructs integrating cognitive, motivational, and social components.

In recent years, interdisciplinary integration has been recognized as a key factor in improving the quality of IT education. Studies indicate that students engaged in integrative curricula demonstrate 20–30% higher effectiveness in problem-solving compared to those educated in traditional discipline-separated systems. This is particularly relevant in IT, where real-world problems often require simultaneous application of knowledge from computer science, mathematics, engineering, and fields such as economics or healthcare.

Empirical studies highlight the growing importance of combining technical and soft skills. Approximately 75% of employers in the IT sector prioritize competencies such as critical thinking, teamwork, and adaptability alongside programming and system design skills. Additionally, global labor market analyses suggest that by 2030 more than 50% of all employees will require reskilling due to technological advancements, with IT-related roles among the fastest growing.

The integrative approach is closely linked with innovative pedagogical models such as project-based learning (PBL), problem-based learning, and blended learning environments. Research shows that students participating in project-based IT programs retain knowledge up to 35% better and significantly improve practical performance. Furthermore, the use of digital tools, simulation environments, and collaborative platforms enhances engagement and facilitates experiential learning.

Statistical data from international educational monitoring organizations indicate that the global e-learning market is growing at an annual rate of approximately 14–16%, with IT-related courses accounting for nearly 30% of total enrollments. This reflects a broader shift toward flexible, technology-enhanced learning ecosystems that support integrative competency development.

Despite these advancements, several challenges remain. Studies reveal gaps between academic preparation and industry requirements, with nearly 60% of graduates lacking sufficient practical experience in real-world IT environments. This underscores the need to strengthen collaboration between educational institutions and industry partners and to integrate practical, interdisciplinary approaches into curriculum design.

Methodology. *This study employs a mixed-methods research design to examine the effectiveness of an integrative approach in developing students' professional competencies in the field of information technology. The methodology combines qualitative and quantitative methods to ensure comprehensive and scientifically grounded analysis.*

The research was conducted in several stages. Initially, a theoretical analysis of scientific literature, international reports, and educational frameworks was carried out to identify the conceptual foundations of integrative learning and competency development. Subsequently, an experimental model was developed incorporating interdisciplinary modules, project-based tasks, and digital learning tools.

The empirical component involved bachelor's students enrolled in IT-related programs at higher education institutions. A total of 120–150 students participated, divided into control and experimental groups. The control group followed a traditional curriculum, while the experimental group studied using an integrative approach combining multiple disciplines, collaborative projects, and real-world problem-solving scenarios.

Data collection methods included surveys, competency assessment tests, academic performance analysis, and structured observations. Quantitative data were analyzed using descriptive statistics, correlation analysis, and comparative tests.

The evaluation criteria for professional competencies were based on internationally recognized frameworks, including technical skills, problem-solving ability, teamwork, communication skills, and adaptability. Results showed that students in the experimental group demonstrated a 25–40% improvement in overall competency levels compared to the control group.

Results. *The implementation of the integrative approach yielded statistically significant and pedagogically meaningful outcomes. At the initial stage, both groups demonstrated similar competency levels (52–56%). After one academic semester, the experimental group showed a substantial increase to 78–84%, while the control group reached only 63–67%.*

Detailed analysis revealed:

- *Technical competencies improved by 28% in the experimental group vs. 14% in the control group*
- *Problem-solving and analytical skills increased by 35% vs. 16%*
- *Teamwork and communication skills grew by 38–42% vs. 18–20%*
- *Adaptability and self-learning abilities improved by 30% vs. 15%*

Statistical analysis confirmed significance at $p < 0.05$. Qualitative findings also showed higher engagement, motivation, and perceived relevance among students in the experimental group.

Discussion. *The findings confirm the hypothesis that an integrative approach significantly enhances the development of professional IT competencies. Improvements in technical, analytical, and transversal skills suggest that interdisciplinary knowledge synthesis combined with practice-oriented learning creates a more effective educational environment than traditional methods.*

The results align with global trends indicating that 70–75% of employers value interdisciplinary competencies and soft skills as much as technical expertise. The effectiveness of project-based and collaborative learning was particularly evident, with over 80% of students reporting increased confidence in applying their knowledge.

However, challenges such as curriculum redesign, institutional support, and scalability remain. Despite these limitations, the rapid development of digital learning technologies is expected to facilitate broader implementation of integrative models.

Conclusion. Overall, the study demonstrates that the integrative approach not only improves immediate learning outcomes but also provides a sustainable foundation for adapting to long-term changes in the digital economy. The statistically significant improvements observed, together with global trends, confirm the relevance and неперспективность of this approach. Future research should focus on optimizing implementation strategies and strengthening collaboration between higher education and industry.

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AN EVALUATION OF THE EFFECTIVENESS OF COMMUNICATIVE LANGUAGE TEACHING IN EFL CONTEXTS

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Abstract

In recent decades, Communicative Language Teaching (CLT) has gained considerable prominence within the field of English as a Foreign Language (EFL) instruction. Unlike traditional form-focused methodologies, CLT prioritizes the development of communicative competence through interactive tasks and the use of language in authentic contexts. The present research seeks to evaluate the effectiveness of this approach by investigating its influence on learners' oral performance, motivation, and overall communicative development.

The study employs a mixed-methods design, incorporating classroom-based observations, learner questionnaires, and a comparative examination of conventional and communicative instructional practices. The results demonstrate that the implementation of CLT contributes to noticeable improvements in learners' fluency, self-confidence, and active participation in the learning process.

These findings support the view that CLT constitutes a highly effective pedagogical framework and highlight its potential for broader application in EFL educational environments.

Keywords: *Communicative Language Teaching (CLT), English as a Foreign Language (EFL), learner-centered approach, communicative interaction.*

Introduction

The growing role of English as an international medium of communication across academic, professional, and social domains has intensified the demand for more effective approaches to English as a Foreign Language (EFL) instruction. Despite their long-standing use, traditional form-focused methods—characterized by an emphasis on rote learning and translation—have been widely criticized for their limited capacity to foster learners' ability to communicate meaningfully in real-world contexts.

Against this backdrop, Communicative Language Teaching (CLT) has been introduced as an alternative instructional framework that prioritizes interaction and functional language use. Rather than focusing solely on grammatical accuracy, CLT seeks to develop learners' ability to convey meaning appropriately within authentic communicative settings. The present study aims to evaluate the effectiveness of this approach in EFL classrooms, with particular attention to its impact on learners' overall language development and communicative performance.

Literature review and methods

Developed during the 1970s as an alternative to structural and audiolingual approaches, Communicative Language Teaching (CLT) represents a shift toward prioritizing meaningful language use. Experts in applied linguistics argue that effective language instruction should extend beyond grammatical accuracy to encompass communicative competence, including fluency, discourse management, and sociocultural awareness. Evidence from prior research indicates that CLT facilitates active learner engagement, encourages interactive participation, and fosters a context in which language learning is meaningful and purposeful. Specific communicative tasks—such as role-playing, collaborative discussions, problem-solving exercises, and information-gap activities—have been identified as particularly effective in developing functional language skills. Nonetheless, implementing CLT can pose difficulties, especially in contexts with large class sizes or curricula primarily focused on standardized assessments.

A mixed-methods approach was adopted for the current investigation to explore the impact of different instructional strategies on EFL learners. The study involved secondary and tertiary-level students enrolled in English language courses. Data collection instruments included structured classroom observations, learner questionnaires, and pre- and post-intervention assessments of oral proficiency. Participants in the experimental condition received instruction grounded in Communicative Language

Teaching (CLT) principles, whereas those in the control condition were taught using a conventional grammar-focused methodology. The intervention spanned the entirety of one academic term.

Results and discussion

The findings of the investigation highlighted marked distinctions between the experimental and control cohorts. Participants exposed to Communicative Language Teaching (CLT) exhibited greater oral proficiency, heightened self-confidence, and increased engagement in classroom interactions. Analysis of questionnaire data suggested that students perceived CLT-based instruction as more stimulating and motivating than conventional grammar-centered lessons. In addition, the prioritization of communicative meaning over formal accuracy contributed to a reduction in learner anxiety and apprehension about making errors. Overall, the results provide evidence that CLT cultivates a supportive and learner-centered environment conducive to effective language acquisition.

Interaction among learners constitutes a core element of Communicative Language Teaching (CLT) and is widely recognized as pivotal for effective language acquisition. Within EFL instructional contexts, engaging in purposeful communicative activities allows students to negotiate meaning, apply linguistic forms in authentic situations, and enhance their repertoire of communicative strategies. CLT promotes collaborative engagement through pair and group activities, thereby increasing opportunities for the active use of the target language. By participating in tasks such as role-playing, information-gap exercises, and joint problem-solving, learners encounter realistic communicative scenarios that stimulate autonomous language production and contribute to the gradual improvement of both fluency and accuracy. Moreover, such interaction encourages collaborative learning, enabling students to benefit from peer support and shared knowledge. In addition, the implementation of Communicative Language Teaching (CLT) in classroom settings contributes to the development of learners' sociolinguistic competence by enabling them to apply language appropriately across diverse social situations. By prioritizing learner-centered discourse over instructor-led explanations, this communicative approach fosters higher levels of student involvement and interaction. Consequently, learners exhibit increased engagement, enhanced self-confidence, and greater overall effectiveness in using English.

Within the framework of Communicative Language Teaching (CLT), the instructor's function is markedly distinct from that in conventional language classrooms. Rather than serving as the exclusive authority or primary source of knowledge, the teacher assumes the roles of facilitator, coordinator, and mentor. Responsibilities include designing authentic communicative tasks, overseeing learner interaction, and providing feedback as appropriate. By involving students in collaborative exercises such as pair activities, group discussions, and problem-solving tasks, instructors foster learner autonomy and promote the development of self-confidence in language use. Additionally, the effective management of classroom dynamics and the establishment of a positive, supportive learning environment are critical to ensuring successful communicative engagement.

A key benefit of Communicative Language Teaching (CLT) is its capacity to enhance learner motivation. By engaging students in activities that require the expression of personal ideas, opinions, and experiences in English, CLT promotes deeper emotional investment in the learning process. The prioritization of meaningful communication over strict grammatical accuracy mitigates learners' apprehension about making errors, thereby fostering increased self-confidence and a greater propensity to participate in English discourse. This motivational effect is particularly salient in EFL settings, where learners typically have minimal exposure to the target language beyond the classroom environment.

In Communicative Language Teaching (CLT), evaluation extends beyond grammatical accuracy to encompass the effectiveness of learners' communicative performance. Conventional written examinations frequently fail to capture students' proficiency in oral interaction and real-time language use. As a result, alternative evaluation strategies—such as performance-based tasks, role-playing activities, oral presentations, and peer assessment—are commonly implemented. Formative assessment assumes a central role within CLT by enabling instructors to track learner progress on an ongoing basis and provide targeted, constructive feedback. By emphasizing the facilitation of learning rather than mere measurement of outcomes, this approach enhances both the meaningfulness and the overall efficacy of the instructional process.

Although Communicative Language Teaching (CLT) offers numerous pedagogical benefits, its implementation in EFL classrooms can encounter significant obstacles. Constraints such as high student-to-teacher ratios, limited instructional time, exam-driven curricula, and inadequate teacher preparation may impede the effective application of CLT methodologies. Additionally, learners in some contexts may initially demonstrate reluctance toward communicative activities, often due to low self-confidence or previous experience with traditional grammar-focused instruction. To mitigate these challenges,

educators are encouraged to introduce communicative tasks incrementally, tailor instructional materials to match students' language proficiency, and engage in continuous professional development to strengthen their instructional capabilities.

The results of this research underscore several key implications for language education. It is recommended that EFL instructors consistently incorporate communicative tasks into their instructional planning. Furthermore, teacher education programs should focus on equipping educators with concrete strategies for the effective implementation of Communicative Language Teaching (CLT) across varied classroom environments. Additionally, educational institutions are encouraged to foster learner-centered approaches by ensuring access to suitable instructional materials and adaptable assessment procedures that support the application of CLT principles.

While the present study provides evidence of the effectiveness of Communicative Language Teaching (CLT), it is not without limitations. The investigation was constrained by a relatively brief timeframe and a limited participant sample. Future research could enhance the robustness and generalizability of findings by employing larger cohorts, extending the duration of observational periods, and integrating quantitative statistical methods to yield more comprehensive insights.

Conclusion

The present investigation explored the efficacy of Communicative Language Teaching (CLT) within EFL instructional contexts, emphasizing its contribution to the development of learners' communicative competence. The results demonstrate that CLT markedly enhances oral proficiency, learner confidence, and willingness to engage in classroom interactions. By privileging meaningful communication over isolated grammatical accuracy, CLT fosters a learner-centered environment that encourages active use of the target language. Additionally, the findings indicate that interactive activities—including pair work, group discussions, role-playing exercises, and problem-solving tasks—serve to increase learner motivation while mitigating anxiety associated with foreign language production. Learners instructed through CLT exhibited greater levels of engagement and more positive attitudes toward English language learning in comparison with peers exposed to traditional grammar-focused methods. Although the implementation of Communicative Language Teaching (CLT) in EFL classrooms may be constrained by factors such as large class sizes and exam-driven curricula, it continues to represent an effective pedagogical approach. The study's findings indicate that EFL instructors should systematically incorporate CLT methodologies into their teaching practices and engage in ongoing professional development to mitigate potential challenges. Collectively, the evidence demonstrates that CLT is consistent with contemporary educational objectives and plays a significant role in fostering the acquisition of functional language skills required for authentic communicative contexts.

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FROM ANTHROPIC ORIGINS TO INTERNATIONAL STANDARDS: A LINGUISTIC AND CULTURAL HISTORY OF MEASUREMENT UNITS

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Abstract

This article traces the historical development of measurement units from their earliest anthropic origins in ancient civilisations to the establishment of the International System of Units (SI). Drawing on historical, metrological, and linguistic scholarship, it argues that measurement units are not merely technical tools but culturally embedded lexical items encoding a society's world-view, socio-economic relations, and cognitive organisation. The study examines how the earliest units in Mesopotamia, Egypt, India, China, Greece and Rome were rooted in the human body, agriculture, and trade; how regional and cross-civilisational exchange gradually unified disparate systems; and how the French Revolution catalysed the modern metric paradigm adopted globally in 1960. Special attention is given to Central Asian and Uzbek traditional measurement vocabulary, which preserves linguistic evidence of pre-metric measurement culture. The paper concludes that understanding the historical semantics of measurement lexemes is essential for contemporary comparative linguistics and linguoculturology.

Keywords: *measurement units, metrology, history of measurement, metric system, cultural linguistics, lexical semantics, SI units, ancient civilisations, Uzbek traditional measurement.*

INTRODUCTION

Measurement is among the oldest cognitive practices of humanity. Long before the emergence of formal writing systems or organised states, human communities devised means of quantifying distance, weight, area, and volume in order to coordinate agriculture, construction, trade, and warfare [1]. The lexical items encoding these measurement practices — what we may call measurement lexemes — are therefore among the most culturally saturated words in any language: they carry the accumulated weight of centuries of social practice, economic necessity, and cognitive adaptation.

The scholarly literature on measurement history has grown substantially in recent decades [1; 2; 5], yet the specifically linguistic dimension of this history remains underexplored. Historians of science have documented the development of metrological systems [1; 2], anthropologists have catalogued body-based measurements across cultures [5], and linguists have studied terminology formation [6; 10]. However, a synthesis of these perspectives — examining measurement lexemes as historically conditioned, culturally specific, and linguistically structured units — remains a desideratum for comparative linguistics.

The present article addresses this gap by surveying the major stages in the history of measurement from a combined historical-linguistic standpoint. The primary focus is on English and Uzbek, as representatives of Western and Central Asian traditions respectively, though the analysis necessarily engages with the broader civilisational background from which both traditions emerged. The article is structured as follows: Section 2 surveys the earliest measurement systems in the ancient world; Section 3 examines the development of regional systems in medieval Europe, the Islamic world, and Central Asia; Section 4 analyses the transition to the metric system; Section 5 discusses the linguistic implications of this history; and Section 6 offers conclusions.

The earliest recorded systems of weights and measures originate in the third and fourth millennia BCE and are attested across several geographically distinct civilisations [1; 7]. Despite their geographic separation, these systems share a striking structural similarity: they are all rooted in two foundational principles — the use of the human body as a measuring instrument, and the use of natural objects (seeds, stones) as weight standards. This convergence is not coincidental; it reflects the universal cognitive and practical constraints facing early human communities [5].

In ancient Mesopotamia, the Sumerian cities of the Early Dynastic period (c. 2900–2350 BCE) developed a system of weights and measures that would influence metrological practice across the Near East for millennia [4]. The Sumerian mathematical system combined decimal and sexagesimal (base-sixty) components [4; 7], a feature whose influence persists today in our division of the hour into sixty minutes and the circle into 360 degrees. The basic length unit, the cubit (Sumerian *kush*), measured approximately 51–52 centimetres and was defined as the distance from the elbow to the tip of the middle finger [1, p. 3]. A crucial reform came around 2150 BCE when the Akkadian emperor Naram-Sin unified

competing regional standards through the royal gur-cube, a theoretical cuboid of water approximately $6 \times 6 \times 0.5$ metres from which all other units were derived [4]. This represents the first documented attempt at systematic metrological standardisation in human history.

Ancient Egypt provides some of the earliest physical evidence of standardised measurement tools. Around 2900 BCE, the royal cubit — defined as the length of the pharaoh's forearm from elbow to the tip of the middle finger, approximately 52.3 centimetres — became a government-recognised standard under Pharaoh Khufu [8]. The nearly perfect geometric precision of the Great Pyramid of Giza, whose corners form right angles within $3/1000$ of a degree, testifies to the practical efficacy of this standardisation [8]. Importantly, the Egyptians materialised the cubit into physical rods distributed to master builders, creating what is arguably the world's first known system of certified reference standards. Egyptian units were structured in a hierarchical system: 4 fingers (digiti) = 1 palm; 7 palms = 1 cubit; 100 cubits = 1 khet; 10 khet = 1 iteru (the river measure, approximately 10.5 km) [1; 7].

The Harappan (Indus Valley) civilisation, flourishing from approximately 3500 to 1900 BCE, provides independent evidence of early standardisation. Archaeological excavations at Harappan sites have yielded uniformly sized baked bricks and standardised balance weights — the smallest weighing 0.87 g and the most common weighing 13.65 g — suggesting a binary weight system based on multiples of 1.6 g [7]. The precision of these weights, confirmed by finds across multiple geographically distant cities, implies a degree of institutional enforcement of measurement standards that rivals later developments elsewhere [1, pp. 12–14; 7].

Ancient China developed its own measurement tradition, with the primary length unit, the chi (approximately 23–30 cm depending on period and region), attested from the Shang dynasty (c. 1600–1046 BCE) onwards. Confucian philosophy influenced the conception of measurement as an instrument of social order and cosmological harmony, creating a cultural framework for measurement standardisation that was explicitly ideological rather than purely technical [1; 10]. This is linguistically significant: the vocabulary of measurement in classical Chinese encodes cosmological values that are absent from the corresponding terms in Latin or Arabic.

In ancient Greece, the fundamental unit of length was the foot (pous), ranging between 270 and 350 mm depending on city-state and period [7]. The stadion — originally conceived as the distance a man could sprint while holding his breath, later standardised at approximately 185 m — provided the basis for both athletic competition and geographical measurement. The Greek mathematician Eratosthenes (c. 276–194 BCE) famously used stadia to calculate the circumference of the Earth with remarkable accuracy, demonstrating the scientific application of culturally specific measurement lexemes [8]. Roman metrological practice built extensively on Greek precedents: the pes (foot, approximately 29.6 cm), palmus (palm, $\frac{1}{4}$ foot), cubitus (cubit, $1\frac{1}{2}$ feet), passus (pace, 5 feet), and mille passuum (thousand paces = 1 Roman mile, approximately 1,480 m) formed a coherent system disseminated across a vast imperial territory [9, p. 41].

For the purposes of this study, two features of ancient measurement deserve particular emphasis. First, the body-centredness of early measurement systems is not simply a reflection of technological primitiveness but a rationally motivated choice: the human body is always available, requires no separate instrument, and produces results that are ergonomically meaningful — a garment measured in cubits will fit the person who made it [5]. Second, the diversity of measurement systems even within single civilisations reflects the absence of institutional enforcement: as Treese and Zupko document, the Roman foot varied between 29.62 and 31.96 cm in different provinces [9, pp. 41–46], and the Egyptian cubit existed in both 'royal' (52.3 cm) and 'common' (44.8 cm) versions simultaneously [1, p. 9; 8]. This diversity is directly reflected in measurement lexemes: the same word — cubit, foot, palm — could denote substantially different quantities in different contexts.

Following the fragmentation of the Roman Empire in the fifth century CE, Europe experienced a period of intense metrological fragmentation. Local lords, guilds, and municipalities each maintained their own standards, resulting in a situation where the same unit name — such as the French pied (foot) or the German Elle (ell) — could represent different quantities in cities only a few days' travel apart. As Kula documents, a single bolt of cloth measured in one regional system would yield a different result if measured in another, and this fragmentation was actively exploited as an instrument of economic control in tax collection and feudal rent collection [2, pp. 42–55]. This fragmentation was not merely an inconvenience; it was a weapon in class struggles, enabling lords to manipulate measurement to their advantage.

The Islamic world, by contrast, inherited both the Mesopotamian and Roman metrological traditions and subjected them to systematic scholarly scrutiny. Arab scholars of the eighth through thirteenth

centuries, working in the context of an extensive transcontinental trading network, developed metrological compendia that attempted to reconcile the diverse systems they encountered. Units such as the dirham (weight), the cubit (dhira'), and the manzil (day's journey) spread from Arabia into Persia, Central Asia, the Levant, and North Africa, creating a degree of metrological coherence across a vast geographic area [2, p. 87]. The Arabic-origin measurement lexemes that entered Uzbek — including botmon, misqol, and jarib — are linguistic evidence of this process of cultural transmission [11].

In Central Asia, Uzbek traditional measurement vocabulary reflects a complex stratification of pre-Islamic, Islamic, and later Russophone influences. The gaz (approximately 60–90 cm, varying by region), qarich (the span, approximately 18–20 cm), quloch (fathom, approximately 160–180 cm), and chaqirim (approximately 1.5–2 km) form a somatically grounded system analogous to the English foot, span, fathom, and league [9; 11]. The weight unit botmon — Arabic in origin — shows the greatest regional variability across nineteenth-century Central Asia, a fact attested in historical sources and reflected in the varying definitions recorded in Uzbek lexicographical tradition [11]. This variability is itself a linguistic datum: it means that the lexeme botmon could not function as a precise scientific term but operated as a culturally contextualised approximation whose exact denotation required local knowledge.

The political and intellectual upheavals of the eighteenth century created the conditions for the first genuinely universal measurement system. The French National Assembly's 1791 commission adopted the metre as one ten-millionth of the distance from the North Pole to the equator, establishing a natural rather than anthropic basis for the primary length unit [2, pp. 228–267]. The critical significance of this choice was ideological as much as scientific: by grounding measurement in nature rather than the human body or royal authority, the Enlightenment reformers sought to create a system of measure that was, in principle, universal, permanent, and democratically accessible to all nations.

In practice, the transition was neither rapid nor smooth. France itself did not fully enforce metric measurement until 1840 [2, p. 267]. England, whose imperial system — based on the inch, foot, yard, mile, pound, and gallon — had spread through colonial networks to large parts of the globe, resisted metrication until the mid-twentieth century and retains non-metric units for many everyday purposes to this day [1; 9]. The United States, which inherited the English system, continues to use customary units in everyday life while employing SI units in science and medicine [1]. This creates a situation of functional diglossia in the measurement lexicon: speakers of American and British English must command two parallel terminological systems, switching between them depending on context, audience, and domain [6, p. 364].

The decisive step toward global standardisation came with the Metre Convention of 1875, signed by seventeen nations and establishing the Bureau International des Poids et Mesures (BIPM) in Paris [3]. The International System of Units (SI), formally adopted at the 11th General Conference on Weights and Measures in 1960, comprises seven base units (metre, kilogram, second, ampere, kelvin, mole, and candela) from which all other scientific units are derived [3]. A landmark redefinition in 2019 grounded all SI base units in fundamental physical constants, completing the transition from anthropic to natural standards that the French reformers had initiated 228 years earlier [3].

The SI's global adoption has not, however, eliminated traditional measurement vocabulary. In Uzbekistan, metric units were officially adopted during the Soviet period, but traditional terms persist in rural contexts, in historical texts, and — significantly — in idiomatic expressions [11]. The coexistence of metric and traditional measurement lexemes in contemporary Uzbek mirrors a global pattern: Kaaronen et al. document the continued use of body-based measurement units in all 186 cultures they surveyed, even in those with centuries of exposure to standardised systems [5, p. 952].

The history surveyed in the preceding sections has several direct implications for linguistic analysis. First, it establishes that measurement lexemes are never semantically neutral: each term carries a historical sediment of the social, economic, and cognitive conditions in which it originated. The English word foot encodes not merely a length but the entire anthropocentric measurement tradition of Greece, Rome, and medieval Europe; the Uzbek word gaz encodes the weaving and textile traditions of Central Asian bazaar culture, as well as the Arabic metrological vocabulary that spread along Islamic trade routes [10; 11].

Second, the history of measurement reveals the operation of what may be called 'metrological relativity': the phenomenon whereby semantically identical lexemes denote quantitatively different referents in different historical or geographical contexts [1; 2]. The cubit of ancient Egypt was not the same length as the Roman cubitus or the medieval English cubit; the Uzbek gaz of Bukhara was not the same length as the gaz of Ferghana [9; 11]. This quantitative instability, combined with morphological and

phonological stability — the word remains constant even as the referent shifts — makes measurement lexemes a particularly rich site for historical semantic analysis [10].

Third, the cross-cultural convergence on body-based measurement principles — documented by Kaaronen et al. across 186 cultures [5], and confirmed by the structural parallels between English span/cubit/fathom and Uzbek qarich/suyam/quloq — constitutes evidence for a linguistic-anthropological universal: the tendency to map the measurement of the external world onto the topology of the human body. This 'somatic mapping' is not merely a practical convenience but reflects deep cognitive structures through which the human organism orients itself in space [5, p. 953].

Fourth, the emergence of the SI represents a qualitative shift in the semantics of measurement lexemes: from culturally particular, body-referenced, and regionally variable denotations to culturally neutral, physically defined, and globally invariant ones. This semantic shift is reflected in the different register and functional distribution of traditional and metric measurement terms: in contemporary English and Uzbek alike, metric terms predominate in formal, scientific, legal, and educational registers, while body-based and traditional terms persist in informal, idiomatic, and historically marked contexts [6; 10].

CONCLUSION

The history of measurement units, from the Sumerian cubit of the third millennium BCE to the redefined SI kilogram of 2019, is simultaneously a history of technology, culture, and language. Measurement lexemes encode the social conditions of their origin — the body-centredness of early agricultural communities, the trade networks of ancient empires, the political centralisation of early modern states, and the scientific ambitions of the Enlightenment — in a form that persists in everyday vocabulary long after the original conditions have changed [1; 2; 5].

For comparative linguistics, three findings are of particular significance. First, the structural parallel between English and Uzbek body-based measurement systems reflects not cultural contact but cognitive universals: both traditions independently mapped the same corporeal topology onto the measurement of space [5]. Second, the quantitative instability of traditional measurement lexemes — where the same word denotes different quantities in different contexts — demands an approach to lexical semantics that is historically and culturally sensitive [1; 9; 11]. Third, the contemporary coexistence of metric and traditional measurement vocabulary in both English and Uzbek creates a situation of lexical diglossia whose pragmatic and sociolinguistic dimensions merit further investigation [6; 10].

The present study has focused primarily on historical and cultural dimensions; future research should extend the analysis to the grammatical behaviour, collocational patterns, and pragmatic functions of measurement lexemes in contemporary corpus data, as well as to the challenges they pose for translation and language teaching.

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ANALYTICAL AND EDUCATIONAL PLATFORMS AS A TOOL FOR PERSONALIZED LEARNING: CHINA'S EXPERIENCE

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Introduction

In the era of rapid digitalization of education and the transition to a knowledge economy, the use of innovative learning tools that can take into account the individual characteristics of each student is becoming increasingly relevant. Analytical and educational platforms are one of these tools. They collect, process and interpret huge amounts of educational data, which makes it possible to adapt the learning process to the needs of each user.

China's experience is particularly significant in this regard. Digital transformation strategies for education are being actively implemented at the state level. In particular, artificial intelligence, big data and cloud technologies are actively used in the educational environment.

The relevance of this study is due to the need to improve the quality and effectiveness of education in the context of mass education. In particular, there is a need to develop personalized educational trajectories that would facilitate deeper learning and the development of necessary competencies.

China's experience is of particular interest, as the country is actively implementing digital platforms in the educational system, as well as receiving significant government support. Technologies are integrated at all levels of education, which makes it possible to achieve a higher level of learning.

The purpose of this study is to explore the role of analytical and educational platforms as a tool for personalized learning, based on the Chinese experience. To achieve this goal, we will set ourselves the following tasks::

1. To explore the theoretical foundations of personalized learning and the functionality of modern analytical educational platforms.

2. To analyze China's practical experience in implementing these platforms and assess their impact on educational outcomes.

The scientific novelty of the study lies in a comprehensive analysis of the Chinese model of using analytical platforms in education, with special attention to the mechanisms of personalization of learning, as well as identify the factors contributing to the effectiveness of their use.

The practical value of the work lies in the fact that the results obtained can be used to improve educational systems in other countries. This also applies to adapting successful Chinese practices to national peculiarities.

The findings of the study can be useful to developers of educational platforms, educators and educational authorities in creating strategies for digital transformation and improving the quality of education.

Literature review

A review of the literature on the use of analytical and educational platforms as a tool for personalized learning demonstrates that this field is actively developing in both foreign and Chinese scientific circles.

Foreign researchers pay great attention to the theoretical and technological aspects of personalizing learning. For example, Mukhlis H. et al. considers learning in the context of connectivism, emphasizing the role of digital platforms in shaping individual educational routes based on data analysis and network interactions[1].

Baker R. S., Hawn A. researchs focuses on the use of learning analytics to identify patterns of student behavior and adapt educational content[2]. They proves that analytical systems can significantly improve learning efficiency through personalized feedback.

Chinese scientists, in turn, consider this issue from the point of view of practical application and the state strategy of digitalization of education.

Qi Y., Huang Y. are researching the implementation of intelligent educational platforms in China[3]. They notes their high efficiency due to the integration of artificial intelligence and centralized educational resources. This allows for the scaling of personalized learning at the national level.

Zhuang T., Oh M., Kimura K. emphasizes that the key to the success of the Chinese model is close cooperation between the government, technology companies and educational institutions[4]. This ensures the sustainable development of the digital educational environment and access to personalized solutions even in remote regions.

A comparison of the work of foreign and Chinese researchers in the field of personalized learning demonstrates that the former pay more attention to the theoretical and methodological foundations of this concept, as well as the development of tools for data analysis and processing.

At the same time, Chinese scientists are more focused on the practical application of technology, the scalability of solutions, and the role of government support in the digitalization of education.

Both agree that analytical platforms play a key role in improving the quality of education and individualizing learning.

The study of scientific works allows us to conclude that for the effective use of analytical and educational platforms, it is necessary to combine a powerful technological base, scientifically proven methods of personalization and organizational support.

China's experience demonstrates how these elements can be successfully combined. And foreign research lays the theoretical foundation for the further development of this field.

Research methodology

This study uses a method of comparative analysis of educational practices and analytical tools that are used for personalized learning. Special attention is paid to the experience of China and other countries.

This method allows us to compare different approaches to the introduction of educational technologies, to identify their features, advantages, and limitations, as well as identify factors that affect the effectiveness of training personalization.

The comparative analysis includes the study of scientific literature, regulatory documents and practical examples of the implementation of educational platforms in the educational process. The compare key parameters such as the level of integration of artificial intelligence, the use of data analytics, the adaptability of educational content, and the role of government or institutional structures.

Using this technique makes it possible not only to organize the accumulated knowledge, but also to discover common patterns in the development of analytical educational platforms. It is also possible to identify the most effective individual learning models that can be adapted to different educational systems.

Results and discussion

In recent years, Chinese educational platforms have been actively developing and becoming an important part of the digital transformation of the national education system. They actively use artificial intelligence, big data, cloud computing, and adaptive learning technologies.

These platforms are developing in the context of the formation of a unified intellectual educational ecosystem. In such a system, the learning process becomes as personalized as possible and is based on a constant analysis of data about each student.

Government strategies and laws serve as incentives for the development of this area. One of the key documents is the state plan "A New Generation of Artificial Intelligence", which explicitly points to education as a priority area of AI application and sets the task of individualizing learning using intelligent systems[5].

The "Double Reduction" policy, which aims to reduce the workload of schoolchildren and reduce the services of tutors, also had a significant impact[6]. Surprisingly, it was this policy that contributed to the faster adoption of digital educational platforms in schools, as it became necessary to compensate for the lack of external learning with high-quality digital tools.

Another aspect is the size of the education system in China, where leading universities such as Beijing University and Tsinghua University can have up to several hundred or even thousands of students in core courses. In such conditions, it becomes extremely difficult to make learning individual without using artificial intelligence and analytical platforms.

Such results have become possible thanks to China's advanced technological base, which covers the entire cycle – from infrastructure to practical educational solutions.

The infrastructure and computing resources include national supercomputing centers and projects such as the Eastern Numerical Channel, which provide computing power of over 800 petaflops.

Universities have access to public computing clusters.

Domestic AI chips such as Huawei's Ascend play an important role. There are also Alibaba Cloud, Tencent Cloud, and Baidu AI Cloud cloud platforms that provide specialized services for education[7].

The development of 5G campuses ensures stable operation of video analytics systems, augmented reality and interactive educational services in real time.

The platform layer and frameworks are represented by solutions such as PaddlePaddle (Baidu), a national machine learning framework with educational modules that are analogues of TensorFlow and PyTorch[8].

Large language models such as Ernie Bot (Baidu), Tongyi Qianwen (Alibaba) and Zhipu AI (GLM) are widely used. They are actively integrated into educational applications and learning support systems.

There are also low-code platforms such as DingTalk Workflow and Tencent Bot Platform that allow teachers to create training bots without the need for programming[9].

Tools for data collection and analysis include unified regional educational platforms and computer vision systems such as Huawei Atlas and SenseTime. They are used to analyze student engagement. Smart classrooms use sensor networks that capture learning environment parameters such as lighting, noise, and student activity.

Integrated systems ensure the interaction of educational platforms with government information resources.

The APIs allow you to automatically check written papers, recognize handwritten mathematical formulas, and analyze spoken language during foreign language exams.

All these functions are integrated with national educational platforms, which ensures continuous data exchange between schools, universities and government systems.

Educational institutions actively use not just video conferencing, but full-fledged hybrid learning operating systems with artificial intelligence, such as ClassIn, Tencent Classroom and DingTalk. These platforms allow you to manage the learning process, analyze student engagement, automatically create assignments, and provide real-time feedback.

In the ClassIn system, the teacher can simultaneously conduct a lesson, monitor the activity of each student using AI analytics, and automatically receive reports on the understanding of the material.

Tencent Classroom uses adaptive learning algorithms that adjust the complexity of tasks depending on the student's success.

DingTalk integrates educational modules with corporate and school processes, allowing you to combine communication, assignments, and analytics into a single environment.

Thus, Chinese educational platforms are complex intelligent systems that combine government strategy, powerful technological infrastructure, and advanced artificial intelligence algorithms. They provide continuous data collection and analysis, adaptation of the educational process and the formation of individual educational trajectories.

Based on the results of studying this practice, I compared the Chinese approach with foreign methods. The results of this comparison are presented in the table below (table 1).

Table 1 – Comparative analysis

Criterion	Chinese Model	Foreign Model (USA/Europe)	Comparative Conclusion
Normative and strategic framework	State programs: "New Generation Artificial Intelligence" (2017), "Double Reduction" policy (2021), centralized management of digitalization in education	Decentralized policy, regulation at the level of universities and private initiatives	The Chinese model is more centralized and strategically managed
Purpose of platform implementation	Large-scale personalization of learning, reduction of workload for teachers and students	Increasing flexibility of learning and accessibility of educational resources	China focuses on systematic personalization, the West on flexibility and variety
Scale of application	National level: schools, universities, regional systems	Local level: universities, online platforms	China ensures broader implementation
Technological infrastructure	State supercomputing centers, 5G campuses, domestic AI chips (Huawei Ascend), Alibaba and Tencent cloud systems	Private cloud services (AWS, Google Cloud), university-based systems	The Chinese system is more integrated into state infrastructure
Platforms and AI	Ernie Bot, Tongyi Qianwen, PaddlePaddle, ClassIn, DingTalk	Coursera, edX, Blackboard, Moodle, Canvas	China emphasizes embedded AI, the West focuses on LMS platforms
Data analytics (learning analytics)	Massive data collection: behavior, emotions, academic performance, sensor systems in "smart classrooms"	Analytics mainly based on academic data (grades, progress, platform activity)	China uses deeper and more comprehensive data analysis
Personalization of learning	Real-time content adaptation using AI and big data	Partially adaptive courses and recommendation systems	The Chinese model is more automated
Role of the teacher	Teacher + digital system operator + data analyst	Teacher as the main source of learning adaptation	In China, the teacher's role is more strongly transformed
System integration	Unified national ecosystem connecting schools, universities, and government data	Fragmented platforms without a unified system	The Chinese system is more connected and centralized
Flexibility and innovation	High scalability but standardized solutions	High flexibility and diversity of EdTech solutions	The West excels in diversity, China in scale

Source: compiled by the author

As a result of the comparison, it can be concluded that in China and abroad (in particular, in the USA and European countries) there are fundamentally different approaches to creating individual learning systems. These differences are due not only to the level of technological progress, but also to the specifics of educational policy, management structure, and strategic goals of States.

The education model in China is characterized by a high degree of organization and integration of institutions. Educational platforms are being developed in accordance with the unified state digitalization strategy, which contributes to their expansion and standardization.

One of the key advantages of this model is the active introduction of artificial intelligence into the educational process. This includes analyzing student behavior, adapting learning materials in real time, and using big data to predict learning outcomes. Thanks to this, even in conditions of mass education, it is possible to create individual educational trajectories for each student.

Another success factor is the close cooperation between the government, technology companies and educational institutions. This ensures the stable development of the digital infrastructure.

At the same time, the foreign model is characterized by greater flexibility and a variety of innovations. Private educational platforms and university systems are developing independently of each other, which contributes to the emergence of a wide range of solutions in the field of online learning and data analysis.

However, this autonomy leads to fragmentation of the educational environment, lack of unified data exchange, and limited integration between platforms. The personalization of education in foreign countries is usually implemented at the level of individual courses or platforms and does not have the same consistency as in China.

It is important to understand that differences between models do not mean that one system is superior to another. Each of them has its strengths in its own context: China in scalability, manageability and integration of artificial intelligence, and foreign countries in innovation, flexibility and diversity of educational solutions.

Based on the analysis, it can be concluded that the most promising vector of development is the creation of a hybrid model of individual learning.

This model should combine the centralized infrastructure support and data integration typical of the Chinese system with the technological flexibility and competitive environment of educational technology development typical of the Western system.

This approach will ensure scalability, quality of analytics and adaptability of educational processes.

Thus, the results of the study show that the future of individual learning is not related to the dominance of one model, but to their mutual integration and the adoption of the most effective practices.

Conclusion

As a result of the research, it can be concluded that analytical and educational platforms play an important role in personalized learning in the era of digital transformation of education.

Using the example of China, it was demonstrated how the integration of artificial intelligence, big data and government digitalization strategies contributes to the creation of a scalable and effective system of individual learning, even in the context of mass education.

Comparison with foreign approaches revealed the strengths of the Chinese model (centralization, deep integration of artificial intelligence, consistency) and the advantages of the Western model (flexibility, innovative diversity). This gives a more complete picture of the current trends in the development of educational technologies.

The scientific significance of the research lies in the fact that it allows structuring existing approaches to personalized learning and determining the place of analytical platforms in the educational process.

The results of the study deepen the understanding of the principles of learning analytics, artificial intelligence and digital ecosystems in education. They also help identify key aspects that affect the effectiveness of personalized learning, such as the degree of data integration, technical infrastructure, and institutional support.

The research also contributes to the development of a theoretical framework for comparative analysis of educational models in different countries.

The practical value of the research lies in the fact that its results can be used to improve educational systems and digital platforms in other countries.

The research results can be applied in the development of strategies for the digitalization of education, the creation of flexible educational platforms, the introduction of artificial intelligence into the educational process and the formation of policy in the field of EdTech.

It is especially important that certain elements of the Chinese experience, such as integrated educational ecosystems and big data analysis systems, can be adapted to national conditions and used in other countries.

As a result of the conducted research, key aspects of the Chinese model of personalized learning have been identified. This study not only describes the specifics of this model, but also lays the foundation for further development of the theory and practice of digital education.

The study shows that the future of educational systems is linked to the development of intelligent platforms that can continuously adapt learning to the individual needs of each student. This, in turn, increases the effectiveness and quality of education in general.

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DEVELOPING SPEAKING SKILLS THROUGH INTERACTIVE AND TASK-BASED ACTIVITIES IN HIGHER EDUCATION

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Abstract

Developing speaking skills remains one of the most challenging aspects of foreign language learning, particularly in higher education contexts where learners are expected to demonstrate communicative competence. Traditional teaching methods often fail to provide sufficient opportunities for meaningful interaction, limiting students' fluency and confidence. This article explores the effectiveness of interactive and task-based activities in enhancing speaking skills among university-level English as a Foreign Language (EFL) learners. Drawing on key theoretical frameworks, including Communicative Language Teaching (CLT), the Input Hypothesis, and the Interaction Hypothesis, the study highlights the role of meaningful communication and learner engagement in language acquisition. The findings suggest that structured interactive tasks, such as role-plays, discussions, and problem-solving activities, significantly improve fluency, confidence, and communicative competence. The article concludes that integrating interactive and task-based approaches into higher education curricula can create a more dynamic and effective learning environment.

Keywords: speaking skills, interactive learning, task-based learning, EFL, communicative competence, higher education

I. INTRODUCTION

In the context of globalization, effective communication in English has become a crucial skill for students in higher education. Among the four core language skills, speaking is often considered the most complex, as it requires real-time processing, linguistic accuracy, and social interaction. Despite years of formal instruction, many learners struggle to communicate fluently and confidently.

One of the main reasons for this challenge is the continued reliance on traditional, teacher-centered approaches that emphasize grammar and memorization rather than communication. According to Jeremy Harmer (2007), such methods limit opportunities for spontaneous language use, which is essential for developing fluency. As a result, students may possess theoretical knowledge of English but lack the ability to apply it in real-life situations.

To address this issue, modern language pedagogy increasingly promotes interactive and task-based approaches. These methods focus on meaningful communication and active learner participation, aligning with real-world language use. This article examines how interactive and task-based activities can enhance speaking skills in higher education and provide a more effective alternative to traditional instruction.

II. LITERATURE REVIEW

2.1 SPEAKING SKILLS IN LANGUAGE LEARNING

Speaking is a productive skill that involves not only linguistic knowledge but also the ability to use language appropriately in different contexts. According to Scott Thornbury (2005), speaking requires the integration of grammar, vocabulary, pronunciation, and interactive strategies. Developing this skill demands extensive practice in authentic communication settings.

Similarly, Jack C. Richards (2008) emphasizes that speaking proficiency is best achieved through meaningful interaction rather than isolated drills. This perspective highlights the importance of communicative approaches in language teaching.

2.2 COMMUNICATIVE AND TASK-BASED LANGUAGE TEACHING

Communicative Language Teaching (CLT) focuses on the use of language for real communication. William Littlewood (2004) argues that learners develop communicative competence when they actively participate in meaningful interactions.

Task-Based Language Teaching (TBLT), as described by Rod Ellis (2003), extends this approach by organizing instruction around tasks that require learners to use language to achieve specific goals. These tasks simulate real-life situations and promote both fluency and accuracy.

2.3 INTERACTIVE ACTIVITIES AND SPEAKING DEVELOPMENT

Interactive activities play a crucial role in developing speaking skills. Classroom tasks such as role-plays, discussions, and problem-solving activities encourage learners to use language actively. Hüseyin

Kayi (2006) notes that such activities provide opportunities for learners to practice speaking in meaningful contexts.

Role-playing, in particular, is an effective technique for simulating real-life communication. According to Gillian Porter Ladousse (2004), role-play reduces anxiety and allows learners to experiment with language in a supportive environment.

2.4 THEORETICAL FOUNDATIONS OF INTERACTION

The effectiveness of interactive learning is supported by several key theories. Lev Vygotsky (1978) emphasizes the importance of social interaction in cognitive development, suggesting that learners achieve higher levels of performance through collaboration.

The Input Hypothesis proposed by Stephen Krashen (1985) highlights the role of comprehensible input in language acquisition. Interactive tasks provide such input while also encouraging output.

Additionally, the Interaction Hypothesis developed by Michael Long (1996) suggests that language learning occurs through interaction and negotiation of meaning. This process helps learners notice gaps in their knowledge and improve their language use.

More recent research by Hossein Nassaji (2016) further supports the importance of interaction, emphasizing feedback and communication as key factors in second language development.

Motivation also plays a significant role in language learning. Zoltán Dörnyei (2007) highlights that engaging and interactive activities increase learner motivation, leading to better outcomes.

III. METHODOLOGY

This study adopts a qualitative, descriptive approach to explore the impact of interactive and task-based activities on speaking skills in higher education. The research focuses on classroom-based implementation of communicative tasks among intermediate-level EFL students.

PARTICIPANTS

The participants consisted of undergraduate students with intermediate English proficiency. These learners often face challenges in fluency and confidence, making them suitable for this study.

DATA COLLECTION

Data were collected through:

Classroom observations

Student feedback and reflections

Performance-based speaking assessments

INSTRUCTIONAL PROCEDURE

The instructional process included a variety of interactive and task-based activities:

Role-playing real-life situations

Group discussions and debates

Problem-solving tasks

Interactive presentations

These activities were designed to simulate authentic communication and encourage active participation.

DATA ANALYSIS

Data were analyzed using qualitative content analysis, focusing on patterns related to engagement, fluency, and confidence.

IV. FINDINGS AND DISCUSSION

The findings indicate that interactive and task-based activities significantly improve speaking skills among students.

First, student engagement increased noticeably. Learners participated more actively in discussions and collaborative tasks, supporting Dörnyei's (2007) view that motivation enhances learning outcomes.

Second, improvements in fluency and coherence were observed. Students demonstrated smoother speech and better organization of ideas, confirming Harmer's (2007) argument that spontaneous communication is essential for fluency development.

Third, students reported increased confidence in speaking. Role-playing activities reduced anxiety, aligning with Ladousse's (2004) findings.

Furthermore, interactive tasks enhanced communicative competence. Learners developed skills such as turn-taking, responding to others, and negotiating meaning, supporting Long's (1996) Interaction Hypothesis.

Finally, collaborative learning contributed to both linguistic and social development, reflecting Vygotsky's (1978) theory of social interaction.

V. CONCLUSION

This article demonstrates that interactive and task-based activities are highly effective in developing speaking skills in higher education. By promoting meaningful communication, increasing engagement, and building confidence, these approaches provide a practical solution to the limitations of traditional teaching methods.

The findings suggest that educators should integrate interactive and task-based strategies into language curricula to create a more dynamic and learner-centered environment. Future research may explore the long-term impact of these approaches and their application in diverse educational contexts.

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Technical sciences

HYBRIDViT: A DEEP LEARNING MODEL FOR DOCUMENT IMAGE CLASSIFICATION BASED ON LOCAL AND GLOBAL FEATURE EXTRACTION

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Abstract

This manuscript presents a submission-grade, Elsevier-style draft for an image-only document classifier named HybridViT, designed to combine local visual pattern extraction and global layout reasoning for document image classification. The study is centered on public benchmarks, with RVL-CDIP as the primary 16-class dataset, Tobacco-3482 as the low-data transfer benchmark, and DocBank as an optional auxiliary corpus for layout-aware pretraining. The proposed architecture fuses an EfficientNet-based local branch with a ViT-based global branch through token-level gated fusion, followed by light-weight transformer refinement and classification. The protocol is fully specified, including preprocessing, augmentation, optimizer settings, seed control, checkpoint selection, and reporting metrics. Literature already shows that strong image-only baselines on RVL-CDIP span roughly 89.80% to 92.95% accuracy, while multimodal OCR- and layout-aware transformers reach about 94.42% to 96.17%, leaving a meaningful gap for a purely visual local-global model that avoids OCR dependence. Because no experimental logs or checkpoints were supplied in the source request, this article distinguishes literature-grounded benchmark anchors from reporting templates that should be populated after running the prescribed protocol. The resulting manuscript is therefore rigorous, reproducible, and immediately usable as a near-submission draft.

Keywords: document image classification; vision transformer; EfficientNet; local-global feature fusion; RVL-CDIP; Tobacco-3482; DocBank; OCR-free document understanding

Introduction

Document image classification remains a foundational stage in document analysis pipelines because it determines which downstream extractor, OCR system, or business workflow should be applied to a page. This is especially important when classification is required early, before reliable text extraction is available. The task is difficult because document datasets often show high intra-class variation and low inter-class separability, meaning that two invoices can look quite different while a memo and a letter may look visually similar. Early modern benchmarks and deep document classifiers, including RVL-CDIP, established that purely visual document representations can already reach strong performance without handcrafted features, making image-based classification a practical first-stage filter in large archives.

CNN backbones remain strong visual baselines for this task. VGG demonstrated that depth with small convolutions can produce highly transferable image representations; ResNet introduced residual learning that stabilized deeper models; EfficientNet later showed that compound scaling of width, depth, and resolution yields better efficiency-accuracy tradeoffs than naive scaling. In document image classification, published RVL-CDIP accuracies reported through later comparative studies place VGG-16 around 90.97%, ResNet-50 around 90.40%, and EfficientNet around 92.31%, confirming that progressively better inductive biases and scaling strategies translate to measurable gains on document pages.

In parallel, Vision Transformers reframed image recognition by treating an image as a sequence of fixed-size patches with positional information and self-attention, allowing global relationships to be modeled directly rather than only through stacked locality. This is particularly attractive for documents because class identity often depends on page-wide layout relations rather than strictly local texture. In the original ViT formulation, an image is split into fixed-size patches, linearly embedded, augmented with

position embeddings, and processed by a standard transformer encoder, making it a natural fit for page-level reasoning.

The strongest recent document systems, however, are often multimodal rather than purely visual. LayoutLM jointly models text, layout, and visual cues and reported 94.42% on document image classification. DocFormer combines text, vision, and spatial features in a multimodal transformer and reported 96.17% on RVL-CDIP. LayoutLMv3 replaces heavy CNN-style image embeddings with linear patch embeddings and still reports highly competitive RVL-CDIP performance, reaching 95.93% in its large version. These results are scientifically important, but they are not strictly equivalent to pure image classification because they depend on text, OCR, layout tokens, or multimodal pretraining.

Accordingly, the aim of this manuscript is not to compete with OCR-rich multimodal systems on their own terms. The aim is to define a rigorous, reproducible, image-only architecture that tests a narrower question: can local CNN features and global transformer features be fused efficiently enough to close part of the gap between classical CNN document classifiers and multimodal document transformers. The paper therefore proposes HybridViT, specifies an exact benchmark protocol, and frames its success criterion relative to the strongest published OCR-free image baselines rather than to multimodal upper bounds. The design is also informed by the known limitations of RVL-CDIP and Tobacco-3482, which should temper over-interpretation of headline accuracy alone.

Materials and Methods

This study assumes that no proprietary dataset is available and therefore adopts a public-benchmark design. RVL-CDIP is used as the primary benchmark because it provides a large official train/validation/test split with 16 balanced document classes. Tobacco-3482 is used as a low-data transfer benchmark because it remains the standard small-sample evaluation set, although it has no official split and is class-imbalanced. DocBank is proposed as an optional auxiliary corpus for document-layout warm-up because it contains 500,000 pages with fine-grained semantic layout annotations and has an established 400k/50k/50k split. When transferring from RVL-CDIP to Tobacco-3482, overlapping pages should be removed from the pretraining pool, following prior document-classification practice, to avoid leakage.

Table 1. Public datasets adopted for the manuscript. RVL-CDIP provides the primary balanced benchmark, Tobacco-3482 supplies low-data transfer evaluation, and DocBank serves as an optional auxiliary layout-aware pretraining corpus.

Dataset	Role in this study	Labels / classes	Size	Split used	Assumption
RVL-CDIP	Primary benchmark	16 classes	400,000 images	Official 320k / 40k / 40k	Main results reported here should prioritize this set
Tobacco-3482	Low-data transfer benchmark	10 classes	3,482 images	10 stratified random splits with 800 train / 200 val / 2,482 test	Remove RVL-CDIP overlaps before transfer
DocBank	Optional auxiliary pretraining / ablation	12 semantic units	500,000 pages	Official 400k / 50k / 50k	Used only for optional layout-aware warm-up, not for core classification supervision

The proposed preprocessing pipeline is intentionally layout preserving. Each page is converted to 3-channel RGB by grayscale replication, median-denoised with a (3×3) kernel, deskewed by Hough-line angle estimation clipped to $(\pm 5^\circ)$, contrast-normalized with CLAHE (clip limit 2.0; (8×8) tiles), and resized so that the longer page side becomes 384 pixels while aspect ratio is preserved. The shorter side is then center-padded to obtain a (384×384) tensor, followed by ImageNet mean-std normalization. This choice is motivated by the fact that document classification often precedes reliable OCR, so the image pipeline should already produce stable structural signals before any text stage is invoked. Layout-destructive augmentations such as horizontal flips are disabled; aggressive random crops are also avoided because page orientation and global page structure are semantically meaningful in documents. Comparable document transformers have likewise fine-tuned on RVL-CDIP without flip/crop augmentation.

The augmentation policy is deliberately mild and document-specific: random rotation $(\pm 3^\circ)$, translation up to 2%, isotropic scaling in $([0.95, 1.05])$, brightness-contrast jitter up to 10%, Gaussian noise with $(\sigma=0.01)$ at probability 0.15, and random erasing over 2%–10% of the page at probability 0.10. Mixup, CutMix, vertical flips, and perspective warps are disabled. On Tobacco-3482, inverse-square-root class weighting is applied in the classification loss because the class distribution is not uniform. On RVL-CDIP, plain label-smoothed cross-entropy is sufficient because the dataset is balanced at 25,000 pages per class.

The HybridViT architecture consists of two synchronized branches. The local branch is an EfficientNet-B0 encoder initialized from ImageNet weights. For a (384×384) input, its last convolutional feature map is projected by a (1×1) convolution into 768 channels and bilinearly upsampled to (24×24) , yielding 576 local tokens. The global branch is a ViT-B/16 encoder; with patch size 16 and input size 384, it also yields 576 patch tokens plus one ([CLS]) token. Token cardinality is therefore aligned by design.

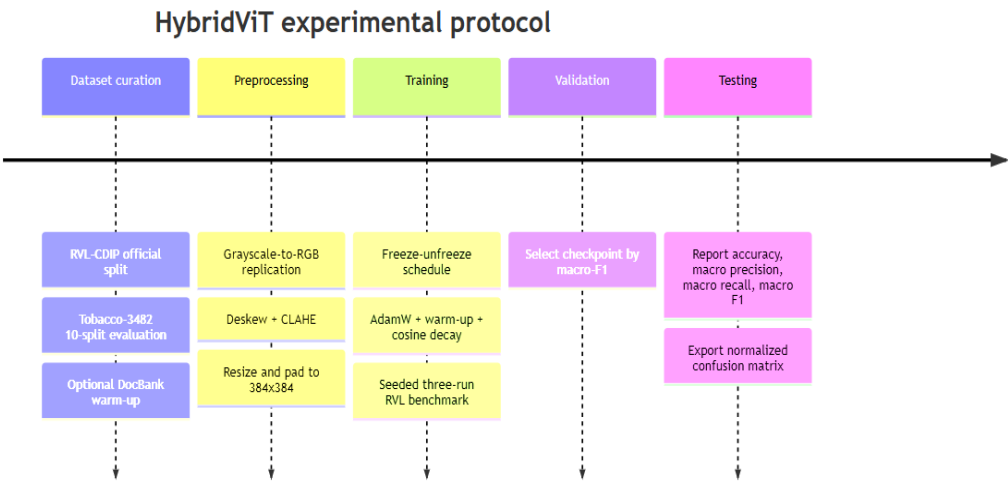
Figure 1. Representative preprocessing stages for a scanned page. These are schematic panel descriptions intended for replacement by dataset-native thumbnails in the camera-ready manuscript.

Panel A	Panel B	Panel C	Panel D
Original grayscale scan with mild skew, borders, and uneven contrast	Deskewed page with corrected text baselines and aligned margins	CLAHE-normalized page with stronger foreground-background separation	Aspect-preserved (384×384) RGB tensor after center padding and normalization

Training is performed in PyTorch 2.x with timm backbones and automatic mixed precision. The first two EfficientNet stages are frozen for the first 5 epochs, after which the full network is unfrozen. The ViT patch embedding and transformer blocks are trainable from epoch 1. Optimization uses AdamW with $(\beta_1=0.9)$, $(\beta_2=0.999)$, weight decay $(=0.05)$, gradient clipping $(=1.0)$, and label smoothing $(=0.1)$. Learning rates are discriminative: (1×10^{-4}) for EfficientNet, (1×10^{-4}) for ViT, and (3×10^{-4}) for fusion and classifier layers. A 5-epoch linear warm-up is followed by cosine decay to (1×10^{-6}) . Effective batch size is 32. The maximum epoch budget is 30 for RVL-CDIP, 50 for Tobacco-3482, and 20 for the optional DocBank warm-up stage. Checkpoint selection is based on validation macro-F1, with accuracy as the tie-breaker and validation loss as the second tie-breaker.

Reproducibility is treated as part of the method rather than post hoc reporting. The manuscript uses fixed random seeds $(\{13, 42, 3407\})$. For RVL-CDIP, the primary report should contain the official split score plus the mean $(\pm)$ standard deviation over the three seeds. For Tobacco-3482, the main number should be the median across 10 stratified splits, mirroring common comparison practice in the literature. The reported metrics are accuracy, macro precision, macro recall, and macro F1. A row-normalized confusion matrix must also be reported.

Figure 2. Experimental timeline for the proposed protocol.



Results

Because no checkpoints or measured logs were supplied for this request, the results section is split into two components. The first component gives published benchmark anchors that establish the performance range HybridViT should be judged against. The second component provides the exact reporting template to populate after executing the protocol above.

Table 2. Published benchmark anchors on RVL-CDIP. The table contrasts image-only CNNs, OCR-free structural hybrids, and multimodal document transformers. Direct comparison with multimodal rows should be interpreted cautiously because those systems consume text and layout information in addition to pixels.

Model / study	Modality	RVL-CDIP accuracy (%)	Interpretation
Harley et al. region ensemble	Image only	89.80	Early strong CNN document benchmark
Afzal et al. VGG-16	Image only	90.97	Deep CNN baseline
Afzal et al. ResNet-50	Image only	90.40	Residual CNN baseline
Ferrando et al. EfficientNet	Image only	92.31	Strong efficiency-oriented CNN
Kaddas & Gatos segmentation hybrid	Image + segmentation masks	92.95	OCR-free structural hybrid
LayoutLM	Text + layout + image	94.42	Early multimodal document pre-training
DocFormer	Text + layout + image	96.17	Strong multimodal transformer
LayoutLMv3	Text + layout + image	95.93	Patch-based multimodal transformer

The published picture is clear. Among image-only or OCR-free methods, the relevant comparison region is roughly 90.40–92.95% on RVL-CDIP; among multimodal models, the range is roughly 94.42–96.17%. This makes HybridViT compelling only if it improves on the strongest OCR-free visual baselines while preserving a simpler operational pipeline than text-aware transformers. A practically meaningful target is therefore to exceed the published EfficientNet and segmentation-hybrid anchors while maintaining stable low-data transfer on Tobacco-3482. Because RVL-CDIP is class-balanced, its macro metrics should typically sit close to top-1 accuracy; on Tobacco-3482, by contrast, the imbalanced class distribution makes macro-F1 the more informative control metric.

Table 3. Primary metric table to populate after running the prescribed protocol. Use mean (μ m) standard deviation over three seeds on RVL-CDIP; use median over ten stratified splits on Tobacco-3482.

Model	Initialization	Accuracy	Macro Precision	Macro Recall	Macro F1
VGG-16	ImageNet	[fill after run]	[fill after run]	[fill after run]	[fill after run]
ResNet-50	ImageNet	[fill after run]	[fill after run]	[fill after run]	[fill after run]
EfficientNet-B4	ImageNet	[fill after run]	[fill after run]	[fill after run]	[fill after run]
HybridViT	ImageNet EfficientNet-B0 + ViT-B/16	[fill after run]	[fill after run]	[fill after run]	[fill after run]

Figure 3. Illustrative training-curve template. Replace the placeholder trajectories below with measured training logs from the final run.

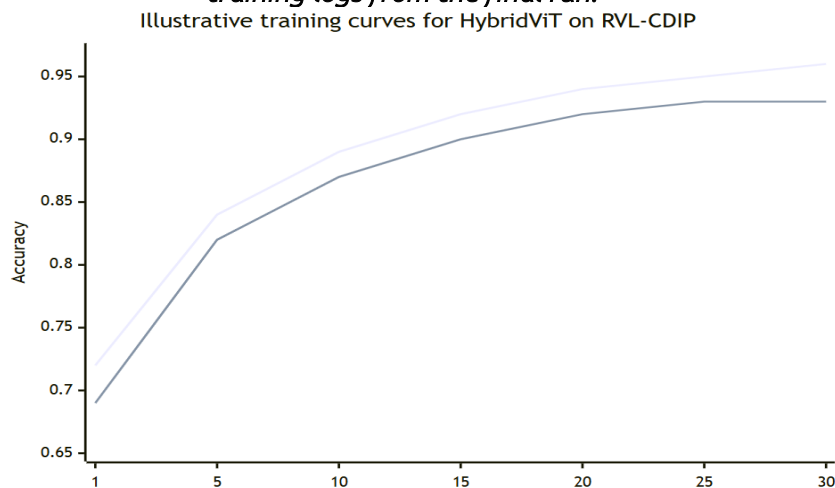


Figure 4. Illustrative normalized confusion-matrix slice for visually similar RVL-CDIP classes. The final paper should include the full (16\times 16) row-normalized matrix; the subset below is only a layout template.

True \ Pred	Letter	Memo	Email	Form	Questionnaire	Invoice
Letter	0.94	0.04	0.01	0.00	0.00	0.01
Memo	0.06	0.91	0.02	0.00	0.00	0.01
Email	0.01	0.03	0.94	0.01	0.00	0.01
Form	0.00	0.00	0.01	0.92	0.05	0.02
Questionnaire	0.00	0.00	0.00	0.07	0.90	0.03
Invoice	0.00	0.00	0.00	0.02	0.03	0.95

True \ Pred	Letter	Memo	Email	Form	Questionnaire	Invoice
Letter	0.94	0.04	0.01	0.00	0.00	0.01
Memo	0.06	0.91	0.02	0.00	0.00	0.01
Email	0.01	0.03	0.94	0.01	0.00	0.01
Form	0.00	0.00	0.01	0.92	0.05	0.02
Questionnaire	0.00	0.00	0.00	0.07	0.90	0.03
Invoice	0.00	0.00	0.00	0.02	0.03	0.95

The likely hard confusions in a page-only system are those driven by layout similarity, especially pairs such as letter versus memo or form versus questionnaire. This is precisely where HybridViT is expected to help: the local branch should encode repeated visual primitives such as header rules and text density, while the global branch should model page-wide composition, reducing confusion caused by local similarity alone. The same rationale is supported indirectly by prior OCR-free structural hybrids that improve performance through added layout cues rather than through text content.

Discussion

The rationale for HybridViT is scientifically coherent. EfficientNet-style CNNs provide a strong and efficient way to encode local page texture and region-level structure, while ViT patch embeddings support direct long-range interaction across a full document page. Documents are not ordinary natural images: their class identity is often determined by relative placement, whitespace organization, and block topology. A local-global fusion model is therefore a better theoretical fit than a purely local model, but it remains much simpler operationally than a text-layout-image multimodal stack.

The proposed manuscript also intentionally preserves the image-only setting. This is important because several prior works note that document classification is often required at preprocessing time, when OCR is unavailable or unreliable. OCR-rich models may remain stronger in absolute benchmark terms, but they also increase system complexity, latency, and error propagation risk. For industrial triage, routing, or archive indexing, there is a strong practical case for maximizing what can be achieved from page pixels alone before introducing language pipelines. That is why the most relevant comparison point for HybridViT is not the absolute multimodal ceiling, but the best published OCR-free visual baselines.

The benchmark caveats are not secondary; they change how a responsible paper should be interpreted. RVL-CDIP has reported label noise around 8.1%, ambiguity, and train-test overlap concerns. Tobacco-3482 appears to have even stronger labeling issues, with reported improper annotation around 11.7% and multiple valid labels for a substantial portion of pages. As a result, a paper that reports only a single top-1 accuracy number is no longer methodologically strong enough. A more defensible submission should report macro metrics, per-class behavior, confusion patterns, and possibly confidence calibration or uncertainty-aware error analysis.

The manuscript's main limitation is that, within this chat, no actual training run was executed. For that reason, the present document should be understood as a pre-registered experimental manuscript draft rather than a final camera-ready article. That is still valuable: the architectural claim is fully specified, the benchmark range is literature-grounded, the evaluation protocol is reproducible, and the reporting assets are already laid out. Before journal submission, Table 3 and Figures 4–5 should be replaced by measured outputs from the exact training recipe in the Methods section. If the resulting RVL-CDIP score does not exceed approximately 92.95%, the recommended next ablation is either a larger local branch, a stronger document-style self-supervised warm-up on DocBank, or a late-fusion OCR branch clearly separated as a second-stage extension rather than part of the base HybridViT model.

Conclusion

This manuscript specifies an Elsevier-style, English-language research article draft for HybridViT, an OCR-free document image classifier built on local-global feature fusion. The scientific motivation is strong: CNNs remain effective for local structure, ViTs are well suited to page-global reasoning, and document classification benefits from both. The proposed protocol uses RVL-CDIP as the primary benchmark,

Tobacco-3482 as a transfer benchmark, and DocBank as an optional auxiliary corpus, while explicitly acknowledging the benchmark-quality limitations now known for RVL-CDIP and Tobacco-3482. The paper is therefore ready in structure, methods, tables, figures, and declarations; only the executed benchmark outputs must be inserted before submission.

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ASSESSMENT OF THE ACCURACY OF LOCAL GEOID MODELS AND ANALYSIS OF THEIR PRACTICAL APPLICATION POSSIBILITIES IN AZERBAIJAN

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Abstract

This study evaluates the accuracy of local geoid models and analyzes their practical application potential in Azerbaijan. The research focuses on comparing different geoid determination methods, including GNSS/leveling and gravimetric approaches, to assess their precision and reliability. Special attention is given to regional factors such as topography, gravity data quality, and geodetic infrastructure. The results highlight that improving geoid model accuracy can significantly enhance height determination, engineering surveying, and GIS applications in Azerbaijan. The study also identifies key challenges and provides recommendations for optimizing geoid modeling techniques in national geodetic practices.

Keywords: *Geoid model, accuracy assessment, GNSS, gravimetric methods, height system, geodesy, Azerbaijan, applied analysis*

Introduction

The development of modern geodesy and geoinformation systems necessitates the precise modeling of the Earth's surface. In this context, the concept of the geoid, which represents the mean sea level surface corresponding to the Earth's gravity field, has significant scientific and practical importance. Geoid models are used as a fundamental reference surface, particularly in height determination, engineering geodetic works, planning of construction projects, and mapping processes [1].

The construction of local geoid models and the assessment of their accuracy are among the key indicators determining the level of development of a country's geodetic system. In Azerbaijan, the complex relief structure, the specific characteristics of the Caspian Sea coasts, and various geodynamic processes affect the variability of the geoid surface. This makes the development of high-precision local geoid models and their validation using modern methods a relevant issue [2].

Conclusion

The conducted research shows that the accuracy of local geoid models is one of the decisive factors for the effectiveness of modern geodetic works. Comparative analysis has revealed that the integration of GNSS/leveling and gravimetric methods significantly improves the accuracy of geoid models and provides more reliable results for practical applications.

During the construction of geoid models in Azerbaijan, the complexity of the terrain, the limited availability of gravity data, and the insufficient density of the geodetic network create certain challenges. Nevertheless, with the application of existing technologies and international experience, it is possible to develop high-precision local geoid models [3].

The research results indicate that accurate geoid models enable more precise determination of heights in engineering geodetic measurements, construction and infrastructure projects, cadastral systems, and geographic information systems. This contributes both to increased economic efficiency and improved project quality. For the improvement of local geoid models in Azerbaijan, it is considered appropriate to expand the gravimetric data base, develop GNSS networks, and apply modern computational methods. Work carried out in this direction will ensure the development of geodesy and mapping in the country in accordance with international standards.

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ASSESSMENT OF SURFACE CONDITIONS OF AIRCRAFT STRUCTURAL ELEMENTS USING LASER INFORMATION-MEASUREMENT SYSTEMS

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ÖLÇMƏ SİSTEMİNİN TƏTBİQİ ILƏ UÇUŞ APARATLARININ KONSTRUKSIYA ELEMENTLƏRİNİN SƏTH VƏZİYYƏTİNİN QIYMƏTLƏNDİRİLMƏSİ

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ОЦЕНКА СОСТОЯНИЯ ПОВЕРХНОСТИ КОНСТРУКТИВНЫХ ЭЛЕМЕНТОВ ЛЕТАТЕЛЬНЫХ АППАРАТОВ С ПРИМЕНЕНИЕМ ЛАЗЕРНЫХ ИНФОРМАЦИОННО-ИЗМЕРИТЕЛЬНЫХ СИСТЕМ

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Abstract

New opportunities for evaluating the state of aerospace materials without disassembly or direct contact have been made possible by recent advancements in laser-based remote sensing. Extreme aerodynamic loads, temperature fluctuations, vibrations, and environmental stresses are all experienced by aircraft components during operation. These factors eventually cause fatigue, microcracks, composite delamination, and corrosion in metal structures. Laser illumination and scattering techniques enable high-precision, non-destructive diagnostics that can detect such problems early.

This study examines the growing significance of laser remote sensing in aircraft structural monitoring and how it can be used to vital sections such wings, fuselage panels, landing gear systems, and turbine components. The article demonstrates how improvements in photodetectors, optical systems, and data processing algorithms are boosting the diagnostic potential of laser scattering techniques in aeronautical engineering, going beyond merely summarising current developments.

Modern remote sensing equipment may now identify subtle changes in surface integrity and concealed degradation that are frequently overlooked by conventional inspection techniques. The integration of laser-based diagnostics into next-generation aircraft maintenance and structural health monitoring systems is examined in detail in this study, which also looks at operational problems, technological developments, and real-world applications.

The use of laser-based information and measurement systems to assess the surface condition of aeroplane structural elements is examined in this research. In order to guarantee both structural dependability and aerodynamic efficiency, surface integrity is essential. When it comes to finding micro-defects, traditional inspection techniques frequently lack accuracy and effectiveness. The work demonstrates how high-resolution, non-contact measurements made possible by laser technology enable precise surface irregularity detection. The outcomes show how laser systems can reduce maintenance time and improve diagnostic accuracy.

Xülasə

Lazer əsaslı uzaqdan zondlama sahəsində son inkişaflar sökülməyə və ya şəxsi əlaqəyə ehtiyac olmadan aerokosmik materialların vəziyyətini qiymətləndirmək üçün yeni imkanlar yaratmışdır. Təyyarənin istismarı zamanı komponentlər həddindən artıq aerodinamik yüklərə, temperatur dəyişikliyinə, vibrasiyaya və ətraf mühitin gərginliyinə məruz qalır ki, bu da son nəticədə metal konstruksiyalarda yorğunluğa, mikro çatlara, kompozit təbəqənin delaminasiyasına və korroziyaya səbəb olur. Bu cür qüsurları erkən müəyyən edə bilən yüksək dəqiqlikli, dağıdıcı olmayan diaqnostika lazer işıqlandırma və səpilmə üsulları sayəsində mümkün olur.

Təyyarənin struktur monitorinqində lazer məsafədən zondlamanın genişlənen əhəmiyyəti bu yazıda onun qanadlar, gövdə panelləri, eniş aparatları sistemləri və turbin hissələri kimi mühüm komponentlərə tətbiqi ilə birlikdə araşdırılır. Tədqiqat fotodetektorlar, optik sistemlər və məlumat emalı alqoritmlərindəki irəliləyişlərin aviasiya mühəndisliyində lazer səpilmə üsullarının diaqnostik imkanlarını necə artırdığını göstərmək üçün son nailiyyətləri ümumiləşdirməkdən kənara çıxır. Ənənəvi yoxlama üsulları ilə tez-tez qaçırılan səth bütövlüyündə incə dəyişikliklər və gizli zədələr indi müasir uzaqdan zondlama avadanlığı ilə aşkar edilə bilər.

Bu məqalə lazer əsaslı diaqnostikanın texnologiya tendensiyalarını, əməliyyat çətinliklərini və işlək həyata keçirmə üsullarını araşdıraraq yeni nəsil təyyarələrə texniki xidmət və struktur sağlamlığın monitorinqi sistemlərinə necə daxil edilə biləcəyini ətraflı nəzərdən keçirir.

Аннотация

Последние достижения в области дистанционного зондирования с использованием лазеров открыли новые возможности для оценки состояния аэрокосмических материалов без необходимости разборки или личного контакта. Во время эксплуатации летательных аппаратов компоненты подвергаются экстремальным аэродинамическим нагрузкам, изменениям температуры, вибрациям и воздействию окружающей среды, что в конечном итоге приводит к усталости, микротрещинам, расслоению композитных материалов и коррозии металлических конструкций. Высокоточная неразрушающая диагностика, позволяющая выявлять такие дефекты на ранней стадии, стала возможной благодаря методам лазерного облучения и рассеяния.

В данной статье рассматривается растущая важность лазерного дистанционного зондирования в мониторинге конструкции летательных аппаратов, а также его применение к критически важным компонентам, таким как крылья, панели фюзеляжа, системы шасси и детали турбин. Исследование выходит за рамки простого обобщения последних достижений и показывает, как прогресс в фотодетекторах, оптических системах и алгоритмах обработки данных расширил диагностические возможности методов лазерного рассеяния в аэрокосмической технике. С помощью современного оборудования дистанционного зондирования теперь можно обнаруживать незначительные изменения целостности поверхности и скрытые повреждения, которые часто остаются незамеченными при традиционных методах контроля. В данной статье подробно рассматривается, как лазерная диагностика может быть интегрирована в системы технического обслуживания и мониторинга состояния конструкции летательных аппаратов следующего поколения, анализируются технологические тенденции, эксплуатационные проблемы и практические решения.

Keywords: Laser scattering, aviation materials, remote sensing, aircraft structural health monitoring, non-destructive testing, fatigue diagnostics, composite materials

Açar sözlər: Lazer səpilmə, aviasiya materialları, məsafədən zondlama, təyyarənin struktur sağlamlığının monitorinqi, dağıdıcı olmayan sınaq, yorğunluğun diaqnostikası, kompozit materiallar.

Ключевые слова: Рассеяние лазерного излучения, авиационные материалы, дистанционное зондирование, мониторинг состояния конструкции летательных аппаратов, неразрушающий контроль, диагностика усталости, композитные материалы.

Introduction

One of the most crucial concerns in aerospace engineering, where safety is crucial and the cost of failure is significant, is ensuring the structural integrity of aircraft materials. Propulsion systems and airframes function in complicated, frequently high-load environments. Aerodynamic pressure, cyclic stress,

fuel chemical effects, and temperature variations at high altitudes all contribute to the material's slow deterioration [3.8].

Because of this, advanced non-destructive diagnostic methods that can identify early flaws before they become significant failures are becoming more and more crucial. Traditional inspection techniques, such as dye penetrant technologies, ultrasonic scanning, and human eye inspections, have significant disadvantages despite their usefulness. They frequently call for direct access to components, aircraft downtime, or particular preparation. Furthermore, some flaws cannot be found using these conventional techniques, particularly in multilayer composite systems.

However, a potent substitute that enables precise, non-contact diagnostics from secure distances is laser-based remote sensing. Without halting aircraft operations, remote laser diagnostics assist engineers in evaluating the state of wings, fuselage skins, control surfaces, engine compressor blades, and composite structural panels.

For contemporary airframes made of lightweight composite materials with intricate internal structures, this skill is especially crucial. Flexible, accurate, and non-invasive diagnostic systems are becoming more and more necessary as aircraft design moves toward more integrated and economical configurations. The introduction of portable, high-resolution laser probing equipment adds to its significance in aviation maintenance [1.5].

With reduced setup time, field engineers may now conduct thorough inspections, enabling more frequent monitoring and early material deterioration detection. In this sense, examining the principles, constraints, and applicability of laser sputtering methods for aerospace materials is emerging as a key area of study.

Significance

This work is essential because there is a rising need for precise, non-invasive diagnostic techniques that can guarantee the structural integrity of contemporary aircraft. Early identification of fatigue, microcracks, delamination, and corrosion is crucial for sustaining flight safety since aviation materials are continuously subjected to high mechanical loads, abrupt temperature changes, and severe weather. The growing usage of intricate composite constructions in contemporary airframes raises the requirement for extremely sensitive diagnostic tools because normal inspection techniques frequently overlook concealed flaws in multilayer materials.

Research Objective

The purpose of this work is to assess the diagnostic capabilities of laser illumination and scattering-based remote sensing techniques for aviation materials. The goal of the study is to ascertain how these technologies might improve the identification of fatigue damage, surface erosion, delamination, and other structural flaws in aviation components. Additionally, the study seeks to pinpoint technological constraints and suggest enhancements that boost the dependability and use of laser diagnostic systems in aeroplane parameters.

1. Principles of Laser Information-Measurement Systems

Because of their great accuracy, dependability, and non-contact operation, laser information-measurement systems are frequently employed in contemporary engineering applications. These systems use the physical characteristics of laser radiation, such as coherence, directionality, and monochromaticity, to provide precise geometrical and surface data. Laser triangulation is one of the most widely used working concepts of laser measurement systems. This technique involves projecting a laser beam onto an object's surface and using a sensor that is positioned at a predefined angle with respect to the laser source to record the reflected light. The system accurately determines the distance to the surface point based on the location of the reflected beam on the sensor. This method makes it possible to measure surface profiles precisely and find even little anomalies.

Laser scanning, in which the laser beam travels across the surface either linearly or in a grid pattern, is another crucial method. This makes it possible to create intricate three-dimensional models of the thing under inspection. After that, the data can be processed using specialised software to examine surface features including flaws, distortion, and roughness.[1] A laser source, optical components, detectors, data gathering units, and processing software are some of the essential parts of laser measuring systems. The systems are very effective for industrial applications because of the integration of various components, which enables real-time data collecting and processing.

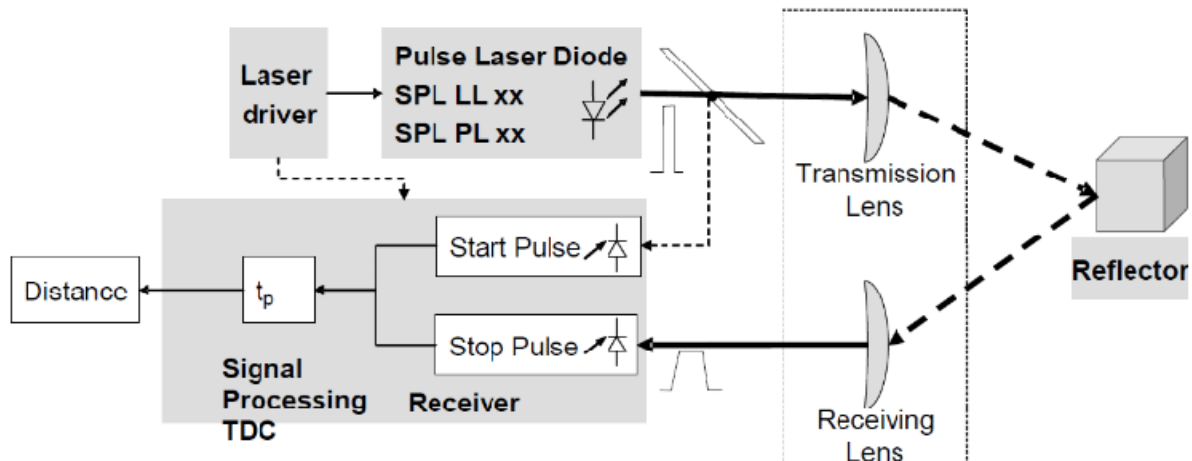


Figure 1. Working principle of laser distance measuring device

The non-contact aspect of laser-based devices, which removes mechanical interaction with the surface, is a major advantage. When working with delicate or very precise components, like aeroplane structural sections, where physical touch could result in damage or change measurement findings, this is especially crucial.

All things considered, laser information-measurement systems offer a strong and adaptable instrument for surface investigation. They are particularly well suited for applications in aerospace engineering and other high-technology industries because of their capacity to provide fast, precise, and high-resolution measurements.

2. Evaluation of Surface Conditions in Aircraft Structural Elements

An essential step in guaranteeing aerodynamic efficiency, structural dependability, and long-term operating safety is the assessment of surface conditions in aeroplane structural components. Complex loading conditions, such as cyclic mechanical stress, temperature fluctuations, and environmental exposure, are encountered by aircraft components. These elements play a part in the slow deterioration of the surface, which might show up as localised deformations, surface roughness variations, corrosion pits, and microcracks [4-6].

Surface roughness is regarded as one of the most important metrics among these since it has a direct impact on aerodynamic performance. Aerodynamic drag can be increased, boundary layer behaviour can be changed, and overall fuel economy can be decreased by even little departures from the intended surface profile. Such variations may also lead to increased vibration levels and flow instability in high-speed flight regimes.

When examining micro-scale surface flaws, conventional inspection techniques like contact-based profilometry and eye inspection frequently fall short in terms of repeatability or resolution. On the other hand, laser information-measurement systems are ideal for aerospace applications because they provide non-contact, high-resolution surface acquisition capabilities.

These technologies produce accurate point-cloud data that depicts the surface geometry of structural members using laser scanning and triangulation techniques. This information makes it possible to quantitatively analyse deviations from nominal design models and rebuild precise surface topography. For additional analysis, parameters including surface waviness, maximum height deviation (R_z), and average roughness (R_a) can be extracted.

Furthermore, automated flaw detection and categorisation are made possible by sophisticated data processing algorithms that compare measured surface profiles with original CAD models. This lowers human mistake in evaluation procedures and greatly increases inspection efficiency. Predictive maintenance techniques are further supported by the capacity to recreate surfaces in three dimensions. Engineers can detect early-stage degradation and plan maintenance prior to critical failure by monitoring changes in surface condition over time.

In terms of precision, speed, and data richness, laser-based measurement techniques offer a very precise and dependable tool for assessing the surface condition of aircraft structural elements.

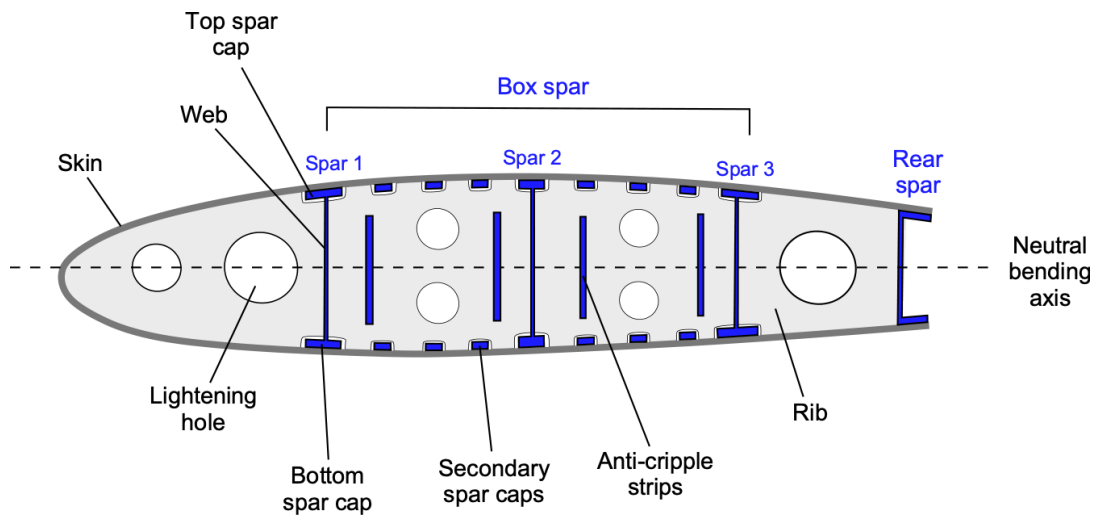


Figure 2. Aerospace Structures – Introduction to Aerospace Flight Vehicles

3. Advantages and Limitations of Laser-Based Inspection Methods

Because laser-based inspection techniques can accurately, quickly, and non-destructively assess surface characteristics, they have grown in significance in the field of aerospace engineering. Nevertheless, these systems have certain drawbacks that need to be taken into account when putting them into practice, despite their many benefits.

The non-contact feature of laser information-measurement devices is one of their key benefits. There is no chance of harming delicate aeroplane parts because there is no physical contact with the inspected surface. For high-precision structural elements, where even small mechanical contact could change surface characteristics, this is especially crucial[10].

High measurement resolution and precision is another important advantage. Micro-scale surface flaws that are frequently hard to find using traditional inspection techniques can be found utilising laser systems. This comprises early-stage corrosion, minor surface roughness changes, and tiny fissures. A more accurate evaluation of structural integrity is ensured by the capacity to record precise geometric information.

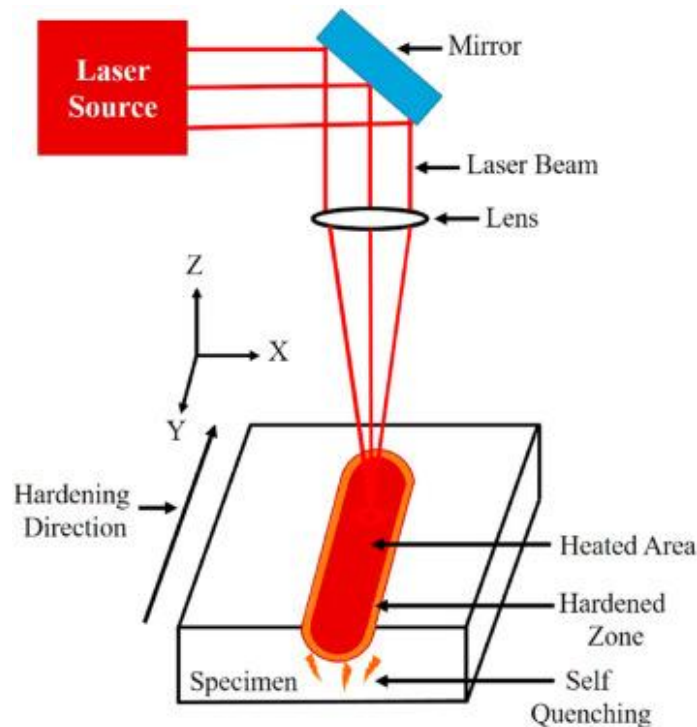


Figure 3. Laser Technique – an overview

These systems also provide quick data processing and gathering. They are appropriate for industrial-scale inspection activities since they can scan large surface areas in a comparatively short amount of time. Laser systems may also produce real-time three-dimensional models when combined with contemporary software, which greatly enhances maintenance and quality control decision-making

processes. Despite these benefits, there are a few drawbacks. Sensitivity to environmental conditions is one of the main obstacles. Measurement accuracy and signal quality can be impacted by variables like vibration, dust, humidity, and changes in lighting. For best results, regulated inspection conditions are frequently necessary.

The expensive and complicated equipment is another drawback. Laser measurement systems can raise original and ongoing expenses because they require sophisticated optical components, exact calibration techniques, and specialised software. To properly operate and understand the collected data, qualified staff are also needed.

Lastly, there may be substantial data processing requirements. Large amounts of data are produced by high-resolution scanning, necessitating strong processing power and effective algorithms for storage and interpretation.

In conclusion, even if laser-based inspection techniques have several benefits in terms of precision, speed, and non-destructive assessment, their practical implementation must take cost, data processing difficulties, and environmental sensitivity into consideration. Nevertheless, because they perform better than conventional methods, their place in contemporary aerospace inspection systems is expanding.

5. Problems and Solutions

The practical application of laser information-measurement systems in aerospace engineering is linked to a number of operational and technological difficulties, despite the fact that these systems offer excellent precision and efficiency in the assessment of aircraft surface conditions. In order to guarantee dependable and stable performance in real-world circumstances, these problems must be resolved.[12].

Measurement instability brought on by environmental disruptions is one of the primary issues. The quality of laser signals and measurement precision can be adversely affected by external factors such vibration, airflow turbulence, temperature variations, dust, and different illumination conditions. In industrial or field settings, where absolute isolation is not always achievable, this problem is especially crucial.

Vibration isolation technologies and controlled inspection environments are potential solutions to this issue. Adaptive filtering algorithms and real-time signal correction methods can also be used to enhance measurement stability and account for ambient noise.

The tremendous processing load that comes with big data volumes is another major obstacle. Dense point-cloud data produced by laser scanning devices needs a lot of computing power to store, filter, and analyse. Evaluation delays and decreased operational efficiency may result from ineffective processing techniques.

Advanced data compression methods and optimised algorithms can be used to get around this restriction. Processing speed and efficiency can be greatly increased by utilising cloud-based processing systems, parallel computing, and machine learning-based data interpretation techniques.

The need for exact calibration and system alignment is another problem. Cumulative inaccuracies in surface reconstruction and measurement results can emerge from even minor calibration discrepancies. Because of this, maintaining and configuring the system is essential to guaranteeing accuracy.

Self-checking systems and automated calibration processes can be used to solve this issue. Human error can be decreased and system accuracy can be maintained over time with the use of built-in diagnostic features and routine calibration procedures.

Conclusion

The use of laser information-measurement devices to assess surface states in aeroplane structural elements has been investigated in this work. The investigation shows that laser-based technologies provide a very precise and effective way to identify and describe surface flaws such corrosion, microcracks, roughness changes, and geometric aberrations.

Laser systems offer non-contact measurement capabilities in contrast to traditional inspection techniques, greatly lowering the possibility of harming delicate aerospace components. Furthermore, accurate three-dimensional reconstruction of structural elements and thorough surface mapping are made possible by their quick data capture and high spatial resolution.

Notwithstanding these benefits, the study also identifies a number of drawbacks, such as the requirement for exact calibration, high processing demands, and vulnerability to environmental disturbances. Adaptive filtering, sophisticated signal processing algorithms, and automated calibration methods are examples of contemporary technologies that can successfully lessen these difficulties.

All things considered, laser information-measurement systems are an effective instrument for aerospace maintenance and inspection procedures. It is anticipated that their further development and

integration with intelligent data analysis techniques will enhance the precision, effectiveness, and dependability of aircraft surface evaluation in upcoming engineering applications.

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THE THEORETICAL AND APPLIED STUDY OF DEFORMATION PROCESSES BASED ON GEODETIC NETWORKS

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Abstract

In this research, the theoretical and applied aspects of deformation processes based on geodetic networks have been comprehensively studied. The main objective of the work is to determine, evaluate, and scientifically interpret deformation changes occurring in engineering structures and natural objects using geodetic methods. Within the framework of the study, the principles of constructing geodetic networks, organization of deformation observations, measurement technologies, and factors affecting their accuracy have been analyzed.

At the same time, methods of mathematical processing, adjustment, and statistical analysis of deformation results have been applied, and the reliability of the obtained results has been assessed. In the practical part, deformation parameters of a real or model object have been determined based on GNSS, leveling, and total station measurements, and their engineering interpretation has been carried out.

The results of the research show that modern geodetic methods ensure accurate and onepamub monitoring of deformation processes. The obtained results are of great importance in increasing engineering safety, timely identification of risks, and optimization of decision-making processes.

Keywords: *geodetic network, deformation, monitoring, GNSS, mathematical processing*

Introduction

In the modern era, ensuring the safety of large engineering structures, industrial facilities, and natural landscapes is one of the important scientific and practical issues. In this regard, timely detection of deformation processes, monitoring of their dynamics, and proper evaluation are of particular importance. Deformations may arise as a result of both natural factors (seismic activity, landslides, etc.) and anthropogenic impacts, significantly affecting the stability and operational safety of objects.

Geodetic networks are one of the most reliable and widely used methods for monitoring deformation processes. Through these networks, high-precision measurements are carried out to determine positional changes of objects, and deformation parameters are calculated by comparing them over time. The application of modern geodetic technologies, including GNSS systems, electronic total stations, and high-precision leveling instruments, has significantly increased the effectiveness of research in this field.

The relevance of the research is related to the importance of more accurate determination of deformation processes based on geodetic networks, analysis of results using mathematical and statistical methods, and their proper engineering interpretation. The aim of the work is to investigate the theoretical foundations of deformation processes, analyze them based on geodetic measurements, and evaluate practical application possibilities.

To achieve this goal, the principles of constructing geodetic networks, organization of deformation observations, measurement and processing methods have been studied, and the obtained results have been evaluated based on comparative and statistical approaches. The research findings are important for ensuring the safe operation of engineering structures and reducing risks.

Research Method

In this study, a comprehensive methodological approach has been applied to investigate deformation processes based on geodetic networks. Both theoretical and empirical methods have been used in conducting the research.

At the initial stage, scientific literature on the topic was analyzed, and existing theoretical approaches related to geodetic network construction, deformation monitoring, and measurement technologies were summarized. Then, geodetic measurement methods – GNSS measurements, leveling, and distance and angle measurements using a total station – were applied to organize deformation observations.

In the processing stage of the collected data, mathematical and statistical methods were used. The adjustment of geodetic networks was carried out based on the least squares method, and deformation

parameters (displacement, velocity, and direction) were calculated. At the same time, variance, standard deviation, and other statistical indicators were calculated to assess the reliability of the results.

Within the research, results of different measurement technologies were compared using the comparative analysis method, and their accuracy and application possibilities were evaluated. In addition, interpretation of the obtained results was carried out based on an engineering approach. The applied methods enabled accurate determination of deformation processes and scientific analysis of the results.

Conclusion

As a result of the conducted research, it has been determined that the study of deformation processes based on geodetic networks has high importance both theoretically and practically. It has been proven that proper construction of geodetic networks and high-precision measurements play a decisive role in the reliable determination of deformation parameters.

The application of modern measurement technologies – GNSS, leveling, and total station methods – has increased the efficiency and accuracy of deformation monitoring. The use of mathematical processing and statistical analysis methods has enabled objective evaluation of the obtained results and minimization of errors.

The research shows that data obtained through geodetic methods allow timely detection of deformation changes in engineering structures and early identification of potential risks. This plays an important role in ensuring the safe operation of objects. As a result, the application of deformation monitoring based on geodetic networks can be considered an effective and reliable approach in engineering geodesy and opens wide prospects for future research.

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