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Sociological Sciences

Research on Service Product Innovation and Membership Marketing of Community Eldercare under the Silver Economy

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Abstract

With the accelerated aging of China's population and the deepening of the national silver economy policy, community eldercare has become the basic carrier of the aged care service system, while the service product innovation and membership marketing capacity of community eldercare institutions have become the core bottlenecks restricting their sustainable operation. Taking the community eldercare sector as the research object, this paper systematically analyzes the current situation, modern challenges and optimization paths of service product innovation and membership marketing of community eldercare under the background of the silver economy, by means of a research route combining literature analysis, policy text analysis and typical case analysis. The research shows that, driven by the national policy environment and the demographic dividend of the aging population, China's community eldercare institutions have made positive progress in service portfolio expansion and customer relationship maintenance, forming preliminary experience in product stratification, membership system design and community-based operation. However, under the combined effect of internal structural constraints such as product homogeneity, shortage of professional talents and weak digital capabilities, and external environmental pressures such as stratified payment capacity, consumer trust deficit and intensified competition from multiple market players, the sector still faces systematic barriers such as unclear value positioning, imperfect membership operation mechanism and incomplete profitability model. On the basis of an in-depth diagnosis, this paper further proposes a phased and hierarchical optimization framework, covering a demand-driven innovation strategy, service product portfolio design and scenario upgrading, as well as membership marketing and organizational guarantee mechanisms, providing operable references for the high-quality development of community eldercare institutions and effectively supplementing the empirical research system of localized service marketing in the silver economy field.

Key words

silver economy; community eldercare; service product innovation; membership marketing; customer retention

Introduction

In recent years, with the deep adjustment of China's population structure and the continuous improvement of the national social security system, the aging of the population has become an important basic national condition affecting economic and social development. According to the data released by the National Bureau of Statistics in January 2025, by the end of 2024, the population aged 60 and above in China had reached 310.31 million, accounting for 22.0 percent of the total population, and the population aged 65 and above had reached 220.23 million,

accounting for 15.6 percent. The accelerating aging process has spawned a huge demand for aged care services, and in January 2024 the General Office of the State Council issued the Opinions on Developing the Silver Economy and Improving the Well-being of the Elderly, which clearly proposed to cultivate the silver economy as a new growth point and to develop diversified aged care services, marking the elevation of the silver economy to the level of national strategy. In the construction of the aged care service system, community eldercare, as the basic link connecting family care and institutional care, has become the main battlefield of the national "9073" aged care pattern (90 percent home-based care, 7 percent community-based care and 3 percent institutional care), and its marketization and commercialization have become the inevitable trend of the industry development.

For community eldercare institutions, the essence of marketization operation lies in two core capabilities: on the one hand, the capacity for service product innovation, that is, the ability to transform the differentiated needs of the elderly into a systematic, scenario-based and sustainable service product system; on the other hand, the capacity for membership marketing, that is, the ability to transform one-time customer acquisition into long-term customer relationship maintenance through membership design, rights and interests operation and loyalty cultivation. However, in the actual operation process, community eldercare institutions generally face a series of prominent problems: the serious homogeneity of service products, the low willingness of the elderly to pay, the high customer churn rate and the difficulty of forming a closed-loop profitability model, which are also the core practical problems encountered in the research of the DBA thesis on the market-oriented operation and marketing model of community eldercare services. At present, the academic circle has carried out relatively sufficient research on the aged care service industry from the perspectives of public policy, social work and public administration, and has formed a relatively complete theoretical system in aspects such as the public service attribute of aged care, the construction of the social care service system and the government purchase of services. However, there is an obvious research gap in the market-oriented empirical research that takes community eldercare institutions as the main body and analyzes their service product innovation and membership marketing from the perspective of service marketing and customer relationship management, especially the research that combines the actual operation of Chinese community eldercare institutions with the silver economy policy context. Most of the existing studies either stay at the macro level of policy design or focus on the welfare attribute of aged care, and lack micro and systematic case research on a single type of community eldercare business.

Therefore, this paper takes the service product innovation and membership marketing of community eldercare under the silver economy as the research object, and through the comprehensive use of literature analysis, policy text analysis and typical case analysis, systematically sorts out the theoretical foundation, current situation and modern challenges, and puts forward scientific and feasible optimization paths. This research not only fills the gap of relevant empirical research on the market-oriented operation of community eldercare in the field of silver economy, but also provides direct and targeted practical guidance for the marketization transformation of community eldercare institutions and the high-quality development of the aged care service industry.

1 THEORETICAL FOUNDATIONS OF SERVICE PRODUCT INNOVATION AND MEMBERSHIP MARKETING OF COMMUNITY ELDERCARE

1.1 Core Concepts Definition and Connotation Analysis

The silver economy refers to the sum of economic activities formed around the material and spiritual needs of the elderly population, covering the entire industrial chain from aged care services, medical care and health management to elderly consumer goods, smart health technology and elderly finance. As an economic concept with clear policy orientation and market connotation, the silver economy emphasizes the shift from a purely welfare-oriented view of aging to an economic view of aging, that is, treating the elderly group not only as the object of social protection but also as an important consumer group and market subject. Under this background, the aged care service industry has changed from a single public service product to a market field with multi-level and diversified demands, which provides the institutional premise and market space for the marketization operation of community eldercare.

Community eldercare refers to the aged care service model that relies on communities and provides home-based, daytime and full-time care services for the elderly living at home, including daily care, meal assistance, cleaning assistance, medical care, rehabilitation care, spiritual comfort and cultural entertainment. As an intermediate model between family care and institutional care, community eldercare has the dual attributes of public welfare and marketization, and its sustainable operation depends on the organic combination of government support, social participation and market operation. In this paper, community eldercare is understood as a marketized service business carried out by enterprises or social organizations as the main body with community service stations, day care centers and other facilities as the carrier, which is the micro basis of the marketization operation of the silver economy.

Service product innovation refers to the process in which service providers continuously develop new service functions, new service combinations, new service scenarios and new service experiences to meet the differentiated needs of consumers. For community eldercare institutions, service product innovation is not limited to the addition of single service items, but more importantly, the systematic design of service product portfolios, the scenario-based integration of service contents and the stratified matching of service levels, so as to transform the generalized care needs of the elderly into specific, purchasable and renewable service products. Membership marketing refers to a marketing model in which enterprises establish long-term, stable and mutually beneficial relationships with target customers through membership system design, rights and interests operation, points incentive and personalized service, so as to improve customer stickiness, repurchase rate and lifetime value. For the aged care service industry with high service continuity and strong relationship dependence, membership marketing is not only a marketing tool, but also a management mechanism that matches the psychological needs of the elderly for stability, trust and belonging, and is the core support for the sustainable operation of community eldercare institutions.

1.2 Core Theoretical Bases for Service Product Innovation and Membership Marketing

The theoretical basis of this paper is constructed on the organic integration of relationship marketing theory, service-dominant logic and customer loyalty theory, forming a multi-dimensional analytical framework for the service product innovation and membership marketing of community eldercare.

First, relationship marketing theory provides the basic analytical framework for the customer relationship dimension of membership marketing. Morgan and Hunt (1994) constructed the commitment-trust theory of relationship marketing and pointed out that relationship commitment and trust are the two core intermediary variables for the success of cooperative relationship marketing, and enterprises should cultivate customer relationship commitment through trust building. Berry (1995) systematically discussed the application of relationship

marketing in the service industry and emphasized that for service enterprises with high customer contact and high relationship dependence, retaining existing customers is often more cost-effective than acquiring new customers. Sheth and Parvatiyar (1995) further extended relationship marketing to the consumer market and pointed out that the antecedents of consumers' participation in relational exchange include the pursuit of simplification, efficiency and risk reduction, and its consequences include enhanced loyalty and reduced churn. These theoretical propositions are highly compatible with the consumption characteristics of the elderly group: the elderly have strong needs for service stability and trust, and are more inclined to maintain long-term relationships with familiar service providers, which provides a solid theoretical basis for the design of community eldercare membership system.

Second, service-dominant logic provides the theoretical support for the service product innovation dimension. Vargo and Lusch (2004) proposed that the core of marketing has shifted from goods-dominant logic to service-dominant logic, that is, the fundamental unit of exchange is service, and value is co-created by enterprises and customers in the process of interaction. Under this logic, the service products of community eldercare institutions are not a one-way delivery of standardized services, but a value co-creation process jointly completed by institutions and the elderly and their families in daily interaction. The application of service-dominant logic to the aged care field means that service product innovation must deeply embed the participation of the elderly, collect demand feedback through membership interaction, and continuously iterate service scenarios and combinations, which provides a theoretical direction for the scenario-based and interactive innovation of community eldercare service products.

Third, customer loyalty theory explains the mechanism of membership marketing and the economic value of customer retention. Oliver (1999) systematically analyzed the formation process of consumer loyalty and pointed out that loyalty is a deep commitment formed through cognitive, affective, conative and behavioral stages, and satisfaction is a necessary but not sufficient condition for loyalty. Reichheld and Sasser (1990) empirically demonstrated that a small reduction in customer defection rate can significantly increase enterprise profits, revealing the economic logic of customer retention. For community eldercare institutions, the service continuity determines that the value of customers accumulates over time, and only through systematic membership management can the elderly's satisfaction be transformed into loyalty and the customer lifetime value be realized. In addition, Yoon et al. (2009) summarized the research on consumer decision making and aging and pointed out that the cognitive processing mode of the elderly is significantly different from that of the young, and their decision-making relies more on emotional cues, prior experience and trust relationships, which provides a consumer behavior basis for the design of community eldercare service products and membership communication strategies adapted to the elderly.

Through the organic integration of the above three theoretical systems, this paper constructs an analytical framework of "relationship marketing (customer relationship foundation)- service-dominant logic (product innovation direction)- customer loyalty theory (value realization mechanism)" for the service product innovation and membership marketing of community eldercare, which provides a solid theoretical basis for the subsequent analysis of the current situation, challenges and optimization paths.

1.3 International and Domestic Experience and Benchmarking of Community Eldercare Service Innovation and Membership Marketing

Internationally, developed countries and regions have accumulated rich experience in the marketization operation of community eldercare. Japan, which entered the aging society earliest, established a community-based integrated care system (Chiiki Hokatsu Kea) with the long-term care insurance system as the core. By dividing service types such as visiting care, day care and short-term stay, and through the operation of community care management, it realized the

stratified matching of service supply and demand, and community eldercare institutions in Japan generally adopt a point and membership-based operation model to improve customer stickiness. The United States has formed a mature community eldercare market, among which the Continuing Care Retirement Community (CCRC) model realizes the full-cycle value chain management of the elderly from independent living to assisted living to nursing care, and uses membership fees and monthly service fees as the core business model, providing a reference for the membership operation of community eldercare in China. European countries, represented by Germany and Sweden, combine social insurance and market services to form a community care model with clear government responsibilities and active social participation, and their experience in service quality standards and customer satisfaction evaluation is also worth learning from. At the domestic level, with the implementation of the national policy on developing the silver economy, community eldercare in first-tier cities such as Beijing, Shanghai and Hangzhou has taken the lead in exploring marketization: Beijing has promoted the combination of community day care centers and medical care, and explored the subscription and membership model of aged care services; Shanghai has built a smart aged care service platform to realize the online and offline integration of community eldercare services, and uses digital membership tools to carry out customer precision operation; Hangzhou has explored the linkage between community canteens, aged care stations and smart home care, and formed an integrated community aged care service scenario. These international and domestic experiences show that the sustainable operation of community eldercare depends on the organic combination of service product systematic innovation and membership-based customer relationship management, which provides a practical benchmark for the analysis of this paper.

2 CURRENT SITUATION OF SERVICE PRODUCT INNOVATION AND MEMBERSHIP MARKETING OF COMMUNITY ELDERCARE IN CHINA

2.1 Policy Environment and Development Context of the Silver Economy

The policy environment is the fundamental driving force for the development of community eldercare in China. Since the 13th Five-Year Plan period, the state has successively issued a series of policy documents to promote the development of the aged care service industry. In January 2024, the General Office of the State Council issued the Opinions on Developing the Silver Economy and Improving the Well-being of the Elderly, which is the first national policy document specifically targeting the silver economy, clearly proposing to develop diversified aged care services, cultivate new business forms of the silver economy such as smart health care, and support the development of community aged care service institutions. Under the guidance of this policy, all localities have introduced supporting measures covering financial subsidies, tax incentives, land supply and talent training, providing a favorable institutional environment for the marketization operation of community eldercare institutions. At the same time, the demographic structure provides the market foundation for the development of the silver economy. According to the data released by the National Bureau of Statistics in January 2025, by the end of 2024, the population aged 60 and above in China accounted for 22.0 percent of the total population, and the population aged 65 and above accounted for 15.6 percent. With the deepening of aging, the demand for aged care services will continue to grow, especially in the community field, where the contradiction between the huge service demand and the insufficient supply of marketization has become increasingly prominent, providing a broad market space for the service product innovation and membership marketing of community eldercare institutions.

2.2 Implementation Status and Effect Analysis Based on Typical Cases

In terms of implementation status, the service product innovation and membership marketing of community eldercare in China are still in the exploratory stage, and the overall level of marketization is not high, but some typical cases have already shown a replicable direction. From the perspective of service product innovation, the service products of community eldercare

institutions have gradually expanded from a single daily care service to a multi-category product system covering day care, meal assistance, cleaning assistance, bathing assistance, medical care, rehabilitation care, spiritual comfort and cultural entertainment. Some leading institutions have begun to explore scenario-based product design, such as combining community canteens with nutrition and health management to launch meal packages for the elderly, combining day care centers with rehabilitation care to develop short-term rehabilitation products, and combining cultural and entertainment services with social interaction needs to organize interest groups and themed activities, forming an initial service product portfolio. From the perspective of membership marketing, some community eldercare institutions have begun to try membership card systems, points systems and subscription models: for example, some institutions issue physical or digital membership cards to lock in the elderly through stored-value cards and monthly subscription packages; some institutions maintain customer relationships through points redemption and birthday care, holiday gifts and other rights and interests operations; some institutions use community group chats and offline activities to build customer communities and enhance customer stickiness. The effect analysis shows that the institutions that carry out service product innovation and membership marketing have a significantly higher repurchase rate and customer retention rate than those that operate with a single service, and the proportion of recurring revenue in their revenue structure has increased, preliminarily verifying the positive role of service product innovation and membership marketing in improving the operational efficiency of community eldercare institutions.

2.3 Existing Development Characteristics and Evolution Trends

At present, the development of service product innovation and membership marketing of community eldercare in China shows the following characteristics and trends. First, the policy-driven and market-oriented dual-track development is accelerating. Under the guidance of the silver economy policy, capital and social forces are accelerating their entry into the community eldercare field, and the marketization operation is changing from government-led to government-guided and market-led. Second, the demand stratification promotes the product stratification. With the diversification of the elderly groups' income level, health status and lifestyle, the demand for community eldercare services is increasingly differentiated, which promotes institutions to design hierarchical service product portfolios from basic care to value-added services and high-end health management, forming a multi-level service supply system. Third, digitalization is reshaping the service and marketing model. With the popularization of smart terminals and the construction of smart aged care platforms, community eldercare institutions are accelerating the use of digital tools to carry out online appointment, health data management and precision marketing, and the online and offline integrated service model is becoming the mainstream trend. Fourth, chain operation and brand operation are becoming the direction of industry evolution. Individual community eldercare institutions are gradually transforming into chain brands through standardized management, unified service standards and brand output, which provides a scale foundation for membership marketing across sites and improves the overall service quality and customer trust. These characteristics and trends show that the marketization operation of community eldercare is in the transition period from the initial exploration stage to the standardized development stage, and the market space and competitive intensity are increasing at the same time.

3 MODERN CHALLENGES IN SERVICE PRODUCT INNOVATION AND MEMBERSHIP MARKETING OF COMMUNITY ELDERCARE IN CHINA

3.1 Internal Structural Challenges of Community Eldercare Service Providers

At the internal level, community eldercare institutions face four prominent structural challenges. First, the service products are seriously homogeneous. At present, most community eldercare institutions provide similar basic services such as day care and meal assistance, lacking

differentiated service products designed according to the health status, economic capacity and interest preferences of different elderly groups, which makes it difficult to form a core competitive advantage and the price competition becomes the main competitive means, seriously compressing the profit space. Second, the professional talent is insufficient. The community eldercare service industry has the characteristics of high labor intensity, low salary level and low social recognition, which leads to the shortage and high turnover of professional service personnel, especially the lack of compound talents with professional nursing knowledge, service design ability and marketing skills, restricting the service quality improvement and product innovation. Third, the digital operation capability is weak. Many community eldercare institutions, especially small and medium-sized ones, lack the construction of information systems and the application of digital tools, and the customer data, service records and health data are scattered in paper documents or isolated systems, making it difficult to carry out precision marketing and refined customer relationship management. Fourth, the fund is constrained and the profitability model is not yet mature. Due to the low willingness and ability of the elderly to pay, the high operating cost and the long investment recovery period, the sustainable operation of community eldercare institutions faces great financial pressure, and the effective connection between service products and profit models has not yet been established.

3.2 External Environmental Challenges in the Silver Economy Era

At the external level, the development of community eldercare institutions faces multiple environmental challenges in the era of the silver economy. First, the payment capacity of the elderly is stratified and the market demand is insufficiently activated. The income sources and consumption concepts of the elderly groups are highly heterogeneous: the urban elderly with pensions and the elderly in rural areas, the young elderly and the old elderly, the healthy elderly and the disabled elderly have significant differences in willingness and ability to pay for services, and the effective market demand for community eldercare services is still insufficiently activated, which makes the marketization operation face the difficulty of demand cultivation. Second, the consumer trust mechanism is imperfect. As the aged care service has the characteristics of credence goods, the elderly and their families have high uncertainty about service quality and are sensitive to safety risks, and the industry trust deficit caused by negative events such as a few aged care institutions' illegal fund-raising and poor service quality directly inhibits the consumption willingness of the elderly. Third, the competitive pattern is becoming more complex. In addition to the competition among traditional aged care institutions, real estate enterprises, insurance companies and Internet platforms are accelerating their entry into the community eldercare market, and they occupy the high-end customer groups and online customer traffic with capital advantages, channel advantages and data advantages, forming a strong competitive pressure on the survival of small and medium-sized community eldercare institutions. Fourth, the policy implementation and regulatory environment need to be improved. Although the state has issued a series of support policies, there are still problems in the implementation process such as the difficult landing of subsidies, the inconsistent implementation standards in various localities and the unclear regulatory rules, and the boundary between the public welfare attribute and the marketization operation of community eldercare is still unclear, which brings institutional uncertainty to the marketization operation of institutions.

3.3 Systematic Barriers to Implementation

At the systematic level, the service product innovation and membership marketing of community eldercare face three deeper implementation barriers. First, the value positioning is unclear and the boundary between public welfare and marketization is blurred. Community eldercare has both public service attributes and market operation attributes, and many institutions do not clearly define their own value positioning in the process of marketization transformation, either overemphasizing public welfare and falling into operational difficulties, or

simply pursuing profits and deviating from the social function of community eldercare, resulting in the failure to form a clear brand image and customer cognition. Second, the service standard system and quality evaluation mechanism are not perfect. The community eldercare service industry lacks a unified and refined service standard system and a scientific quality evaluation mechanism, which makes it difficult for service product innovation to be quantified and replicated, and also makes it difficult for customers to judge service quality before purchase, further strengthening the trust deficit. Third, the industry data sharing and interoperability mechanism is absent. The health data, service data and consumption data of the elderly are scattered in medical institutions, community service stations, aged care institutions and social security systems, and the lack of a unified data standard and sharing mechanism makes it impossible to form a complete customer portrait, which restricts the precision of service product design and membership marketing. These systematic barriers are rooted in the early stage of the marketization of the aged care service industry, and their solution requires the joint efforts of the government, industry associations, market entities and consumers.

4 PERSPECTIVES AND PRACTICAL SOLUTIONS FOR SERVICE PRODUCT INNOVATION AND MEMBERSHIP MARKETING OF COMMUNITY ELDERCARE IN CHINA

4.1 Strategic Guidance: Establishment of a "Demand-Driven Innovation" Development Strategy

To overcome the above challenges, community eldercare institutions should first establish a demand-driven innovation development strategy at the strategic level. The core of this strategy is to shift from the supply-oriented thinking of "what services the institution can provide" to the demand-oriented thinking of "what needs the elderly and their families really have", and to realize the precise matching of service supply and demand through customer stratification, demand research and scenario mining. Specifically, institutions should, on the basis of a comprehensive customer survey and data analysis, divide the community elderly into basic care type, health management type, spiritual and cultural type and emergency assistance type according to the health status, economic capacity and lifestyle of the elderly, and design differentiated service product portfolios and membership levels for different customer segments. At the same time, institutions should embed the demand-driven innovation strategy into the whole process of organizational management, establishing a customer feedback closed-loop mechanism, regularly collecting and analyzing the service experience and demand changes of the elderly and their families, and taking the customer demand as the source of service product iteration and the basis of membership marketing, so as to ensure that service product innovation and membership marketing always point to the real needs of the market. In addition, institutions should actively align with the national silver economy policy orientation, make good use of government subsidies, tax incentives and industry standards to transform policy dividends into operational advantages, and at the same time strengthen cooperation with medical institutions, rehabilitation institutions and smart technology enterprises to build an open ecosystem of community aged care services.

4.2 Service Product Innovation: Portfolio Design and Scenario Upgrading

At the product level, community eldercare institutions should carry out systematic service product innovation around portfolio design and scenario upgrading. In terms of portfolio design, institutions should construct a three-tier service product system: the first tier is the basic guarantee services, including daily care, meal assistance, cleaning assistance and other just-needed services, which mainly solve the basic living needs of the elderly and serve as the traffic entrance to acquire customers; the second tier is the value-added services, including rehabilitation care, health management, psychological counseling and other services, which mainly meet the health and wellness needs of the elderly and serve as the profit growth point; the third tier is the experience-based services, including cultural entertainment, social interaction, tourism and leisure and other services, which mainly meet the spiritual and cultural needs of the elderly and serve as the differentiation advantage. The three tiers of service products should be designed in a

coupled manner, forming a product matrix from traffic entrance to profit pole to differentiation. In terms of scenario upgrading, institutions should shift from a single service item to scenario-based service design, such as constructing an integrated service scenario of "community canteen + nutrition and health management", an integrated scenario of "day care + rehabilitation care + family respite", and an integrated scenario of "smart home care + emergency assistance + health monitoring", so that the elderly can obtain a one-stop service experience in a complete service scenario. At the same time, institutions should make full use of digital technology to carry out intelligent upgrading of service products, such as developing smart wearable devices, health management apps and online consultation platforms, realizing the online and offline integration of service products, and providing data support for the precision of service products through the collection and analysis of service data.

4.3 Membership Marketing and Organizational Guarantee: Customer Operation and Mechanism Innovation

At the marketing and management level, community eldercare institutions should build a systematic membership marketing system and organizational guarantee mechanism. In terms of membership marketing, institutions should, on the basis of customer stratification, design a membership hierarchy system with clear rights and interests differences, such as setting basic members, premium members and exclusive members, and providing differentiated rights and interests such as priority appointment, exclusive pricing, health assessment and family care for members at different levels, so as to realize the precision matching of customer value and service supply. Institutions should make full use of membership tools to carry out points incentive, coupon redemption, birthday care, holiday gifts and other rights and interests operations, and transform the one-time service transaction into a long-term customer relationship through continuous rights and interests feedback. Drawing on the theoretical insights of relationship marketing, institutions should take trust cultivation and relationship commitment as the core of membership marketing, improve the trust of the elderly and their families in the institution through transparent service pricing, standardized service quality and timely feedback handling, and promote the transformation of customer satisfaction into customer loyalty. In terms of organizational guarantee, institutions should establish a dedicated customer relationship management function, equip professional membership operation personnel, and build a customer database covering basic information, health status, service records and consumption behavior of the elderly; formulate a unified service standard manual and staff training system to improve the service quality and marketing skills of front-line personnel; and establish a customer churn warning mechanism to timely identify and recover at-risk customers. In addition, institutions should actively explore the linkage between membership marketing and service product innovation, for example, through the collection and analysis of membership data to guide service product iteration, through the design of exclusive membership service products to enhance the value of membership, and through the construction of customer communities to achieve the co-creation of service products and the dissemination of word of mouth, so as to form a closed loop of "membership marketing- customer data- product innovation- loyalty enhancement".

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

Returning to the central question of this paper, the research demonstrates that under the background of the silver economy, the sustainable operation of community eldercare depends on the organic coupling of service product innovation and membership marketing, and this coupling must be supported by a demand-driven development strategy, a systematic service product portfolio and a membership marketing mechanism with trust as the core. Based on the comprehensive analysis of the theoretical foundation, current situation and modern challenges, this paper draws the following core conclusions. First, at the theoretical level, the integration of relationship marketing theory, service-dominant logic and customer loyalty theory provides a

complete analytical framework for the service product innovation and membership marketing of community eldercare, in which the customer relationship foundation, the product innovation direction and the value realization mechanism jointly constitute the three pillars of the marketization operation of community eldercare. Second, at the practical level, the service product innovation and membership marketing of community eldercare in China are still in the exploratory stage, facing the internal structural challenges of product homogeneity, talent shortage, weak digital capability and financial constraints, the external environmental challenges of stratified payment capacity, trust deficit and intensified competition, and the systematic barriers of unclear value positioning, imperfect service standards and absent data sharing mechanism. Third, at the path level, community eldercare institutions should establish a demand-driven innovation strategy, build a three-tier service product system of basic guarantee, value-added and experience-based services, realize the scenario-based upgrading of service products, and construct a membership marketing system with trust cultivation as the core and customer relationship management as the support, so as to realize the transformation from one-time customer acquisition to long-term customer value. These conclusions directly respond to the core practical problems encountered in the research of the DBA thesis on the market-oriented operation and marketing model of community eldercare services, and provide clear problem orientation and operable solutions for the marketization transformation of community eldercare institutions.

The contribution of this paper is mainly reflected in three aspects: theoretically, it extends the application of service marketing and customer relationship management theories to the silver economy field, and constructs a localized analytical framework for the marketization operation of community eldercare; practically, it provides phased and operable optimization paths for community eldercare institutions, which can be directly used to guide the service product innovation and membership marketing practice of institutions; methodologically, it provides an empirical research supplement for the market-oriented operation of aged care services through the combination of literature analysis, policy text analysis and typical case analysis. However, this paper also has certain research limitations: the research mainly relies on literature analysis, policy text analysis and typical case analysis, and lacks the support of large-sample questionnaire survey and field research data; the research focuses on the service product and membership marketing links of community eldercare, and does not involve the overall marketization operation strategy and other business links of the institutions; the research is mainly conducted from the macro and meso levels of the industry, and has not yet conducted a systematic comparative analysis of specific institution types in different regions. For future research, the expansion can be carried out from the following directions: first, on the basis of this paper, carry out empirical research combining questionnaire survey and field research on specific community eldercare institutions, and use quantitative methods to verify the mechanism of the influence of service product innovation and membership marketing on customer satisfaction and loyalty; second, expand the research scope to the entire marketization operation system of community eldercare, and carry out in-depth analysis of the integration of pricing mechanism, channel construction and brand operation; third, carry out comparative research on community eldercare institutions in different regions and different types, and explore the applicability boundary and regional adaptation path of the optimization framework proposed in this paper; fourth, combine the development trend of smart health care and digital transformation, and carry out in-depth research on the digital membership operation and precision marketing of community eldercare, so as to provide more in-depth theoretical and practical support for the high-quality development of the silver economy.

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КӨШБАСШЫ ӘЙЕЛДЕР БЕЛСЕНДІЛІГІНІҢ ОТБАСЫН САҚТАУ, БАЛА ТӘРБИЕСІ ЖӘНЕ ҚОҒАМДАҒЫ ОРНЫ: КОНСТИТУЦИЯЛЫҚ- ҚҰҚЫҚТЫҚ АСПЕКТ

Назым Алиева

аль Фараби атындағы ҚазҰУ докторанты, заң ғылымдарының магистрі

Аңдатпа. Мақалада қазіргі Қазақстан қоғамындағы әйел көшбасшылығының отбасы тұрақтылығын қамтамасыз етудегі, бала тәрбиесіндегі және қоғамдық даму үдерістеріндегі рөлі қарастырылады. Әйелдердің білім, ғылым, еңбек, мемлекеттік басқару, қоғамдық ұйымдар мен кәсіподақтар қызметіне белсенді араласуы олардың қоғамдағы әлеуметтік мәртебесін арттырумен қатар, отбасы мен кәсіби қызметті үйлестіру мәселесін де өзекті етіп отыр. Зерттеудің өзектілігі Қазақстан Республикасының жаңа Конституциясында отбасы институтына берілген конституциялық мәртебемен айқындалады. Конституцияның 27-бабында «Неке мен отбасы, ана мен әке және бала мемлекеттің қорғауында болады» деп бекітілуі отбасы құндылықтарының мемлекеттік деңгейде қорғалатынын көрсетеді. Сонымен бірге Конституцияда балаларына қамқорлық жасау мен оларды тәрбиелеу ата-ананың етене құқығы әрі міндеті ретінде белгіленген. Мақалада осы конституциялық қағидалардың әйел көшбасшылығы феноменімен өзара байланысы талданады. Көшбасшы әйелдің отбасыдағы рөлі оның кәсіби жетістігімен ғана емес, балаға үлгі болуымен, отбасындағы жауапкершілік мәдениетін қалыптастыруымен және қоғамдық құндылықтарды кейінгі ұрпаққа жеткізуімен сипатталатыны негізделеді. Зерттеу нәтижесінде әйел көшбасшылығын отбасы құндылықтарына қарама-қарсы қоюға болмайтыны, керісінше, отбасы мен қоғамдық белсенділіктің үйлесімділігі әйелдің әлеуметтік әлеуетін толық жүзеге асыруға мүмкіндік беретіні тұжырымдалады.

Түйін сөздер: әйел көшбасшылығы, отбасы, бала тәрбиесі, әйел құқықтары, Конституция, гендерлік теңдік, азаматтық қоғам, әлеуметтік жауапкершілік, кәсіподақ, отбасы құндылықтары, әлеуметтік тұрақтылық.

Кіріспе. Қазіргі қоғамдағы әлеуметтік өзгерістер әйелдердің қоғамдық және кәсіби өмірдегі белсенділігінің артуымен сипатталады. Бүгінде әйелдер тек отбасы мен бала тәрбиесіне жауап беретін әлеуметтік топ ретінде емес, ғылымда, білім беруде, мемлекеттік басқаруда, экономикада, мәдениетте, қоғамдық ұйымдар мен еңбек қатынастары саласында маңызды шешімдер қабылдайтын көшбасшылар ретінде көрініп отыр. Бұл құбылыс әйелдің қоғамдағы рөлін жаңа тұрғыдан зерделеуді талап етеді. Әйел көшбасшылығы мәселесі көбінесе кәсіби жетістік, мансаптық өсу немесе басқару қабілеті тұрғысынан қарастырылады. Алайда әйелдің әлеуметтік рөлін тек осы өлшемдермен шектеу жеткіліксіз. Өйткені әйел көшбасшылығы отбасы институтымен, бала тәрбиесімен, ұрпақ сабақтастығымен және қоғамның моральдық-адамгершілік құндылықтарымен тығыз байланысты. Отбасы – қоғамның бастапқы әлеуметтік институты. Баланың дүниеге келуі, оның тәрбиесі, тұлға ретінде қалыптасуы, еңбекке, білімге, қоғамға және адамдар арасындағы қарым-қатынасқа көзқарасының қалыптасуы ең алдымен отбасында жүзеге асады. Осы тұрғыдан алғанда, отбасы институтын нығайту – мемлекеттің ғана емес, қоғамның әрбір мүшесінің ортақ міндеті. Қазақстан Республикасының жаңа

Конституциясында отбасының әлеуметтік маңызы арнайы конституциялық норма арқылы бекітілген. Конституцияның 27-бабының 1-тармағында:

«Неке мен отбасы, ана мен әке және бала мемлекеттің қорғауында болады» – деп көрсетілген. Бұл ереже отбасының жеке адамдардың жеке мәселесі ғана емес, мемлекеттік қорғауға алынатын қоғамдық құндылық екенін білдіреді. Сонымен бірге Конституцияның осы бабы ата-аналардың бала тәрбиесіне қатысты жауапкершілігін де айқындайды: «Балаларына қамқорлық жасау және оларды тәрбиелеу – ата-ананың етене құқығы әрі міндеті». Осы конституциялық норма әйел көшбасшылығы мәселесін зерттеу үшін ерекше маңызды. Себебі әйелдің қоғамдағы белсенділігі оның ана ретіндегі міндетін жоққа шығармайды. Керісінше, заманауи қоғамда отбасы мен кәсіби қызметті үйлестіру әйелдің әлеуметтік әлеуетін толық жүзеге асырудың маңызды шартына айналып отыр.

1. Әйел көшбасшылығының әлеуметтік табиғаты. Көшбасшылық – белгілі бір әлеуметтік топты ортақ мақсатқа жұмылдыра білу, жауапты шешім қабылдау, адамдарға ықпал ету және әлеуметтік өзгерістерге бастамашылық жасау қабілеті. Әйел көшбасшылығы осы жалпы сипаттармен қатар, әлеуметтік жауапкершілік, коммуникациялық қабілет, эмоционалдық интеллект, ынтымақтастық орнату және түрлі әлеуметтік рөлдерді үйлестіру қабілеттерімен ерекшеленеді. Қазіргі кезде әйелдердің көшбасшылық әлеуетін тек экономикалық немесе басқарушылық ресурс ретінде емес, әлеуметтік капитал ретінде қарастырудың маңызы артып келеді.

Көшбасшы әйелдің қызметі үш негізгі кеңістікте көрінеді:

1. отбасылық кеңістік – ана, жар, тәрбиеші ретінде;
2. кәсіби кеңістік – маман, басшы, ғалым, қызметкер ретінде;
3. қоғамдық кеңістік – азамат, қоғамдық белсенді, ұйым немесе қауымдастық көшбасшысы ретінде.

Бұл үш бағыт бір-біріне қайшы болмауы тиіс.

Керісінше, олардың үйлесімділігі әйелдің тұлғалық және әлеуметтік әлеуетін күшейтеді.

2. Конституциядағы отбасы институтының қорғалуы және әйел көшбасшылығы.

Қазақстан Республикасының жаңа Конституциясында адам құқықтары мен отбасы құндылықтарының арақатынасы маңызды орын алады.

Конституцияның 1-бабында Қазақстан Республикасы өзін демократиялық, зайырлы, құқықтық және әлеуметтік мемлекет ретінде орнықтыратыны және оның ең қымбат қазынасы адам, адамның өмірі, құқықтары мен бостандықтары екені бекітілген.

Бұл конституциялық қағида отбасы мәселесін де адам құқықтары тұрғысынан қарастыру қажеттігін көрсетеді.

Отбасы – адамның жеке өмірінің маңызды бөлігі. Конституцияның 18-бабында әркімнің жеке өміріне қол сұғылмауына, өзінің және отбасының құпиясы болуына құқығы белгіленген.

Демек, отбасы адамның жеке өмірінің ғана емес, оның құқықтық мәртебесінің де маңызды құрамдас бөлігі болып табылады.

Ал 27-бапта отбасының, ана мен әкенің және баланың мемлекеттік қорғауда болуы тікелей көрсетілген.

Осы үш конституциялық қағиданы өзара байланыстыра отырып қарасақ, Қазақстандағы отбасы саясатының негізінде үш маңызды құндылық жатқанын көруге болады:

біріншісі – отбасының тұтастығы;

екіншісі – ата-ананың жауапкершілігі;

үшіншісі – баланың мүддесін қорғау.

Бұл қағидалар әйел көшбасшылығы мәселесімен тікелей байланысты.

3. Көшбасшы әйел және отбасы тұрақтылығы

Әйелдің кәсіби немесе қоғамдық белсенділігі отбасының әлсіреуінің себебі ретінде қарастырылмауы тиіс.

Отбасының тұрақтылығы әйелдің ғана отбасылық міндеттерді орындауына тәуелді емес. Ол ерлі-зайыптылардың өзара сыйластығы, жауапкершілікті бөлісуі, материалдық және моральдық қолдауы, бала тәрбиесіне бірлесіп қатысуы арқылы қалыптасады.

Сондықтан қазіргі отбасы моделінде әйел мен ер адамның әлеуметтік рөлдерін өзара толықтыратын серіктестік қағидатын дамыту маңызды.

Конституцияның 27-бабында балаға қамқорлық жасау мен оны тәрбиелеу ата-ананың «етене құқығы әрі міндеті» ретінде белгіленуі осы жауапкершіліктің тек анаға емес, ата-анаға ортақ екенін көрсетеді.

Бұл жерде ерекше назар аударатын мәселе – әйелдің қоғамдық белсенділігі мен ана ретіндегі жауапкершілігін қарама-қарсы қоюдан бас тарту.

Көшбасшы әйел өз баласына:

- еңбек ету;
- білім алу;
- мақсат қою;
- жауапкершілік алу;
- адамдарды құрметтеу;
- өз құқығын білу;
- қоғамға пайдалы болу

сияқты құндылықтарды өзінің күнделікті өмірімен көрсете алады.

Осы тұрғыдан алғанда, әйел көшбасшылығы бала тәрбиесінің әлеуметтік ресурстарының бірі ретінде қарастырылуы мүмкін.

4. Көшбасшы әйелдің бала тәрбиесіндегі рөлі

Баланың тұлғалық қалыптасуы ең алдымен отбасындағы әлеуметтік ортаға байланысты.

Ата-ананың өмір салты, мінез-құлқы, кәсіби қызметі және қоғамдық ұстанымы бала үшін әлеуметтік модель болып табылады.

Көшбасшы әйелдің бала тәрбиесіндегі маңызды ерекшелігі – оның баласына сөзбен ғана емес, өзінің өмірлік тәжірибесі арқылы үлгі көрсетуінде.

Мысалы, ғылыми қызметпен айналысатын ана балаға білімнің маңызын көрсетеді; қоғамдық жұмыста жүрген ана азаматтық жауапкершіліктің мәнін түсіндіреді; еңбек ұжымын басқаратын әйел баласына жауапкершілік пен ұйымдастырушылықтың үлгісін көрсетеді.

Бұл әсіресе қыз балалардың болашақ өмірлік стратегиясын қалыптастыруда маңызды.

Қыз бала анасының қоғамдық және кәсіби белсенділігін көре отырып, әйел адамның қоғамда маңызды рөл атқара алатынын түсінеді.

Сондықтан әйел көшбасшылығының тәрбиелік әсерін жеке отбасы шеңберімен ғана шектеуге болмайды. Ол келесі ұрпақтың әлеуметтік санасына ықпал ететін фактор болып табылады.

5. Отбасы құндылығы және әйелдің қоғамдық белсенділігі

Қазіргі қоғамда отбасы құндылықтарын сақтау мен әйелдердің қоғамдық белсенділігін арттыру бір-біріне қарама-қайшы бағыттар ретінде қабылданбауы керек.

Керісінше, отбасы тұрақты болған сайын әйелдің қоғамдық әлеуетін іске асыру мүмкіндігі де артады.

Әйелдің қоғамдық белсенділігі оның отбасынан бас тартуын білдірмейді. Ол азаматтық жауапкершіліктің кеңеюін білдіреді.

Бұл тұрғыда Конституцияның 23-бабында Қазақстан Республикасы азаматтарының бірлесу бостандығына құқығы бекітілген және қоғамдық бірлестіктердің қызметі заңмен реттелетіні көрсетілген.

Осы конституциялық мүмкіндік әйелдердің қоғамдық ұйымдарға, кәсіби бірлестіктерге және кәсіподақтарға қатысуына құқықтық негіз қалыптастырады.

Әйелдердің қоғамдық ұйымдардағы белсенділігі олардың әлеуметтік мәселелерді көтеруіне, азаматтардың құқықтарын қорғауына және әлеуметтік саясаттың жетілдірілуіне үлес қосуына мүмкіндік береді.

6. Әйел көшбасшылығы және кәсіподақ қозғалысы

Әйелдердің көшбасшылық әлеуетін жүзеге асыратын маңызды институттардың бірі – кәсіподақтар.

Кәсіподақтар еңбек адамының құқықтары мен әлеуметтік-экономикалық мүдделерін қорғауға бағытталған қоғамдық институт ретінде әйелдердің еңбек саласындағы мәселелерін көтеруге мүмкіндік береді.

Әсіресе жұмыс істейтін әйелдердің:

- еңбек құқықтарын сақтау;
- еңбек жағдайларын жақсарту;
- бала тәрбиесі мен еңбек қызметін үйлестіру;
- әлеуметтік кепілдіктер;
- кәсіби даму;
- мансаптық өсу;
- еңбек саласындағы кемсітушіліктің алдын алу

сияқты мәселелері кәсіподақ қызметінің маңызды бағыттарына айналуы мүмкін.

Әйел кәсіподақ көшбасшылары өз тәжірибесі арқылы еңбек ұжымдарында әлеуметтік әділеттілік, өзара қолдау және әлеуметтік әріптестік мәдениетін қалыптастырады.

Бұл өз кезегінде отбасыға да оң әсер етеді. Өйткені қызметкердің еңбек құқықтары мен әлеуметтік кепілдіктерінің қорғалуы оның отбасының экономикалық және әлеуметтік тұрақтылығын қамтамасыз ететін факторлардың бірі болып табылады.

7. Конституциялық құндылықтар және отбасының болашағы

Жаңа Конституциядағы отбасыға қатысты нормалардың ғылыми және әлеуметтік маңызы өте жоғары.

Конституцияның 27-бабының үш тармағы отбасының негізгі субъектілерін – отбасыны, ананы, әкені және баланы, сондай-ақ олардың өзара құқықтары мен міндеттерін қамтиды.

Бірінші тармақ мемлекетке отбасыны қорғау міндетін жүктейді.

Екінші тармақ ата-ананың бала алдындағы құқықтары мен міндеттерін бекітеді.

Үшінші тармақ ұрпақтар арасындағы жауапкершілікті көрсетеді: кәмелетке толған еңбекке қабілетті балалар еңбекке жарамсыз ата-аналарына қамқорлық жасауға міндетті.

Осылайша Конституция отбасыны бір бағыттағы ғана емес, ұрпақаралық жауапкершілікке негізделген әлеуметтік институт ретінде қарастырады.

Бұл қағиданың әйел көшбасшылығына да қатысы бар.

Өйткені көшбасшы әйел тек өзінің кәсіби жетістігіне ғана емес, өзінің балаларына, ата-анасына, отбасына және қоғамға деген жауапкершілігі арқылы да бағаланады.

8. Әйел көшбасшылығын қолдаудың негізгі бағыттары

Қазақстан қоғамында әйел көшбасшылығын дамыту үшін отбасы мен кәсіби қызметті үйлестіруге мүмкіндік беретін институционалдық жағдайлар қалыптастыру қажет.

Біріншіден, жұмыс берушілер тарапынан отбасыға қолайлы еңбек саясатын дамыту маңызды.

Екіншіден, әйелдердің кәсіби дамуына кедергі келтіретін стереотиптерді азайту қажет.

Үшіншіден, ерлердің бала тәрбиесіне және отбасы міндеттеріне белсенді қатысу мәдениетін қалыптастыру керек.

Төртіншіден, әйелдердің қоғамдық және кәсіподақ көшбасшылығын қолдайтын бағдарламаларды дамыту қажет.

Бесіншіден, жас қыздардың көшбасшылық қабілеттерін білім беру жүйесінде ерте кезеңнен дамыту маңызды.

Алтыншыдан, отбасы құндылықтарын сақтау мен әйелдердің қоғамдық белсенділігін біртұтас әлеуметтік саясаттың екі бағыты ретінде қарастырған жөн.

Қорытынды

Қазіргі Қазақстан қоғамындағы әйел көшбасшылығы – әлеуметтік дамудың маңызды ресурстарының бірі.

Әйелдің кәсіби, ғылыми, басқарушылық және қоғамдық белсенділігі оның отбасыдағы рөліне қайшы келмеуі тиіс. Керісінше, отбасы мүшелерінің өзара қолдауы мен жауапкершілігіне негізделген жағдайда әйелдің қоғамдық белсенділігі отбасының әлеуметтік әлеуетін арттыра алады.

Қазақстан Республикасының жаңа Конституциясы отбасы институтына ерекше құқықтық мәртебе береді. Оның 27-бабында «Неке мен отбасы, ана мен әке және бала мемлекеттің қорғауында болады» деп нақты бекітілуі отбасы құндылығының мемлекеттік деңгейдегі маңызын көрсетеді.

Сонымен қатар ата-ананың бала тәрбиесіне қатысты құқығы мен міндетінің қатар белгіленуі отбасыдағы жауапкершіліктің екіжақты сипатын айқындайды.

Осы конституциялық қағидалар әйел көшбасшылығының табиғатын жаңа қырынан түсінуге мүмкіндік береді. Көшбасшы әйел – тек кәсіби ортадағы басшы емес. Ол – отбасының құндылықтарын сақтаушы, бала тәрбиесіне ықпал етуші, қоғамның әлеуметтік дамуына үлес қосушы және келесі ұрпаққа үлгі көрсетуші тұлға.

Сондықтан әйел көшбасшылығын дамыту саясаты «отбасы немесе мансап» деген таңдау қағидатына емес, «отбасы және кәсіби-қоғамдық даму» қағидатына негізделуі қажет.

Әйелдің қоғамдағы белсенділігі отбасының әлсіреуіне емес, керісінше, отбасы мүшелері арасында өзара түсіністік пен жауапкершілік қалыптасқан жағдайда оның нығаюына ықпал ете алады.

Осыған байланысты Қазақстандағы отбасы саясаты, гендерлік саясат және әйелдердің көшбасшылық әлеуетін дамыту саясаты өзара байланыста жүзеге асырылуы тиіс.

Отбасы – қоғамның негізі болса, әйел – осы негіздің тұрақтылығы мен дамуына елеулі үлес қосатын тұлға. Ал көшбасшы әйелдің қоғамдық белсенділігі – бүгінгі қоғамның ғана емес, келешек ұрпақтың әлеуметтік капиталына салынған инвестиция.

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Historical Sciences

Зеренді ауданының киелі жерлері туралы аңыздардың тәрбиелік мәні

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Ақмола облысы мәдениет басқармасының «Тарихи-мәдени мұраны қорғау және пайдалану орталығы» КММ-нің маманы

Ақмола облысы тарихы мен мәдениеті жағынан бай, киелі орындарға толы аймақ болып саналады. Зеренді ауданы бойынша 12 киелі жер аймақтық маңызы бар киелі жерлер тізіміне енген болатын. Әрбір киелі жердің аңызы бар, бұл жерлерге адамдар зиярат жасап, ниеттеніп келушілер саны артып келеді. Дертіне дауа іздеп, арман, мақсаттарына жету үшін халық наным-сеніммен киелі жерге келеді. Рухы биік халқымыз әрбір киелі жерлерін қасиетті санайды.

Қазақстан — ғасырлар бойы тарихи, мәдени және рухани құндылықтарды сақтап келген ұлттық бейнесі. Біздің еліміздің кең құшағында көптеген киелі жерлер бар. Олар тек тарихымызды ғана емес, сонымен қатар тұлғаларымыздың рухын, мәдениетін, болашағын айқындайтын маңызды объектілер болып табылады. Осы жерлердің әрқайсы өз тарихымен, аңыздарымен және халықтың өміріне енгізген үлесімен ерекшеленеді.

Кілт сөздер: *Киелі жерлер, аңыз, көрікті жерлер, Айдаһар үңгірі, Әулие тас, мазар, кесене.*

Біріншіден- Уәли хан кесенесі, Бөгенбай кесенесі, Қосағалы батыр кесенесі, Балқадишаның жерленген жері, Ақтоқтының жерленген жері, Дүйсен би жерленген жері, Монтай батыр жерленген жері, Асат бидің жерленген жері, Қалақ батыр жерленген жері, Тіржан қажының жерленген жері ел бірлігінің рухын көтерген тұлғалармен тығыз байланысты. Кесенелер мен жерленген жерлер еліміздің тарихындағы маңызды оқиғаларды бейнелейді.

Екіншіден, Зеренді өңіріндегі табиғи көрікті жерлер де киелі болып саналады. Айдаһар үңгірі, Әулие тас сынды табиғатымыздың көркем, әдемі көріністері болып келеді. Бұл жерлерде ата-бабаларымыздың рухы, ұлттық қасиеттері сақталған және өңірдің ұлттық мәдениетінің белгісі.

Уәли хан кесенесі Қазақстан ауылынан оңтүстік-шығысқа қарай 2,3 км жерде, Қарақалпақ төбесінде орналасқан. Бұл құрылыс 2008 жылы Уәли ханның 270 жылдығына орай тұрғызылды. Ғимараттың жалпы ауданы – 1 920 шаршы метрді құрайды. Биіктігі сегіз метр шамасында. Мазар қызыл кірпіштен төрт бұрыштап салынған. Төрт жақ ірге сары кірпіш және жарты ай бейнесіндегі шақпақ таспен өрілген.

Жасынан жоңғарларға қарсы жорықтарға қатысып, Арғын руының жауынгерлерін басқарды, хан Абылайдың тапсырмасымен елшілермен дипломатиялық келіссөздер жүргізді. Уәли хан Жоңғария мен Орталық Азиядағы Абылай ханның жорықтарына қатысқан. 1769 жылы Қытайға қазақ елшілігін басқарып барған. 1781 жылы әкесі Абылай хан қайтыс болғаннан кейін, Абылай ханның еркіне сай, халық жиналысы оның үлкен ұлы Уәлиді Орта жүздің жаңа ханы етіп сайлады.

Бөгенбай би ауылында орналасқан. Кенесарының хандық құрып тұрған кезінде кеңесші, сенімді өкілдерінің бірі болған. Бөгенбай би әрі шешен, соғыс тәсілдерін жеттік меңгерген батыр. Би XIX ғасырда өмір сүрген. Көріпкелдігінің арқасында әулиелер

қатарында болды. Бөгенби би ғасыр өмір сүріп, 105 жасында өмірден өтті. Тапқырлығымен, даналығымен ерекшеленіп, сол себепті халық оны Әз Көмекей Бөгенбай деп атағаны бекер емес. Бөгенбай бидің рухына бағышталып тұрғызылған бұл кесененің орны бөлек. Себебі, бұндай жерлер біздің тарихымыздан сыр шертіп қана қоймай, оқушылардың бойында ұлттық рух пен ұлттық сананы қалыптастыратыны сөзсіз.

Қосағалы батыр кесенесі- Азат тауында орналасқан.

Қосағалы батыр Төлекұлы (1740-1813) - Көкшетау өңірінің тумасы, Орта жүздің ханы Уәлидің заманында өмір сүрген. Қазақтың белгілі күйшісі Дәулеткерей өзінің «Қосағалы» атты күйін арнаса, Ақмола-Көкше аймағында оның атымен аталатын жер, су атаулары да кездеседі. Қосағалы батыр өзінің ата-бабалары сияқты (бойы 2,76) алып денелі батыр болған. Оның жерлеу орны 4 метрді құрайды.

2015 жылы Зеренді ауданының Зеренді ауылының кіреберісінде Балқадишаға арнап ескерткіш тұрғызылды, ал Балқадиша бейіті Зеренді ауданы, Кеңөткел ауылының мұсылмандар зиратында орналасқан.

Күндердің күнінде Ақан сері шілдехана тойының үстінен түседі. Төрде отырған атақты әнші Ақанның маңына ешкім отырмайды. Бұл ел аузында Ақан сері туралы жын-періге үйленген, есінен ауысқан деген алып-қашпа сөздер жүрген кез. Сонда Қадиша қыз «Сері ағамның жанына мен отырайын» деп Ақанның жанына жайғасады. Қадиша қайтуға жинала бастағанда, Ақан сері қолына домбырасын алып, екі ішекті қағып жіберіп әнді орындай бастайды. Осылайша атақты «Балқадиша» әні дүниеге келеді.

Ақтоқтының зираты Зеренді ауданы, Қызылағаш ауылында орналасқан.

Ақан сері (Ақжігіт) – қазақ даласының атақты ақыны, әншісі, композитор. Ақтоқтыдай сұлуды кездестірген ақын оған ғашық болып қалады. Бірақ Ақтоқты ұзатылып қойған, қос ғашық дала заңы бойынша бірге бола алмады.

Ақтоқты есімі ақынның шығармаларынан кең орын алды. «Ақ көйлек», «Алтыбасар», «Ғашық жарға», «Тағрипың», «Ж-ға», «Ақтоқтының ажары», «Ақтоқтының зары» әндері - Ақтоқтыға арналған махаббат толғаулары. Ақтоқтының бейнесі махаббаттың ұлы күшіне арналған ақын өлеңдерінде нақты көрініс тапты.

Ақын тағдыры, оның қайғылы махаббаты әдеби, драмалық және музыкалық образдар жасауға шабыттандырды. Қазақ жазушысы Ғабит Мүсірепов айырылған қос ғашықтың махаббаты, ақынның қайғылы тағдыры жайында «Ақан сері - Ақтоқты» трагедиясын жазса, ал белгілі композитор С. Мұхамеджанов «Ақан сері - Ақтоқты» атты операсын дүниеге әкелді.

Дүйсен би Есенберліұлы - XVII-XVIII ғасырларда өмір сүрген дала заңының білгірі, Ақмола облысы, Зеренді ауданы, Қошқарбай елінің тумасы. Дүйсен би жас кезінде талай жасы үлкен атақты абыз билердің алдынан өтіп, батасын алады. Аңыз бойынша оның қалыптасуына Қазыбек би мен Қанай би үлкен рөл атқарған. Олардан даналық өмір сабақтарын алды.

Туа біткен дипломат әрі шешен Дүйсен би үш жүздің бірлік пен бейбітшілікте өмір сүруін ойлады. Күрделі мәселелерді шешуде әділдікті басшылыққа алған. Жоңғар басқыншыларына табанды қарсылық көрсетіп, өзін мемлекет және саяси қайраткер ретінде таныта білді.

Дүйсен би Абылай хан қоғамындағы дарынды және батыл саясаткер, қиындықтарды оңай шеше алатын, ақыл-кеңес беретін мықты әскери қолбасшы болды. Үкілі Ыбырайдың көптеген әнінде Дүйсен бидің рөлі мен маңызы ерекше айтылады.

Дүйсен би зираты Зеренді ауданы, Айдарлы ауылында орналасқан.

Монтай батыр – жау басқыншыларымен батыл күрескен ержүрек жауынгер. Оның жерленген жері Ақмола облысы, Зеренді ауданына қарасты Молодежное ауылында орналасқан.

Аңыз бойынша жоңғар шапқыншылығы кезінде Монтай өзінің мергендігімен, батырлығымен Отанын қорғап, Абылай ханның адал досы болған.

Монтай батырдың ерлігі жөніндегі дастан ел ішінде көп тараған. Ол жоңғарларға қарсы шайқастарға қатысып, 200 қолды жасақты бастап барған. Батыр Абылай ханмен бірге барлық қиындықтар мен қауіптерді бөлісе отыра, сарбаздардың батырлық рухын көтеріп отырған. Талай шайқастарда Монтай батырдың ерлігіне риза болған Абылай хан оны жоғары бағалаған.

Асат Алпысұлы (1827-1875) – би, дипломат, сәулетші. Ол Қарашілік ауылына жататын, қазіргі Кішітүкті орман шаруашылығы орналасқан жерде дүниеге келіпті.

Асат тумысынан дипломат болған, оның бір ғана сөзімен небір даулы мәселелер оң шешімін тауып отырған. Ел арасындағы дау-шарларды әділ билігімен, парасатты ақылымен, тапқыр, кесімді пайымдауларымен мүлтіксіз тындырып, атағы шыққан.

Халық арасында Асат Алпысұлы айтты деген мақал-мәтелдері мен өнегелік сөздері кең тараған. Жергілікті халық Асат ата жайында көптеген тарихи әңгімені осы күнге дейін сақтаған, оның бір парасы қоныс аударушылар келе бастаған кезбен байланысты. Олардың арасынан болашақ казак станицаларына жер іздеген Омбының генерал-губернаторы келгендегі кездесу туралы айтуға болады. Келіссөздерден соң Асат Алпысұлы ресейлік губернатордың би мен старшындардың халық арасындағы ықпалы жоғарғы ақсүйектермен бірдей екенін мойындауына мәжбүр етеді.

Аймақтың барша жұрты ұлы би жерленген орынға ризашылықпен еске алуға келеді. Зеренді ауданы, Қарашілік елді-мекені маңында «Асат ата бұлағы» ағып жатыр.

Қалақ батыр - XVII ғасырдың басында өз Отанын қорғау жолында жоңғарға қарсы шайқаста өзін көрсеткен ержүрек жауынгер. Ол жоңғарларға қарсы ең алғашқы шайқасқа қатысқан. Жаудың көптігіне қарамастан, Қалақ батырдың ұйымдасқан әрекеті мен әскери стратегиясының арқасында оның әскері жауға қарсы төтеп бере алды. Осы шайқастан кейін Қалақ батырдың есімі күллі қазақ даласына мәшһүр болды. Аңыз бойынша Алатау етегінде жоңғар басқыншыларымен болған сұрапыл шайқаста ерен ерлік, батылдық көрсеткен екен.

Қалақ батырдың туған және өлген жылдары туралы анық мәліметтер жоғалған. Батыр қазіргі Атбасар мен Сандықтау аудандарының арасында Керегетас жерінде Есілдің маңында дүниеге келгені белгілі.

Қалақ батырдың зираты Зеренді ауданы, Күсеп ауылындағы Қалақ тауында, Айғыржал деген жерде орналасқан.

Тіржан қажы Байғожаұлы 1855 жылы Зеренді ауылына жақын жатқан, соңынан Тіржан ауылы атанған Тасбұлақ деген жерде дүниеге келген. Азан шақырып қойған аты – Әміре. Жеті айлық болып туған ол шілдеханаға дейін сол кездің салтымен атасының бас киімінде жетіліп, бесікке артынан жатқызылды. Бала өте әлсіз болып туғандықтан, әжесі мен анасы сұраған жанға «Әйтеуір бір тірі жан ғой, ілігіп кетсе болды» дейді екен. Содан Тіржан аталып кетсе керек.

Жастайынан еті тірі елгезек, өте зерек бала Тіржан ел тірлігіне, үлкендер ісіне ерте араласып, танымал бола бастайды. Ол табандылығымен, еңбекқорлығымен және адамгершілігімен ерекшеленіп, өз айналасына белгілі замандастарын топтастыра алды.

Қонақжайлы әрі жомарт Тіржан орасан дүние мүліктің иесі болып, сол заманның Тынымбек, Шәкей би, Ақан сері, Үкілі Ыбырай, Науан Хазірет, Азнабай, Нығметжан, Тәшен бай сияқты белгілі адамдарымен тығыз араласып, өзінің озық замандастарымен нан-су бөлісіп, оларды барынша қолдап отырған.

Тіржан қажы жерленген жер Зеренді ауданы, Бәйтерек ауылында орналасқан.

«Айдаһар үңгірі» Зеренді ауданы, Үлгілі ауылында орналасқан. Үңгірдің ұзындығы – 270 м., ені – 70 м., биіктігі - 35 метр шамасында. Үңгірдің кіреберісінде қарағай мен қайың өсіп тұр. Сыртынан шағын болып көрінгенімен, оның ішіне айдаһар сыйып кететіндей

соншалық үлкен екендігі байқалады. «Айдаһар үңгірі» деген атау содан пайда болуы мүмкін. Халық сенімінде үңгір «киелі орын» деп саналады.

Бір аңыз бойынша бұл үңгірде емші өмір сүріпті, оның алдына бару қиынға соққанымен, жеткен адам кез келген ауруынан сауығып кететін болған. Халық емшісінің энергиясы осы үңгірде сақталып, ауруына шипа іздеген жандарға жәрдемін береді екен.

Зеренді ауданының тұрғындары мен туристер осындай табиғаты ғажап тамаша жерге рухани күш-қуат алу үшін келеді.

Әулие тас Көктерек ауылынан 10 шақырым жерде, Зеренді ауданы мен Көкшетау қаласына жақын жерде орналасқан. Әулие тас туралы аңыздар көп, соңын ішінде Әулие тас - адам қолымен емес жаратылыстың құдіретімен орын тепкені анық. Бұрындары жаугершілік замандарда батырлар осы тастың іргесіне қонып, Алладан отбасыларына аман-есен оралуды тілеген, кейін Ұлы Отан соғысы жылдарында Көктерек ауылының майданға аттанған азаматтар ең алдымен осы жерден жолға шығады. Ел болып тілектерін тілеп, ақ баталарын беретін орын болған «Әулие тас» – сол зұлматты жылдардан қалған мәңгілік ескерткіш іспеттес киелі орын болған.

Аталмыш аңыздарға сүйене отырып киелі жерлердің тарихы жайында жас ұрпақтың білімдерін толықтыру. Отансүйгіштікке, елін, жерін сүюге тәрбиелеу басты міндет, парыз болып саналады. Киелі жерлерді насихаттау арқылы өскелең ұрпақ үшін отаншылдық рухта тәрбиелеу, болашаққа сеніммен қарап, бойына қазақстандық патриотизм рухын сіңдіруге, халық тарихынан елеулі орын алады. Киелі жерлер — ұлттық мақтанышымыз ретінде мәңгілік құндылықтар. Оларды қорғау, сақтау және насихаттау арқылы біз тек ұлттық тарихымызды емес, руханиятымызды да ұлықтай аламыз. Киелі жерлер біздің кемелді болашағымыздың есте сақталатын, бағаланатын, мақтан тұтатын мұрасы болып қала бермек.

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Pedagogical Sciences

ARTIFICIAL INTELLIGENCE AS A CO-CREATIVE TOOL IN CONTEMPORARY GRAPHIC DESIGN EDUCATION

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Abstract

The rapid development of artificial intelligence is changing the nature of graphic design and the professional competencies required of future designers. Generative AI tools provide new opportunities for visual experimentation, concept development, image generation, and rapid prototyping. At the same time, the increasing use of AI raises an important educational question: how can these technologies support creativity without replacing fundamental design skills and independent thinking? This article examines artificial intelligence as a co-creative tool in contemporary graphic design education. The study is based on the analysis of current educational practices, student perceptions, and different approaches to AI integration. Particular attention is given to the relationship between human creativity and AI-generated content. The findings support a hybrid educational approach in which artificial intelligence complements traditional design methods and professional software. The article argues that future graphic designers need not only technical AI skills but also visual literacy, critical thinking, ethical awareness, and the ability to evaluate and refine AI-generated solutions.

Keywords: artificial intelligence, graphic design, creativity, design education, generative AI, visual communication, higher education.

Introduction

Artificial intelligence is increasingly influencing the creative industries and changing established approaches to graphic design. Generative AI systems allow users to create visual concepts from text prompts, produce multiple variations of an idea, experiment with styles, and significantly accelerate certain stages of the design process.

This development creates new opportunities for higher education. Graphic design students can use AI to explore ideas, compare alternative visual solutions, develop initial concepts, and experiment with composition, color, and style. At the same time, the accessibility of generative technologies raises concerns about excessive automation and the possible weakening of fundamental professional competencies.

The traditional graphic design process requires students to understand visual communication, composition, typography, color theory, audience, context, and conceptual development. These competencies remain essential even when artificial intelligence is introduced into the workflow. AI can generate images rapidly, but it cannot independently determine whether a visual solution appropriately communicates a particular message within a specific social, cultural, or educational context.

Therefore, the relationship between the designer and artificial intelligence should be understood as a form of **co-creation**. In this model, AI contributes computational speed and the

ability to generate numerous visual alternatives, while the human designer contributes intention, context, critical evaluation, aesthetic judgment, and responsibility for the final result.

The purpose of this article is to examine how artificial intelligence can function as a co-creative instrument in graphic design education and to identify the competencies that students need for effective human–AI collaboration.

Transformation of the Creative Design Process

The introduction of generative artificial intelligence changes several stages of the traditional graphic design workflow. Previously, students typically moved from research and sketching to concept development, digital production, revision, and final presentation. AI makes it possible to introduce rapid visual generation into the early stages of this process.

For example, students can formulate a design problem and use generative tools to explore several visual directions before selecting one for further development. This can increase the speed of experimentation and allow students to compare a greater number of alternatives.

However, the educational value does not lie simply in generating more images. The important skill is the ability to understand **why one solution is more appropriate than another**.

The role of the designer consequently shifts from being primarily a producer of visual material toward becoming an active decision-maker, curator, and interpreter. Students must be able to evaluate whether AI-generated content corresponds to the design brief, target audience, visual hierarchy, cultural context, and communication objectives.

This means that prompt writing alone cannot be considered sufficient professional competence. A successful AI-assisted workflow requires several interconnected stages: problem analysis, concept formulation, generation of alternatives, critical evaluation, selection, professional refinement, and final presentation.

Human creativity therefore remains central. Artificial intelligence can contribute to the generation process, but the designer determines the meaning and quality of the final visual communication.

Student Perception of AI in Graphic Design

The research conducted within the study indicates that students already have significant awareness of artificial intelligence technologies, although this awareness varies depending on the type of system. General-purpose AI platforms are more familiar to students than specialized visual generation tools.

The survey also examined students' opinions regarding the possibility of AI replacing professional graphic design software. The findings demonstrate that complete replacement is not the dominant expectation.

Among respondents, **41 stated that AI could partially replace professional software, 22 believed that it could not replace professional software, 16 considered complete replacement possible, and 20 were uncertain**.

These results are important because they indicate that most students do not view artificial intelligence simply as a substitute for Photoshop, Illustrator, CorelDRAW, or other professional applications. Instead, AI is increasingly perceived as an additional instrument within a broader professional workflow.

The research also showed that time saving was the most frequently identified advantage of artificial intelligence. AI allows users to rapidly create alternative concepts and reduce the time required for some repetitive or exploratory activities.

Nevertheless, efficiency should not become the primary educational objective. A faster design process is not necessarily a better design process. In professional education, the quality of decision-making, originality of the concept, understanding of the communication problem, and ability to justify visual choices remain more important than production speed.

Human–AI Collaboration as an Educational Model

A useful approach to integrating artificial intelligence into graphic design education is a hybrid human–AI model. Such a model does not separate traditional design education from new technologies. Instead, it combines them within one structured creative process.

At the first stage, students should independently analyze the design problem. They should identify the target audience, communication objectives, context, and visual requirements.

At the second stage, students develop initial ideas through research, sketching, references, mood boards, and conceptual exploration. AI tools can then be introduced as one of the instruments for generating and testing alternative directions.

The third stage involves critical evaluation. Students compare AI-generated alternatives according to established design principles. They analyze composition, typography, color, hierarchy, originality, relevance, and communication effectiveness.

Finally, selected concepts should be refined through professional design practice. This may involve manual editing and the use of established graphic design applications. The student, rather than the AI system, remains responsible for the final visual outcome.

This approach helps distinguish **AI-assisted design** from simple AI-generated content. In AI-assisted design, technology supports human decision-making. The designer remains the author of the concept, evaluates the generated material, transforms it, and integrates it into an original professional solution.

New Competencies for Future Graphic Designers

The integration of artificial intelligence requires an expansion of traditional graphic design competencies. Students still need strong fundamental skills in composition, typography, color theory, drawing, visual communication, branding, and digital design. However, these competencies should increasingly be complemented by AI literacy.

AI literacy includes understanding what generative systems can and cannot do. Students should know how to formulate effective prompts, generate meaningful variations, evaluate outputs, recognize limitations, and determine when AI is appropriate for a particular design task.

Critical thinking becomes particularly important. Generative AI can produce visually attractive results very quickly, but visual attractiveness does not necessarily mean that the design communicates effectively. Students must therefore learn to distinguish between an impressive generated image and a professionally justified design solution.

Ethical competence is another essential component. Students should understand issues of authorship, originality, transparency, and academic integrity. When AI contributes to a project, its role should be appropriately disclosed.

The educator also acquires a new role. Instead of assessing only the final visual product, teachers increasingly need to evaluate the design process: how the student formulated the problem, why AI was used, how alternatives were evaluated, what changes were made, and how the final design decision was justified.

Implications for Higher Education in Kazakhstan

The integration of artificial intelligence into graphic design education is particularly relevant for Kazakhstan. Current practices indicate that AI use can be fragmented, with students experimenting with new technologies independently rather than within a systematic educational framework.

A transition toward structured integration is therefore necessary. However, this does not require replacing existing graphic design disciplines with AI courses. A more balanced approach is to integrate AI-related assignments and methods into existing professional subjects while simultaneously developing specialized AI literacy.

Traditional design foundations should remain central. Students must first understand the principles of visual communication before they can effectively evaluate AI-generated content.

Universities should also support professional development for instructors. Teachers need practical and methodological knowledge about the use of AI in creative education, including approaches to assessment and academic integrity.

The ultimate goal should be to prepare graduates who are capable of combining technological competence with independent creative thinking. Such designers will not compete with artificial intelligence simply in the speed of image generation. Their professional value will lie in their ability to formulate meaningful problems, understand audiences, develop concepts, evaluate alternatives, and use technology intentionally.

Conclusion

Artificial intelligence is transforming graphic design, but its educational significance should not be reduced to automated image generation. Its greater potential lies in supporting experimentation, accelerating visual exploration, and expanding the range of creative alternatives available to students.

The findings of this study suggest that the most productive relationship between artificial intelligence and graphic design education is based on **human–AI collaboration**. AI should function as a co-creative instrument that supports the designer rather than replaces professional knowledge and creative responsibility.

A hybrid educational model can combine fundamental design skills with contemporary AI technologies. Within this model, students learn to research and define design problems, develop concepts, use AI to explore alternatives, critically evaluate generated content, and refine selected solutions using professional methods.

For higher education, this requires not only access to new technologies but also curriculum development, instructor training, ethical guidelines, and new assessment approaches. AI literacy should develop alongside visual literacy, critical thinking, creativity, and professional responsibility. The future graphic designer should therefore be prepared not merely to generate visual content with artificial intelligence but to **direct, evaluate, transform, and meaningfully integrate AI-generated material into professional design practice**. In this context, human creativity remains the central element of the design process, while artificial intelligence becomes a powerful instrument for expanding its possibilities.

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The Status of Leisure-Time Educators and the Value of School-Age Children's Clubs in the Educational System

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Abstract

This paper analyzes the status of the leisure-time educator and the perceived value of children's school clubs in Slovakia, within the current educational system. The main objective of the study is to present the results of empirical research focused on mapping educators' opinions and attitudes regarding their professional status, professional identity, and the institutional integration of school clubs. The methodological framework is based on a mixed-methods design, with data collected via a questionnaire survey on a sample of 433 pedagogical professionals. The results reveal a persistent discrepancy between the high demands placed on the professional work of educators and their actual institutional or social recognition compared to regular classroom teachers. The analysis identifies key practical barriers as well as the potential of school clubs for the personal development of children. The discussion places these findings within the context of efforts to professionalize out-of-school education and emphasizes the necessity of building an equal partnership between formal education and non-formal education to ensure the holistic development of students.

Keywords: educator status, after-school clubs, out-of-school education, professional identity, pedagogical staff

Introduction

The profession of an after-school educator is an attractive yet demanding one, continuously placing new demands on its practitioners and presenting them with various challenges. Managing these challenges with professional insight requires integrating knowledge from pedagogical and psychological sciences within the context of everyday educational reality. Within the educational system and process, the educator acts as the bearer of both the objectives and the content of out-of-school education. Should the educator resign from this role, they would *de facto* cease to function as an educator (Bendl, 2015). In Slovakia, the concept of an educator as an experiential pedagogue is increasingly acquiring a pejorative connotation. Compared to classroom teachers, educators are undervalued by parents, the broader community, and even the highest state authorities. The duration and quality of their professional preparation are similarly underestimated. While a teacher is automatically considered an educator, an educator in Slovakia does not automatically hold the status of a teacher. The number of hours dedicated to the theory and methodology of out-of-school education during the preparation of future teaching professionals is insufficient. These classes are typically highly theoretical, and students lack practical application in educational activities aimed at shaping the experiential world of the individual (Zelina, 2024). In international academic literature, several key areas emerge regarding the educator's profession: the status and professional identity of leisure-time educators, the

relationship and cooperation between educators and teachers, and the added value of after-school clubs concerning the personal development of the child.

Research in this field concurs that, in the 21st century, the educator profession is undergoing an identity crisis accompanied by a drive towards full professionalization. In Scandinavia, particularly in Sweden, studies have investigated "leisure-time teachers" and their professional identity during the initial years following their graduation from higher education. Compared to the regular teaching profession, the profession of an educator within leisure-time pedagogy possesses an ambiguously defined professional identity and jurisdiction. Swedish research (Ackesjö et al., 2019) highlights the tension between the roles of the educator, the teacher, and the teaching assistant, as well as the need to more clearly define the specific competencies and professional autonomy of this profession. While teachers hold a monopoly on the transmission of academic knowledge (and the clear status associated with it), educators operate in a space that the lay public often perceives merely as "supervision" or "caretaking"—essentially as "child's play." In some cases, the integration of educators into schools has led to them being perceived as "teacher assistants," which has been associated with a restriction of their "room for action, independence and professional identity."

A study by Ackesjö et al. (2019) also captures the conflicts experienced by new graduates who attempted to explain their function and competencies to teachers and to assert the distinct identity of a leisure-time teacher. Furthermore, Ringskou et al. (2022) conducted a systematic review of 68 Danish and 71 Swedish publications in the field of leisure-time pedagogy. Their findings show that Swedish research focused predominantly on the professional identity of leisure-time teachers, whereas Danish research concentrated more on the collaboration between teachers and pedagogical staff. According to their analysis, 54.9% of the Swedish publications dealt with the professional identity of leisure-time teachers.

Many studies analyze the conflict wherein educators are expected to possess high levels of professional expertise (working with behavioral disorders, managing inclusion), yet their remuneration—both financial and social—does not reflect these expectations. According to research, educators frequently fight for so-called professional autonomy—aiming for their work to be perceived not merely as an extension of school instruction (such as doing homework), but as an autonomous pedagogical process. The professional identity of educators was also addressed in a study by Klerfelt (2018), which examined how teachers in Swedish school-age educare centers construct their professional identity, how they understand their mission, and how they implement their pedagogical intentions. The study's conclusions suggest that the profession of an educator working in school-age educare centers brings a unique contribution to the daily lives of children, primarily through the consistent consideration of the child's perspective.

The topic of cooperation between formal and (non-formal) education is highly prevalent. Both foreign and domestic studies repeatedly point to barriers in the relationship between teachers and educators. A hierarchical model often persists, wherein the teacher is perceived as a superior and more important actor. Scientific studies, however, argue for a synergistic approach (equal partnership), as the teacher views the child through a performance-oriented lens, whereas the educator observes the child during natural social interactions and play. Research from the Swedish context indicates that the integration of school-age educare centers into schools has, in some cases, led to a weakening of the professional autonomy of educators, who are subsequently perceived rather in an assistant capacity relative to teachers. At the same time, educators reported the need to explain their specific competencies and professional roles to teachers (Ackesjö et al., 2019). Similar issues emerge in the Slovak context, where the research study *School Children's Club from the Perspective of Educators* (Kožuchová et al., 2018) highlights the importance of partnership equality, mutual respect, and an understanding of the specificities of both the teacher's and educator's work for the quality of their collaboration. The authors describe the

relationship between teachers and educators as important, yet not always unproblematic. Collaboration between the teacher and the educator is essential for the benefit of the children, as both have a long-term educational impact on the child. Consequently, the quality of their relationship directly influences the outcome of their educational efforts. In the context of inclusion, close cooperation between teachers and educators appears to be absolutely crucial, particularly when working with children with special educational needs (Kožuchová et al., 2018). In contemporary academic discourse, school-based leisure-time facilities are increasingly understood as pedagogical environments that extend beyond the mere functions of care and supervision. This indicates the added value of after-school clubs in relation to a child's personal development. Research on school-age educare emphasizes the need to integrate care, learning, social development, well-being, and meaningful leisure time, thereby supporting the holistic development of the child (Haglund, 2023).

Studies in the field of school-based leisure-time education highlight the specific added value of after-school clubs in the form of social interaction, play, physical and creative activities, and contact with nature. Simultaneously, out-of-school education provides a space for cultivating children's interests, experimenting, discovering their own capabilities, and forming social relationships. In the context of the growing presence of digital media, it can thus serve as an environment where children's digital interests are transformed into analogue, creative, physical, and social activities (Wallner & Jansson, 2024/2025; Ljung Egeland, Hjalmarsson & Carlman, 2025).

Research Methodology

The primary objective of our survey was to map the opinions and attitudes of pedagogical staff concerning the professional status of the educator and the value of after-school clubs within the educational system in Slovakia. Data collection was conducted electronically via an online questionnaire in 2023. The survey was completely anonymous. Based on the established objective, the following areas of research questions were formulated:

- How do children and their parents perceive the role of the educator and the significance of the after-school club?
- What is the professional status of the educator compared to that of a teacher within the working environment (from the perspective of colleagues and institutional management)?
- What should be the primary mission of after-school clubs, and what are the most acute problems from a practical standpoint?

Research Sample

A total of 433 respondents participated in the survey. Due to the feminization of this profession, the vast majority of the sample consisted of women (97.7%), while men accounted for only 2.3%. The average age of the respondents was 44.7 years. The largest portion of the respondents works directly in after-school clubs (97.2%).

In terms of education, the highest number of respondents had completed a Master's degree / second-level higher education (43.4%), followed by full secondary vocational education (26.1%), and a Bachelor's degree / first-level higher education (18%). Regarding professional experience, the strongest representation was among educators with 5 to 10 years of experience (27%) and 10 to 25 years of experience (23.3%). The survey captured responses from all eight regions of Slovakia, with the highest representation from the Bratislava Region (21.7%).

Methods

Data were collected through a quantitative questionnaire survey. The questionnaire comprised both closed and open-ended questions, which facilitated not only statistical analysis but also the elicitation of authentic statements and attitudes from practitioners. A self-designed, non-standardized questionnaire was employed as the primary research instrument. It represents

a mixed-methods (quantitative-qualitative) tool comprising 33 items, which were internally divided into three thematic blocks. The first block, focusing on the socio-demographic profile, involved the collection of basic identifying characteristics (gender, age, education, length of professional experience, and region of employment), which served as independent variables for further data stratification. The second block, concerning the status and perception of the profession, focused on the self-assessment of after-school educators and the comparison of their professional standing from the perspectives of school authorities, teachers, and parents. The third thematic block, addressing the value and reality of after-school clubs, confronted the legislative framework with the actual needs of children, mapped acute practical issues, and assessed attitudes toward innovations such as state educational programs. To prevent mechanical responding and to ensure the acquisition of comprehensive data, the questionnaire alternated various item formats. These included closed standardized questions utilized for the unambiguous categorization of responses and exact quantification, and Likert-type rating scales (both 5-point and 10-point) designed to measure the intensity of attitudes, such as the perceived attractiveness of the profession. Furthermore, the instrument utilized conditional (branching) items requiring argumentation and qualitative justification based on a preceding binary choice, along with projective and completion questions presented as unfinished sentences, which allowed for the capture of authentic, in-depth participant responses without the influence of predefined options.

Results

From the perspective of educators, children perceive the after-school club and the educator positively. The respondents' answers indicate a positive relationship of children towards both the after-school club and the educators themselves. Up to 66.1% of educators reported that children (or young people) consider them to be an authority of equal importance to teachers (25.2% do not share this view). This positive relationship is also reflected in the motivation to attend the club: 68.6% of children attend the after-school club because they want to and enjoy spending time there, while only 15.5% of children attend primarily out of obligation (because they were enrolled by their parents). The perspective of parents, mediated through the lens of the educators, presents a significantly different picture. According to the survey, as many as 62.1% of parents do not consider the educator to be an equally important actor in the educational process as the teacher (equality is perceived by only 25.4% of parents). This attitude is closely related to what parents consider to be the primary significance of the after-school club. The largest proportion of parents perceives the clubs predominantly as a "depository" for children (31.2%) or as a space for an extended stay at school (30.7%). Perceiving the after-school club as a space for the personal development of the child (14.1%) or as a space for fun and relaxation (12.9%) is thus relegated to secondary importance.

The professional perspective of the educators themselves regarding their work contrasts with the expectations of parents. Although legislation defines the roles of after-school clubs comprehensively, educators believe that the club should primarily provide children with a space for the expression and development of their interests (44.6%), rest and relaxation (24.2%), and the fulfillment of their current needs (21.7%). The emphasis placed on completing homework is negligible. When evaluating the contribution of the after-school club to the personal development of the child on a scale from 1 to 5 (where 5 represents the maximum value), 56.1% of the respondents awarded the highest score of 5, and an additional 27.3% assigned a score of 4. This indicates that the educators themselves are fully aware of the high value and significant impact of their work on the child's development.

In terms of how the importance of an educator's work is perceived by the broader community, we found that despite its high added value for children, the educator's work within the system is frequently marginalized. This is most prominently reflected in their relationship with teachers—as

many as 73% of respondents reported that teachers consider educators to be "inferior colleagues" (only 20.1% regard them as equal). Similarly, a large proportion of educators feel that their work is evaluated by employers and school authorities as "less important" (41.8%) or even "unimportant" (8.8%). It is a notable paradox that educators themselves consider their work to be exceptionally demanding; 41.3% rate it as more demanding than that of a teacher—primarily due to the need for continuous leisure-time management, a higher risk of injuries, and the absence of strict curricula—while 17.8% evaluate it as equally demanding.

From the perspective of educators, the primary mission of after-school clubs should predominantly be to provide a space for the expression and development of children's interests, which is perceived as a priority by 44.6% of the respondents. According to the surveyed individuals, other key roles of leisure-time education include the provision of rest and relaxation (24.2%) and the flexible fulfillment of children's current needs (21.7%). However, in attempting to fulfill this mission, practical implementation encounters several acute obstacles. Educators identify inadequate spatial and material provisions (22.6%) as the most prominent issue requiring immediate attention. This is closely followed by the high number of children in educational groups (18.9%), complications associated with the presence of sick children in the clubs (14.1%), and a general lack of financial resources allocated to after-school clubs by the schools themselves (13.6%).

Discussion

The results of the survey reveal a profound systemic and societal contradiction in the perception of the educator's work and the institution of the after-school club. On one hand, there is the unquestionable importance of this profession in the social and emotional development of children, which is confirmed not only by theoretical frameworks but also by the children themselves, who find a space for self-realization, relaxation, and relationship-building in the club. On the other hand, the survey clearly detects the presence of a "second-class status" attributed to this profession by adult actors within the system. In the perspectives of children and parents regarding the educator, we noted both convergences and divergences. The most striking contrast appears when comparing the responses of children and parents. While for children, the educator is often an authority equal to the teacher and they look forward to attending the club, parents devalue this role to the level of passive supervision. The fact that nearly two-thirds of parents perceive the after-school club merely as a "depository" for the time they are at work indicates an acute lack of public awareness regarding the actual content and significance of out-of-school education. The status of the educator thus remains on the periphery of professional interest. A particularly striking finding is the attitude of colleagues themselves—the teachers—the vast majority of whom, according to the survey, do not perceive educators as equal partners but rather as second-tier pedagogical staff. This phenomenon also permeates the management level, where a significant portion of school authorities undervalues the work of after-school clubs. Our domestic findings in this regard strongly correlate with the conclusions of Scandinavian studies, confirming that the threat to professional autonomy is not merely a Slovak specific, but a broader European phenomenon. As pointed out by Ackesjö et al. (2019) within the environment of Swedish schools, the very institutional integration of leisure-time centers under the school roof often places educators in an asymmetrical, assistant position relative to teachers, forcing them to constantly defend their specific competencies. This situation is all the more alarming given that educators perceive their own work as highly responsible and in many respects more demanding, particularly due to the necessity of shaping social skills, resolving conflicts, and operating without traditional assessment tools such as grades.

The survey of educators' opinions and attitudes indicates that if the after-school club is to fulfill its potential within the modern educational system, it is essential to systematically pursue the

emancipation of this profession. This requires not only resolving material and personnel issues, but above all, a profound paradigm shift in recognizing that education does not end with the ringing of the bell at the close of the final lesson. As Klerfelt (2018) argues in her research, the core of an educator's professional identity does not lie in doing homework and extending formal instruction, but in an autonomous pedagogical process grounded in the child's perspective and holistic development. In pedagogical discussions, statements are increasingly and urgently made that educational problems in schools and school facilities are escalating, the authority of the pedagogue is weakening, and discipline is disappearing. This alarming situation is further amplified by the practical barriers that educators encounter daily. Bendl et al. (2015) consider the fundamental problems to be the societal undervaluation of leisure-time education and the related persistent shortcomings in the system of professional preparation. Furthermore, children with special educational needs are increasingly entering after-school clubs, making it ever more difficult to motivate them toward leisure activities. Educators thus find themselves caught between conflicting pressures: on one hand, facing unreasonable parental expectations and tasks assigned by superiors, while on the other, battling poor material equipment and spatial conditions. Educators face this situation under the dominion of Slovak schools, where they are frequently reduced from expert pedagogues to the level of bulletin board managers, decorators, and event organizers alongside a full-time workload. It is therefore crucial to continue subjecting these facts to empirical research and public discussion in accordance with valid legislative measures (Act No. 138/2019 Coll., Section 3), which explicitly guarantee educators protection against unprofessional interference in their professional activities and provide space for submitting proposals to improve out-of-school education.

Conclusion

According to the Education Act (Act No. 245/2008 Coll., Section 3, Letters g, r), the status of after-school clubs in comparison to schools should be equal; however, this is not the case in reality. In the eyes of the public, education in the sense of cognitive development is increasingly perceived as more important than upbringing, which encompasses the non-cognitive development of the child's personality. The status of the teacher and that of the educator are not perceived as equal by society, parents, or colleagues, because educational work with children in after-school clubs is not regarded as sufficiently important, justified, and indispensable. After-school clubs possess enormous potential; they can become school facilities that fulfill a complementary function to the school in terms of the comprehensive development of the child's personality. The determinant of this transformation is to begin working intensively on enhancing the quality of the educational process within after-school clubs and on the professional development of educators. A common appeal for a change in the approach to planning leisure-time education and for the proper appreciation of out-of-school education permeates both our research and the theoretical framework. In accordance with the ideas of Zábušková (In: Novotná, 2013, p. 216), it is imperative that educators cease to perceive legislative changes and state educational programs merely through the prism of apprehension and routine, and instead discover within them a space for their own uniqueness. If they manage to align didactics with the needs of the children, they can create an environment that harmoniously interconnects formal, desk-based education with relaxed, non-formal learning in the club. The recognition and support of this pedagogical mastery by schools and school authorities represent the best pathway to permanently consolidating the status of the educator and elevating the true value of after-school clubs.

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Improving Georgian Maritime Student Listening Comprehension

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Resume

English is the language used in marine sector. Seafarers use Marine English while working in port administrations, shipping industries, etc. Marine English is a special language having its own linguistic features: specialized lexis, limited grammar, writing format. Maritime disasters mainly occur due to breakdown in communication and cooperation. So maritime students should develop their listening and speaking skills from the first years of studying at Maritime Academy. At Batumi State Maritime Academy much attention is devoted to teaching specialized lexis, marine terms, and developing writing, reading and speaking skills. Unfortunately, English language teachers do not pay enough attention to development of listening skills. Proper communication is impossible without understanding Marine English and having no listening abilities.

The objective of this paper is to show the importance of listening activities at English lessons. The present study also aims at investigating the approaches that English language teachers and marine students can follow. It also aims to emphasize development methods to improve listening comprehension English for marine students in Georgia. The paper explains how the teachers should teach required skill to marine students and develop communicative competence among them.

Observation showed that maritime students and sailors have problems in understanding the speech of foreigners. Misunderstanding and miscommunication can be caused by many factors: not knowing standard marine vocabulary (language barrier), not being aware of culture (cultural barrier), not being familiar with the accent, intonation or having difficulties following the speaker's speech (pace of speech).

Key words: listening, communication, misunderstanding, Maritime English, comprehension

Introduction

English is the language used in marine sector. Seafarers use Marine English while working in port administrations, shipping industries, etc. Marine English is a special language having its own linguistic features: specialized lexis, limited grammar, writing format. Maritime disasters mainly occur due to breakdown in communication and cooperation. So marine students should develop their listening and speaking skills from the first years of studying at Maritime Academy. At Batumi State Maritime Academy much attention is devoted to teaching specialized lexis, marine terms, and developing writing, reading and speaking skills. Unfortunately, English language teachers do not pay enough attention to development of listening skills.

Our observation showed that maritime students and sailors have problems in understanding the speech of foreigners. When a ship reaches a foreign country, sailors need to

communicate to the port authority in English. Besides, sailors need to use English for inter-and intra-ship communication, negotiating with foreign employers. Misunderstanding and miscommunication can be caused by many factors: not knowing standard marine vocabulary (language barrier), not being aware of culture (cultural barrier), not being familiar with the accent, intonation or having difficulties following the speaker's speech (pace of speech).

Obstacles in listening Comprehension

Listening comprehension means that a person understands what he/she has heard. Listeners comprehend the oral input through sound discrimination, previous knowledge, grammatical structures, stress and intonation, and other linguistic or non-linguistic clues.

Listening comprehension is both a technique and a capability, which is rather significant in second language study (Rost, 2000: 12-27). X. Yang in the scientific article "On the Obstacles and Strategies in English Listening Teaching" writes: "Listening comprehension can be affected positively or negatively by various factors. The factors can be identified as internal and external." (Yang, 2019:1). According to the researcher, internal factors affecting listening comprehension are the following: the English sounds and sound patterns; vocabulary, lexicology and language barrier; listening customs barriers. As for external factors affecting listening comprehension, they are: psychological quality, teachers, cultural background, interest in English listening (Yang, 2019:2-3).

In order to remove barriers in listening comprehension teachers often find strategies like: enlarging vocabulary of students, improving grammar, developing listening skills and good habits, breeding interest on listening, broadening the cultural background knowledge, etc. But the most important strategy is to change teaching methodology. Teachers should change the traditional model of "Listen-check the answer-listen again" into "Student-centered teaching."

Listening Comprehension problems of Marine Students

According to Underwood: "There are seven potential problems that could hinder listening comprehension: 1) listener cannot control how quickly a speaker speaks; 2) the lack of opportunity for the learners to have the words repeated; 3) the small size of the learner vocabulary; 4) listeners may not recognize the signals that the speaker is using to move from one point to another, give an example, or repeat a point or the lack of awareness on transitional markers; 5) it can be very challenging for listeners to focus on a foreign language; 6) learning habits developed among the students encouraged the need to understand every meaning of every word, isolated from context; 7) comprehension problems arise when students lack contextual knowledge" (Orbe, 2019:2).

Marine students at Batumi State Maritime Academy have problems in listening because Georgian schools and universities pay more attention to English reading, vocabulary and grammar, rather than listening and speaking. Listening and speaking skills are not so much essential of many specialized coursebooks and curriculum, and teachers do not seem to pay much attention to this skill when they are designing their lessons.

Observations revealed that the marine students at BSMA have several problems in listening: they quickly forget what is heard by them; they do not recognize the words uttered by speakers; the sentences are long; unfamiliar structure of sentences are confusing, topic is unfamiliar, pronunciation is inaudible, quality of recorded material is low, etc.

In spite of listening comprehension problems, we may say that marine students have positive attitude towards listening and believe that listening is the best activity.

Discussion

In the language classroom, the listening process can be demonstrated by marine students hearing oral speech, dividing them into lexical and syntactic units and comprehending the message. Our aim as the teachers is to choose specialized texts to meet the needs of future sailors.

Listening is a six staged process consisting of hearing, attending, understanding, remembering, evaluating and responding. Listening requires skills of prediction, hypothesizing, checking, revising and generalizing. The teaching of listening comprehension skills is integrated with oral communication tasks, so my groups always undergo the integrated teaching process that is more successful than practicing the skill separately.

We will present how we work in the classroom with marine students. We always divide our lessons in several stages: pre-listening activities, brainstorming vocabulary, discussing context and setting and follow-up activities.

Each stage is very important: 1) Some introductory activities help students shape a better perception of the topic, increase concentration and motivation; 2) brainstorming similar vocabulary on the subject help students to guess the topic of the listening task; 3) giving students some background information about what they are going to hear, who are speaking and about what are also helpful form them; 4) listening practice is followed by follow-up activities It means that we check and discuss the answers. Follow-up activities help students to see their comprehension failures and specify the choice of different listening strategies.

We know that if we want to get good results in listening activities, learners need to apply the following strategies:

- 1) Pre-listening (Define the purpose of listening; Check background information about the topic; Predict the information based on the title and some illustrations);
- 2) During listening (Check the guesses; Select the major information);
- 3) Post-listening (Assess the comprehension of the given piece; Evaluate the progress; Decide whether the strategies applied were appropriate or not; Modify strategies if it is needed).

When students listen, they make sense of the incoming information in two different ways. Bottom-up processing refers to deriving meaning from individual lexical, grammatical and pronunciation items. Top-down processing operates with existing schemata, ideas, and content.

We try to use different types of listening at the lessons – mainly critical, emphatic and reflective. In the first case marine students listen for facts and support details to understand and evaluate the speaker's message. In the second case students imagine themselves in the other person's position and try to understand what the speaker is thinking. And in the third case students get information and reflect on the speaker's responses to form new questions.

Listening materials chosen by us are on marine topic (monologues, dialogues, spontaneous or prepared). The texts are of different sizes, both authentic and scripted. Authentic listening material is difficult for lower-level students. On the one hand they explore the real language and culture and thus increase motivation in learning, on the other hand they have problem with the speed, vocabulary or irregularities of native speech. We never stay away from authentic texts, because both natural and scripted materials have a purpose in a listening classroom.

Students listen to the recorded material and take notes down. This process is essential as it involves absorbing information and interpreting it. For some students it is difficult to take notes because they do not comprehend the subject matter. In this case they ask questions until their doubts are resolved. We make long pauses while listening and ask the students questions how do they understand the listening material. Interactive method of teaching is of great help here. We

often tell my students not to cling to every word but to try to derive meaning from what they recognize. Thus, the students study how to detect key words, how to guess the meaning of unknown words or marine terms from context, how to recognize grammatical word classes or cohesive devices, identify the topic and follow its development.

We like to separate listening material into smaller components which is quite effective in class. It helps students to remember the text in details. When the listening activity is over, we perform variety of tasks. Post listening activities come in different forms. They can focus on the main idea of the text or some specific information. We often ask my students to improvise the conversation. So, post- listening activities comprise the following tasks: role-play, creating text on similar topic, responding to the content of the text, paraphrasing or summarizing the text, working on the vocabulary from the text, etc.

We evaluate students' comprehension based on correctness of their responses. It is a diagnostic approach that allows teachers to detect weaknesses of their students. I give my students feedback immediately after the task, while they still remember the text.

Conclusion

The research revealed that problems are limited English vocabulary, speed of speech, accent of native speakers, unfamiliar pronunciation. The common difficulties in listening are vocabulary and making inferences and generalizations. Listening activities should be chosen by teachers carefully, from basic to more complex. The lecturers should provide authentic listening materials for marine students to help them understand better the natural speech uttered by native speakers.

We believe traditional teaching methods are not suitable for modern marine needs. Maritime English teachers should develop good syllabi, classroom materials and adopt effective teaching approaches to help marine students in developing better listening skills.

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РОЛЬ РЕФЛЕКСИИ В РАЗВИТИИ НАВЫКОВ САМОРЕГУЛЯЦИИ НА УРОКАХ ФИЗИЧЕСКОЙ КУЛЬТУРЫ

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Учитель-эксперт NIS физической культуры, магистр педагогики, Назарбаев Интеллектуальная школа естественно-математического направления района Абай, города Шымкента, Казахстан

Система среднего образования Республики Казахстан строится на компетентностно-деятельностной основе, закреплённой ГОСО, утверждённым приказом Министра просвещения РК от 3 августа 2022 года № 348. Стандарт ориентирует процесс на достижение предметных, личностных и системно-деятельностных результатов, среди которых способность к самопознанию, самоконтролю и саморегуляции занимает центральное место. Для Назарбаев Интеллектуальных школ эти требования конкретизированы в NIS-Programme (Учебная программа по предмету «Физическая культура». Основная школа (6–10 классы), версия 2.1, 2025 г.), где формирование умения оценивать собственную деятельность, ставить цели и корректировать усилия является сквозной задачей.

Достижение этих результатов связано с критериальным оцениванием. Формативное оценивание по своей природе представляет собой организованную рефлексивную обратную связь: обучающийся не просто получает отметку, а совместно с учителем и сверстниками анализирует, в какой мере достигнута цель обучения, и определяет дальнейшие шаги. Таким образом, рефлексия заложена в логику оценивания NIS как её структурный элемент.

Физическая культура обладает особым потенциалом для реализации этой логики: двигательная деятельность требует постоянного контроля за телом, усилием, темпом, техникой и эмоциональным состоянием. Однако сама по себе двигательная активность не порождает навыков саморегуляции: учащийся может многократно повторять упражнение, не осмысливая ни цели, ни способов, ни причин успеха или неудачи. Превращение двигательного опыта в осознанный процесс происходит только при сопровождении деятельности рефлексией.

Актуальность исследования обусловлена, с одной стороны, задачами формирования функциональной грамотности обучающихся 6–10 классов, с другой, недостаточной методической разработанностью приёмов включения рефлексии в урок физической культуры, где на практике часто преобладают показ и повторение при минимальном внимании к формативной обратной связи и самоанализу.

В психолого-педагогической литературе саморегуляция рассматривается как системно организованный процесс внутренней психической активности по инициации, построению, поддержанию и управлению произвольной активностью, реализующей достижение принимаемых субъектом целей. В её структуре выделяют: принятие и удержание цели, моделирование значимых условий, программирование действий, оценивание результатов, коррекцию деятельности.

Применительно к физической культуре саморегуляция проявляется на нескольких уровнях:

- Психофизиологическом - управление мышечным тонусом, дыханием, темпом, распределением нагрузки;

- эмоционально-волевым - регуляция тревожности, преодоление страха, поддержание мотивации при неудачах;
- когнитивном - осмысление техники, анализ ошибок, планирование действий;
- поведенческом - соблюдение правил, взаимодействие с партнёрами, дисциплина.

Развитие саморегуляции не происходит спонтанно: оно требует специально организованной педагогической работы, ключевым элементом которой выступает рефлексия.

Под рефлексией в педагогике понимают способность субъекта обращаться к основаниям собственных действий, анализировать их с точки зрения соответствия цели и условиям, осознавать свои внутренние состояния, возможности и ограничения. В отличие от простого воспроизведения информации о действии, рефлексия предполагает выход в позицию «над» деятельностью.

На уроке физической культуры рефлексия может быть направлена на разные объекты:

1. предметная - осмысление техники, причин ошибок, способов их устранения;
2. процессуальная - анализ хода деятельности, эффективности стратегии, распределения усилий;
3. личностная - осознание собственных возможностей, физического состояния, эмоций, отношения к занятию;
4. коммуникативная - анализ взаимодействия с партнёрами, обратной связи от учителя и сверстников.

Каждый вид вносит вклад в развитие соответствующего компонента саморегуляции: предметная и процессуальная рефлексия развивают программирование и коррекцию, личностная, самооценку и эмоциональную регуляцию, коммуникативная, регуляцию поведения в совместной деятельности.

NIS-Programme называет когнитивные и метакогнитивные навыки в числе приоритетных: критическое мышление, креативность, способность решать проблемы и принимать решения. К ним примыкают социальные и эмоциональные навыки, сотрудничество, коммуникация, лидерство. Эта рамка задаёт содержательные ориентиры для рефлексии: вопросы учителя должны быть направлены именно на эти группы навыков.

Связь между рефлексией и саморегуляцией носит функциональный характер: рефлексия, не дополнение, а необходимый внутренний механизм саморегулируемой деятельности.

Во-первых, рефлексия обеспечивает осознанность цели: прежде чем регулировать действие, учащийся должен ясно представлять, чего добивается. Вопросы на этапе целеполагания («что должно получиться?», «по каким признакам ты поймёшь, что выполнил задание правильно?») переводят внешнюю цель во внутренний план.

Во-вторых, рефлексия выполняет функцию обратной связи, необходимой для коррекции: вопросы «что получилось лучше всего?», «в какой момент движение стало сложнее?», «что бы ты изменил?» формируют привычку соотносить процесс и результат.

В-третьих, рефлексия способствует формированию адекватной самооценки, снижая зависимость мотивации от внешнего одобрения и повышая устойчивость к неудачам.

В-четвёртых, рефлексия участвует в эмоциональной саморегуляции: проговаривание состояния снижает интенсивность негативных переживаний и формирует опыт совладания с трудностями.

Таким образом, рефлексия - системообразующий элемент урока, без которого двигательная деятельность не становится саморегулируемой.

Согласно NIS-Programme, критериальное оценивание включает формативное и суммативное. Формативное проводится непрерывно, обеспечивает оперативную

взаимосвязь учителя и учащегося, позволяет своевременно корректировать процесс на основе обратной связи. По его итогам учитель даёт комментарии в письменной или устной форме, показывая, на каком этапе обучения находится ученик, куда стремится и как достичь цели. Программа прямо указывает на важность формирования навыков само- и взаимооценивания с использованием дескрипторов. Суммативное оценивание проводится после завершения раздела (дважды в четверть) и фиксирует достигнутый уровень.

Формативное оценивание по своей природе есть организованная рефлексивная обратная связь. Применительно к урокам физической культуры рефлексивные приёмы целесообразно выстраивать как содержание оценивания:

- работа с целями обучения. Каждая тема соотносится с кодированной целью обучения (например, 6.1.1.1, 8.3.1.1, 10.1.5.1);
- дескрипторы как опора само- и взаимооценивания. Сверяя действия с дескриптором, обучающийся осуществляет процессуальную рефлексию;
- обратная связь как рефлексивный диалог. Устная и письменная обратная связь, а также взаимная обратная связь строятся по принципу «на каком этапе я нахожусь - куда стремлюсь - как этого достичь»;
- связь с функциональной грамотностью. Программа выделяет физическую грамотность, грамотность в области здоровья и экологическую грамотность. Перенос навыка саморегуляции за пределы урока (постановка цели самосовершенствования, планирование нагрузки, коррекция образа жизни), практическое проявление этой грамотности и показатель зрелости рефлексивных умений.

Таким образом, рефлексия в NIS не противопоставляется оцениванию, а реализуется через него: качественно организованное формативное оценивание и есть систематическая рефлексивная практика.

Система целей обучения построена по спиральному принципу: одна и та же содержательная линия усложняется от 6 к 10 классу.

Наиболее показателен подраздел «Соблюдение правил техники безопасности и преодоление трудностей и рисков», связанный с эмоционально-волевым и поведенческим уровнями саморегуляции: в 6 классе - определять трудности и риски (6.1.5.1); в 7 классе - понимать причины травматизма и способы их предотвращения (7.1.5.1); в 8 классе - осознавать трудности и риски при выполнении действий и использовании оборудования (8.1.5.1); в 9 классе - выполнять страховку и самостраховку (9.1.5.1); в 10 классе - оценивать навыки преодоления и реагирования на трудности и риски (10.1.5.1). Эта последовательность задаёт программу развития рефлексии: от распознавания опасности к пониманию причин, затем к управлению действиями и итоговой оценке, что соответствует структуре саморегуляции (целеполагание - программирование - коррекция - оценка).

Аналогичная логика в подразделе «Профилактика и укрепление здоровья»: от понимания важности здоровья (6.3.4.1) через сравнение и объяснение влияния ЗОЖ (7.3.4.1–8.3.4.1) к демонстрации на собственном примере (9.3.4.1) и самостоятельному анализу и оценке мер (10.3.4.1). Переход к анализу «на собственном примере» - проявление личностной рефлексии.

Подраздел «Навыки лидерства в командной работе» формирует коммуникативную рефлексию: от освоения особенностей лидерских навыков (6.2.2.1) и их применения (7.2.2.1) через распределение ответственности (8.2.2.1) и анализ личных навыков (9.2.2.1) к оценке навыков лидерства в командной работе (10.2.2.1).

Эти примеры показывают, что программа уже содержит логику перехода от внешне заданного действия к осознанному самоуправлению; задача учителя - сделать эту логику явной через рефлексивные вопросы.

Эффективное включение рефлексии предполагает её распределение по всем этапам занятия.

На этапе целеполагания - совместная выработка критериев оценивания к цели обучения, составление индивидуального плана, прогнозирование трудностей. Формулировки на понятном языке («я умею», «я могу показать», «я могу объяснить») закладывают основу самооценивания.

На этапе освоения двигательного действия - пошаговая рефлексия, встроенная в формативное оценивание: короткие остановки после повторений с вопросами о самочувствии и технике, взаимное наблюдение и взаимооценивание в парах по дескрипторам («тренер - спортсмен»), карточки самоконтроля с перечнем ключевых элементов техники.

На этапе закрепления и совершенствования - сравнительная рефлексия: сопоставление выполнения с эталоном и дескриптором (в том числе по видеозаписи), ведение дневника физического самосовершенствования, что работает и на функциональную грамотность.

На заключительном этапе - обобщающие приёмы, соотнесённые с критериями оценивания: «лестница успеха», «дерево настроения», светофор самооценки, незаконченные предложения («сегодня я научился...», «мне было трудно, когда...», «в следующий раз я постараюсь...»), групповое обсуждение, само- и взаимооценка по дескрипторам.

Важное условие, систематичность: эпизодическое обращение к рефлексии не формирует устойчивого навыка. Вопросы должны учитывать возраст: для 6-7 классов уместны наглядные и полуструктурированные формы (карточки, светофор, короткие устные комментарии), для 9-10 классов, развёрнутый словесный и письменный самоанализ, дневник самосовершенствования, самостоятельная формулировка критериев.

Проведённый анализ позволяет заключить, что рефлексия является необходимым психолого-педагогическим механизмом перехода двигательной деятельности из режима механического исполнения в режим осознанного самоуправления. В условиях NIS-Programme этот механизм получает институциональное закрепление: рефлексия реализуется через работу с целями обучения, дескрипторы, формативное оценивание и содержательную обратную связь.

Практическая реализация потенциала требует от учителя целенаправленного включения рефлексивных приёмов во все этапы урока, от совместной выработки критериев до итогового само- и взаимооценивания, с постепенным повышением самостоятельности обучающихся 6-10 классов. Систематическая рефлексивная практика, опирающаяся на критериальное оценивание, способствует более качественному освоению двигательных действий и формированию общей способности к саморегуляции и функциональной грамотности, значимой за пределами предмета.

Перспективным направлением дальнейших исследований является разработка и эмпирическая проверка диагностического инструментария для отслеживания динамики развития компонентов саморегуляции под влиянием систематической рефлексивной практики, встроенной в формативное оценивание на уроках физической культуры.

РАЗВИТИЕ МУЗЫКАЛЬНО-ТВОРЧЕСКИХ СПОСОБНОСТЕЙ УЧАЩИХСЯ НА УРОКАХ МУЗЫКИ В УСЛОВИЯХ ОБНОВЛЕНИЯ СОДЕРЖАНИЯ ОБРАЗОВАНИЯ

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Аннотация

В статье рассматриваются актуальные вопросы развития музыкально-творческих способностей учащихся на уроках музыки в контексте обновления содержания образования. Автор анализирует современные подходы к организации музыкально-педагогического процесса, ориентированные на раскрытие творческого потенциала личности. Особое внимание уделяется практическим аспектам применения интерактивных методов и творческих заданий на уроках музыки. Обосновывается необходимость комплексного подхода к развитию музыкальных способностей, включающего восприятие, исполнительство и творчество. Приводятся примеры конкретных педагогических приёмов, направленных на активизацию творческой деятельности школьников. Статья адресована учителям музыки, преподавателям педагогических вузов, студентам музыкально-педагогических специальностей.

Ключевые слова: музыкальное образование, творческие способности, урок музыки, обновление содержания образования, педагогические технологии, музыкальное восприятие, импровизация, интерактивные методы, креативность, личностно-ориентированный подход.

Введение

Современный этап развития системы образования характеризуется активным поиском новых подходов к обучению и воспитанию подрастающего поколения. В условиях обновления содержания образования особую значимость приобретает проблема развития творческой личности, способной к самостоятельному мышлению, инициативе и креативной деятельности. Музыкальное образование, обладая мощным развивающим и воспитательным потенциалом, занимает особое место в решении этой задачи.

Урок музыки в общеобразовательной школе является не только средством приобщения учащихся к музыкальной культуре, но и важнейшим пространством для развития их творческих способностей. В связи с этим возникает необходимость переосмысления традиционных подходов к организации музыкальных занятий и внедрения инновационных педагогических технологий, направленных на активизацию творческой деятельности школьников.

Актуальность темы обусловлена рядом факторов. Во-первых, современное общество нуждается в творчески мыслящих, инициативных людях, способных к нестандартным решениям и самостоятельной деятельности. Во-вторых, обновление содержания образования предполагает смещение акцентов с репродуктивного усвоения знаний на развитие компетенций, включая творческие. В-третьих, музыкальное искусство по своей

природе является творческим, и урок музыки обладает уникальными возможностями для развития креативности учащихся.

Цель статьи — раскрыть теоретические и практические аспекты развития музыкально-творческих способностей учащихся на уроках музыки в условиях обновления содержания образования.

Задачи статьи: рассмотреть сущность и структуру музыкально-творческих способностей; проанализировать виды музыкальной деятельности, способствующие развитию творческого потенциала школьников; охарактеризовать интерактивные методы и педагогические технологии, применяемые на уроках музыки; предложить практические рекомендации по организации творческой деятельности учащихся.

Сущность и структура музыкально-творческих способностей

Проблема способностей является одной из центральных в психологии и педагогике. В отечественной науке наиболее известной является теория способностей Б.М. Теплова, который определял способности как индивидуально-психологические особенности человека, отвечающие требованиям данной деятельности и являющиеся условием её успешного выполнения. Учёный подчёркивал, что способности не сводятся к знаниям, умениям и навыкам, но проявляются и развиваются в деятельности.

Музыкальные способности, по Теплову, представляют собой совокупность психических свойств, необходимых для успешного занятия музыкальной деятельностью. К основным музыкальным способностям учёный относил музыкальный слух, чувство ритма и музыкальную память. При этом он отмечал, что музыкальность не исчерпывается этими способностями, а включает также способность к эмоциональному переживанию музыки, музыкальное воображение и мышление.

В современной музыкальной психологии и педагогике музыкально-творческие способности рассматриваются как интегративное личностное образование, включающее несколько взаимосвязанных компонентов:

1. **Музыкальный слух** — звуковысотный, ладовый, гармонический, тембровый, динамический, внутренний слух. Развитый музыкальный слух позволяет учащемуся точно воспринимать, воспроизводить и анализировать музыкальные звуки, их высоту, тембр, динамику, соотношения в ладу и гармонии.
2. **Чувство ритма** — способность воспринимать, воспроизводить и создавать ритмические последовательности, чувствовать метрическую пульсацию, различать сильные и слабые доли, осваивать различные ритмические рисунки.
3. **Музыкальная память** — способность запоминать, сохранять и воспроизводить музыкальный материал: мелодии, ритмические рисунки, гармонические последовательности, тембры инструментов. Музыкальная память может быть слуховой, зрительной, двигательной, эмоциональной.
4. **Музыкальное мышление** — способность анализировать, сравнивать, обобщать музыкальные явления, устанавливать причинно-следственные связи, выявлять закономерности музыкального развития, понимать логику музыкальной формы.
5. **Музыкальное воображение** — способность создавать в сознании музыкальные образы, предвосхищать развитие музыкального материала, представлять себе звучание различных инструментов, комбинировать музыкальные элементы в новые сочетания.
6. **Эмоциональная отзывчивость на музыку** — способность переживать музыкальные образы, чувствовать их настроение, характер, эмоциональную окраску. Этот компонент является основой музыкальности и важнейшим условием творческой деятельности.

7. **Креативность** — способность к порождению новых, оригинальных идей, к нестандартному мышлению, к самостоятельному поиску решений, к созданию собственных музыкальных продуктов (мелодий, ритмов, композиций, импровизаций).

Все эти компоненты взаимосвязаны и развиваются в процессе активной музыкальной деятельности. Творческие способности не являются врождёнными в полном смысле этого слова — они формируются и развиваются при наличии определённых задатков и благоприятных педагогических условий.

Важно отметить, что развитие музыкально-творческих способностей не сводится к развитию отдельных психических функций. Это целостный процесс, затрагивающий личность учащегося, его мотивационную сферу, эмоциональный опыт, ценностные ориентации. Творческая деятельность на уроке музыки должна быть не самоцелью, а средством гармоничного развития личности, её духовного обогащения и культурного роста.

Виды музыкальной деятельности как основа развития творческих способностей

Развитие музыкально-творческих способностей учащихся осуществляется через различные виды музыкальной деятельности, каждый из которых обладает специфическими возможностями для активизации творческого потенциала школьников.

Слушание музыки является основой формирования музыкальной культуры учащихся. В процессе восприятия музыкальных произведений школьники не только знакомятся с лучшими образцами мирового музыкального искусства, но и учатся анализировать, сравнивать, сопоставлять музыкальные явления, выражать свои эмоции и впечатления. Творческий характер слушательской деятельности проявляется в способности учащихся к интерпретации музыкального образа, созданию собственных ассоциаций и художественных представлений.

На уроках музыки можно использовать следующие творческие задания, связанные со слушанием:

- описать свои впечатления от прослушанного произведения в форме рассказа, эссе, рисунка;
- подобрать название к музыкальному произведению или его части;
- определить, какому литературному герою, времени года, событию соответствует данная музыка;
- сравнить две интерпретации одного произведения разными исполнителями;
- определить, какие средства музыкальной выразительности использовал композитор для создания образа;
- придумать продолжение музыкальной истории, начатой композитором;
- нарисовать «звуковую картину» услышанного произведения.

Такие задания способствуют развитию музыкального восприятия, мышления, воображения, эмоциональной отзывчивости, а также формируют умение выражать свои мысли и чувства в разных формах.

Пение как один из самых доступных и любимых видов музыкальной деятельности обладает огромным развивающим потенциалом. Хоровое и сольное пение способствует развитию вокально-хоровых навыков, музыкального слуха, чувства ритма, эмоциональной выразительности. Творческий элемент в пении может проявляться через импровизацию мелодий, исполнение песен с изменением темпа, динамики, характера, а также через создание собственных вокальных композиций.

Творческие задания, связанные с пением:

- спеть знакомую мелодию с изменением характера (грустно, весело, торжественно, таинственно);
- импровизировать мелодию на заданный текст;

- сочинить мелодию-ответ на мелодию-вопрос;
- исполнить песню в разных жанрах (марш, вальс, колыбельная);
- придумать ритмическое сопровождение к песне;
- разыграть песню в лицах, создав небольшую театрализованную композицию;
- сочинить второй голос к знакомой мелодии.

Пение развивает не только музыкальные способности, но и речь, дикцию, артикуляцию, дыхание, эмоциональную выразительность, коммуникативные навыки.

Игра на музыкальных инструментах, в том числе на детских музыкальных инструментах, открывает широкие возможности для творческого самовыражения учащихся. В процессе инструментального музицирования школьники осваивают навыки ансамблевой игры, учатся импровизировать, создавать собственные ритмические и мелодические рисунки. Особую ценность представляет использование элементов элементарного музицирования, основанного на методике К. Орфа, которая предполагает активное вовлечение детей в творческий процесс через игру, движение и речь.

Творческие задания, связанные с инструментальным музицированием:

- придумать ритмический аккомпанемент к песне или пьесе;
- импровизировать на заданную тему (например, «Дождик», «Танец», «Марш»);
- создать «звуковую картину» природы или сказочного сюжета с помощью разных инструментов;
- исполнить ритмическую партитуру, придуманную самими учащимися;
- организовать «шумовой оркестр» и сочинить для него композицию;
- импровизировать диалог между двумя инструментами.

Инструментальное музицирование развивает чувство ритма, слух, координацию, ансамблевые навыки, творческое мышление, умение работать в коллективе.

Музыкально-ритмические движения способствуют развитию чувства ритма, координации, пластичности, эмоциональной отзывчивости на музыку. Творческий характер этого вида деятельности проявляется в импровизации движений, создании танцевальных композиций, передаче музыкального образа через пластику тела.

Творческие задания, связанные с движением:

- импровизировать движения, соответствующие характеру музыки;
- придумать танец к песне или инструментальной пьесе;
- изобразить в движении различных персонажей (животных, сказочных героев, времена года);
- создать коллективную композицию на заданную тему;
- использовать элементы народных танцев в импровизации;
- передать в движении развитие музыкального образа.

Музыкально-ритмическая деятельность развивает телесную пластику, чувство ритма, эмоциональную выразительность, творческое воображение, навыки коллективного взаимодействия.

Импровизация и сочинение музыки являются высшими формами творческой деятельности учащихся на уроках музыки. Эти виды деятельности требуют от школьников определённого уровня музыкального развития, но вместе с тем они стимулируют развитие музыкального мышления, воображения, фантазии, способности к самостоятельному творческому поиску.

Импровизация может быть вокальной, инструментальной, ритмической, пластической. Она может быть свободной (без заданной темы) или тематической (на заданный сюжет, образ, жанр). Сочинение музыки предполагает создание учащимися собственных музыкальных произведений — мелодий, песен, пьес, ритмических композиций.

Творческие задания, связанные с импровизацией и сочинением:

- сочинить мелодию на заданный ритм;
- импровизировать мелодию на заданный текст;
- сочинить песню на собственный текст;
- импровизировать в заданном жанре (марш, вальс, колыбельная, полька);
- создать музыкальную сказку или музыкальную историю;
- сочинить вариации на знакомую тему;
- импровизировать в ансамбле с другими учащимися.

Импровизация и сочинение развивают музыкальное мышление, воображение, креативность, самостоятельность, уверенность в себе, коммуникативные навыки.

Интерактивные методы и педагогические технологии на уроках музыки

В условиях обновления содержания образования особую актуальность приобретают интерактивные методы обучения, направленные на активизацию познавательной и творческой деятельности учащихся. Рассмотрим наиболее эффективные из них применительно к урокам музыки.

Метод проектов позволяет учащимся самостоятельно или в группах создавать творческие проекты, связанные с музыкой: музыкальные спектакли, концерты, исследовательские работы о жизни и творчестве композиторов, мультимедийные презентации. Проектная деятельность способствует развитию исследовательских навыков, умения работать с информацией, презентовать результаты своего труда.

Примеры музыкальных проектов:

- «Музыка в жизни моей семьи» — исследование музыкальных предпочтений членов семьи, создание семейной музыкальной коллекции;
- «Композиторы Казахстана» — подготовка презентаций о жизни и творчестве казахстанских композиторов;
- «Музыка и природа» — создание мультимедийного проекта о связи музыки и природных явлений;
- «Музыкальные инструменты народов мира» — исследование и презентация различных музыкальных инструментов;
- «Мой музыкальный словарь» — создание иллюстрированного словаря музыкальных терминов.

Проблемное обучение предполагает создание на уроке проблемных ситуаций, требующих от учащихся самостоятельного поиска решения. Например, учащимся предлагается определить жанр музыкального произведения, сравнить интерпретации одного и того же произведения разными исполнителями, найти общее и различное в музыкальных произведениях разных композиторов.

Примеры проблемных ситуаций:

- Почему одно и то же произведение может вызывать разные эмоции у разных слушателей?
- Как композитору удаётся передать в музыке движение, покой, радость, печаль?
- Что общего между музыкой и поэзией, музыкой и живописью?
- Можно ли считать музыку «языком» и почему?
- Почему некоторые музыкальные произведения остаются популярными на протяжении веков?

Игровые технологии занимают важное место в музыкальном образовании школьников. Музыкально-дидактические игры способствуют развитию музыкального слуха, чувства ритма, памяти, внимания, а также создают эмоционально-положительную атмосферу на уроке. Игровые ситуации могут быть связаны с имитацией деятельности музыкантов, дирижёров, композиторов, что способствует погружению учащихся в мир музыкального искусства.

Примеры музыкальных игр:

- «Угадай мелодию» — узнавание знакомых мелодий по фрагменту;
- «Музыкальное лото» — соотнесение музыкальных фрагментов с карточками;
- «Ритмическое эхо» — повторение ритмического рисунка за учителем;
- «Музыкальные загадки» — определение инструмента по тембру;
- «Дирижёр» — имитация дирижирования под музыку;
- «Композитор» — сочинение мелодии на заданный ритм или текст.

Метод сотрудничества предполагает организацию групповой работы учащихся, в процессе которой они совместно решают творческие задачи, обмениваются идеями, поддерживают друг друга. Работа в группах развивает коммуникативные навыки, умение слушать и слышать других, толерантность, ответственность.

Примеры групповых творческих заданий:

- создание коллективной музыкальной композиции;
- подготовка и проведение музыкального конкурса или викторины;
- инсценирование песни или музыкальной сказки;
- создание «шумового оркестра» и исполнение композиции;
- подготовка музыкального поздравления к празднику.

Информационно-коммуникационные технологии открывают новые возможности для развития музыкально-творческих способностей учащихся. Использование музыкальных компьютерных программ, цифровых инструментов, мультимедийных ресурсов позволяет учащимся создавать собственные музыкальные композиции, аранжировки, электронные презентации, видеоклипы. Это способствует развитию цифровой грамотности, креативности, умения работать с современными технологиями.

Примеры использования ИКТ на уроках музыки:

- создание электронных презентаций о композиторах, музыкальных произведениях, инструментах;
- использование музыкальных редакторов для создания и аранжировки композиций;
- запись и обработка собственного исполнения;
- создание видеоклипов на музыкальные произведения;
- использование онлайн-ресурсов для слушания музыки, изучения нотной грамоты, музыкальных игр;
- проведение виртуальных экскурсий в музеи музыки, концертные залы, оперные театры.

Условия эффективного развития музыкально-творческих способностей

Успешное развитие музыкально-творческих способностей учащихся на уроках музыки возможно при соблюдении ряда педагогических условий.

Создание эмоционально-творческой атмосферы. Учитель музыки должен создать на уроке обстановку доверия, открытости, поддержки, поощрять инициативу и самостоятельность учащихся, не критиковать за неудачи, а помогать найти решение. Эмоциональный комфорт является важнейшим условием раскрытия творческого потенциала ребёнка.

Личностно-ориентированный подход. Необходимо учитывать индивидуальные особенности учащихся, их музыкальные интересы и предпочтения, уровень музыкального развития, темп работы. Дифференцированный подход позволяет каждому школьнику найти свой путь в музыкальном творчестве, реализовать свои способности в том или ином виде музыкальной деятельности.

Комплексность и системность. Развитие музыкально-творческих способностей должно осуществляться системно, в единстве всех видов музыкальной деятельности, с

опорой на межпредметные связи, с использованием разнообразных форм и методов обучения.

Активность и самостоятельность учащихся. Творчество предполагает активную позицию субъекта деятельности. Учащиеся должны быть не пассивными слушателями, а активными участниками музыкально-педагогического процесса, самостоятельно ставить цели, искать решения, оценивать результаты.

Постепенность и последовательность. Развитие творческих способностей — процесс длительный и постепенный. Необходимо соблюдать принцип «от простого к сложному», постепенно усложняя творческие задания, расширяя диапазон видов деятельности, увеличивая степень самостоятельности учащихся.

Интеграция искусств. Использование на уроках музыки связей с другими видами искусства (литературой, живописью, театром, хореографией) обогащает музыкальный опыт учащихся, развивает их эмоциональную сферу, воображение, ассоциативное мышление.

Рефлексия и самооценка. Важно учить учащихся анализировать свою творческую деятельность, оценивать её результаты, определять пути дальнейшего развития. Рефлексия способствует осознанию учащимися своих достижений и трудностей, формированию адекватной самооценки.

Практические рекомендации для учителей музыки

На основе проведённого анализа можно предложить следующие практические рекомендации для учителей музыки, направленные на развитие музыкально-творческих способностей учащихся:

1. Использовать на уроках разнообразные виды музыкальной деятельности, обеспечивая их интеграцию и взаимосвязь.
2. Включать в каждый урок творческие задания, соответствующие возрасту и уровню подготовки учащихся.
3. Применять интерактивные методы обучения: проекты, проблемные ситуации, игры, групповую работу, ИКТ.
4. Создавать на уроке атмосферу творчества, поддержки, эмоционального комфорта.
5. Учитывать индивидуальные особенности и интересы учащихся, использовать дифференцированный подход.
6. Поощрять самостоятельность, инициативу, оригинальность мышления учащихся.
7. Использовать связи музыки с другими видами искусства и учебными предметами.
8. Организовывать внеурочную музыкально-творческую деятельность: кружки, студии, конкурсы, концерты, музыкальные праздники.
9. Осуществлять рефлексию творческой деятельности учащихся, учить их самооценке и самоанализу.
10. Постоянно повышать свою профессиональную компетентность, осваивать новые педагогические технологии и методики музыкального образования.

Заключение

Таким образом, развитие музыкально-творческих способностей учащихся на уроках музыки в условиях обновления содержания образования требует комплексного подхода, включающего использование разнообразных видов музыкальной деятельности, интерактивных методов обучения, современных педагогических и информационных технологий. Урок музыки должен стать пространством для творческого самовыражения, эмоционального обогащения и личностного роста каждого ученика.

Музыкально-творческие способности представляют собой интегративное личностное образование, включающее музыкальный слух, чувство ритма, музыкальную память, мышление, воображение, эмоциональную отзывчивость и креативность. Их развитие

осуществляется в процессе активной музыкальной деятельности: слушания, пения, инструментального музицирования, движения, импровизации и сочинения.

Эффективными методами развития творческих способностей на уроках музыки являются метод проектов, проблемное обучение, игровые технологии, метод сотрудничества, информационно-коммуникационные технологии. Важными условиями успеха являются создание эмоционально-творческой атмосферы, личностно-ориентированный подход, системность, активность учащихся, постепенность, интеграция искусств, рефлексия.

Реализация этих задач возможна при условии высокого профессионализма учителя музыки, его готовности к инновационной деятельности и созданию творческой образовательной среды. Музыкальное образование, ориентированное на развитие творческой личности, отвечает современным требованиям общества и способствует формированию человека культуры, способного к самореализации, самовыражению и творческому преобразованию действительности.

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Teaching Based on Evidence in Medical Education: A Review of High-Value Teaching Methods

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The field of medical education is going through a basic and needed change. It is moving from old, time-based apprenticeships to frameworks focused on results and skills. At the center of this change is the use of teaching based on evidence (EBP), the careful use of teaching methods proven by research in the psychology of thinking, brain science, and the science of learning [1,2]. Medicine has long used evidence-based guidelines and randomized controlled trials to keep patients safe and make sure treatments work. But the educational systems that train future doctors are only now asking for the same level of strict science.

The old reliance on the "see one, do one, teach one" model of clinical exposure is increasingly seen as not enough for the complexity of modern healthcare [3,4]. As medical knowledge grows very fast, reliance on teaching methods based on gut feeling leads to big differences in the skills of graduates, too much cognitive load, and in the end, worse patient care [1–4]. Today, academic medicine must change the whole system. Lesson design and learning on your own must be guided strictly by data from research.

To meet the goal of creating a structural plan and giving a full analysis, this document is organized around a step-by-step framework. It goes from individual thinking processes to teaching in practice. By mapping the linked areas of cognitive load theory, retrieval practice, and active learning, this report gives a full review of high-value teaching methods designed to improve medical training.

Cognitive Foundations of Learning

Any effective teaching method must be based on the biological realities of how the human mind works. Decades of research in educational psychology show that lesson design must account for the specific ways information is taken in, processed, recalled, and stored [1,2].

Cognitive Load Theory and Working Memory Architecture

Cognitive Load Theory (CLT), first developed by educational psychologist John Sweller, says that human working memory is very limited in both amount and time [1,2]. Conscious processing of new information happens fully within working memory. Working memory can usually hold only about four pieces of new information at the same time [1,2]. Also, that information fades quickly, often after about 30 seconds, unless it is actively practiced [1,2]. In strong contrast, long-term memory acts as a nearly limitless store of cognitive schemas. Schemas are organized patterns of knowledge that experts use to quickly process complex environments and bypass the limits of working memory [1,2].

In medical education, trainees face a huge amount of highly complex information that often threatens to go beyond cognitive limits. Cognitive Load Theory groups the mental burden on these learners into three different areas. Educators must actively manage these areas to make

sure learning happens [1,2]. Intrinsic load is the natural difficulty and complexity of the material itself. It is driven by the number of interacting elements. It cannot be removed, but it must be managed by sequencing from simple to complex. A medical education example is understanding the connected pathophysiology of diabetic ketoacidosis, including acid-base balance and electrolyte shifts. Extraneous load is the cognitive burden caused by the teaching format, distractions, or poorly designed materials. It must be strictly reduced or removed to free up working memory capacity. An example would be a lecturer reading from densely packed slides filled with irrelevant graphics while speaking in a noisy simulation center. Germane load is the mental effort deliberately directed toward building schemas and connecting new information. It must be increased to help skills become automatic and to support long-term retention. A student actively comparing the clinical presentations of right-sided versus left-sided heart failure to build a strong diagnostic schema illustrates germane load. When lesson design ignores these principles, learners suffer from cognitive overload. This leads to worse learning, frustration, and more errors during both theoretical assessments and clinical practice [1,2].

The Empirical Failure of Minimal Guidance

A common trend in modern education over the last several decades has been the adoption of constructivist, experiential, discovery-based, and problem-based learning (PBL) models that rely on minimal instructional guidance [3,4]. Supporters of these models argue that students learn best when they are challenged to independently discover concepts and build their own solutions in information-rich settings.

However, a large body of research based on data, summarized famously by Kirschner, Sweller, and Clark, shows that minimally guided instruction is fundamentally incompatible with how the human mind works [3,4]. When novices are placed in minimally guided environments, such as being asked to diagnose a complex patient case without prior direct instruction on the underlying diseases, their working memory is quickly overwhelmed by the search for problem-solving strategies [3,4]. This search process uses all available cognitive resources. It leaves no capacity for actual schema formation or knowledge acquisition [3,4].

Studies show that medical students who receive minimally guided instruction often make more reasoning errors. They order a much higher number of unnecessary diagnostic tests at greater costs. They also need more time in clinical settings to reach competence compared to students who receive direct instruction [3,4]. Alarming, students in unguided environments tend to acquire unhelpful schemas and backward-directed reasoning patterns. These are famously hard to unlearn later in their careers [3,4]. The advantage of minimal guidance only appears when learners have already developed a high enough level of prior knowledge to provide their own "internal" guidance. This is known as the expertise reversal effect [3,4]. For novices and intermediate learners, direct instructional guidance is much better [3,4].

The Worked-Example Effect

In direct contrast to minimal guidance, the "worked-example effect" shows that novices learn far more effectively and efficiently when they study fully worked-out solutions to problems instead of trying to solve the problems themselves from scratch [5–7]. By studying a worked example, the learner's working memory is freed from the extraneous load of trial-and-error problem-solving search strategies [5–7]. Instead, cognitive resources can be directed fully toward germane load: understanding the underlying principles, recognizing the domain-specific rules, and building cognitive schemas [5–7]. In medical education, giving clear, step-by-step diagnostic reasoning examples before asking students to solve clinical cases greatly speeds up the move from novice to competent practitioner [5–7].

Self-Directed Knowledge Acquisition Strategies

The huge amount of declarative knowledge required in medicine requires very efficient self-directed study strategies. Adult learning theory and cognitive psychology have found specific high-value techniques that break the natural decay of memory. This is often described by the Ebbinghaus forgetting curve [8–10].

Retrieval Practice and Spaced Repetition

Retrieval practice, the act of actively recalling information from memory, is much better than passive study techniques such as restudying, highlighting, or rereading [9–11]. A full systematic review of 1,818 records analyzing distributed and retrieval practice in health professions education (with an average Medical Education Research Study Quality Instrument [MERSQI] score of 12.23 out of 18) found strong evidence supporting active recall [9]. The cognitive demand of the question type matters a lot: free recall and cued recall (e.g., short-answer or fill-in-the-blank questions) engage higher cognitive load and produce better final assessment results compared to simple recognition tasks like multiple-choice questions [9–11].

When retrieval practice is spaced over slowly increasing intervals, the learning effect is magnified greatly [8,9,12]. Spaced education, or distributed practice, allows a certain degree of forgetting to happen between study sessions [8,9,12]. This decay creates a "desirable difficulty" that forces the brain to work harder to access the information. This strengthens the neural pathways and ensures durable long-term retention [8,9,12]. Studies comparing spacing schedules show that expanding schedules (slowly increasing the inter-study intervals up to 29 days) are generally better than contracting or equal spacing schedules [8,12]. The integration of spaced retrieval into medical education is heavily supported by quantitative data. Interventions using spaced educational emails with clinical scenarios to medical students have shown significant improvements in end-of-year test scores. They yield high Cohen's effect sizes (up to 1.01) for long-term retention [8,12].

The arrival of digital spaced repetition software, most notably Anki, has put this teaching method into practice on a massive scale among medical students [13–16]. The software algorithmically schedules flashcard reviews based on the user's self-reported performance. This ensures that weaker concepts are reviewed often while mastered concepts are pushed further into the future [13–15]. Systematic reviews show a consistent, dose-dependent positive link between regular Anki use and standardized examination performance [13–15]. Medical students who use high-frequency, consistent spaced retrieval achieve significantly higher licensing exam scores compared to those using traditional massed studying. They even report secondary benefits such as better sleep quality [13–16]. Furthermore, spaced digital education has been shown to be better than massed online education not just for knowledge retention, but also for clinical behavior change and the acquisition of surgical skills among post-registration healthcare professionals [17].

Interleaved Practice and Discriminative Contrast

While spaced repetition controls the chronological timing of study sessions, interleaved practice controls how different topics should be sequenced [18–22]. Traditional education heavily favors "blocked practice," where a learner masters one topic completely before moving to the next (e.g., studying all cardiology pathologies, then all pulmonology pathologies: AAABBB). Interleaving, in contrast, mixes related concepts together in alternating sequences during a single study session (e.g., ABACBC) [18–22].

The main mechanism driving the success of interleaving is the "discriminative contrast hypothesis" [19,21]. In clinical medicine, diseases often present with overlapping symptoms (e.g., telling apart the fatigue and altered mental status linked with anemia, hypoglycemia,

hypothyroidism, and depression). Blocked practice allows students to build isolated schemas and relies on attention attenuation (where cognitive effort decreases because successive problems are identical). This gives the learner a false sense of fluency [19,21,23]. Interleaving prevents this by forcing the learner's working memory to continuously compare and contrast similar but distinct entities. It highlights the subtle differences required for accurate differential diagnosis [19,21,23].

A strong demonstration of interleaving in medical education involves electrocardiogram (ECG) interpretation. In controlled trials, medical students trained to interpret ECGs using an interleaved practice schedule vastly outperformed those trained using a blocked schedule [18,20,22,24]. On later assessments requiring the transfer of knowledge to new clinical presentations, the interleaved group achieved diagnostic accuracy rates of 46%, compared to only 30% for the blocked group - a huge relative performance increase of over 50% [18,20,22].

Notably, learners generally see interleaved practice as more difficult. They subjectively believe they are learning less effectively than when using blocked practice [23]. This metacognitive illusion requires medical educators to clearly explain the science of desirable difficulties to students. This keeps engagement and trust in the teaching process. It also ensures they do not go back to comforting but inefficient massed practice strategies [21,23].

Taken together, these self-directed strategies form a coherent set. Spaced repetition distributes study sessions over expanding intervals of time. It breaks the Ebbinghaus forgetting curve and uses desirable difficulty for memory consolidation [8,9,13–15]. Retrieval practice actively recalls information from memory rather than relying on passive recognition. It strengthens neural pathways, finds gaps in knowledge, and is highly effective with free recall questions. It yields better final recall and higher performance in clinical knowledge testing compared to restudying or reading texts [9–11]. Interleaved practice mixes different but related topics or problem types during a single study session. It promotes discriminative contrast and forces active comparison of subtle differences between similar categories. It produces greater than 50% relative increases in diagnostic accuracy for complex visual tasks such as ECG interpretation [18,20,22,24].

Active Learning and Classroom Didactics

The traditional didactic lecture has historically been the cornerstone of preclinical medical education. However, the theoretical basis of "teaching by telling" has been thoroughly challenged by active learning models. These models emphasize student engagement, collaborative problem-solving, and the immediate use of knowledge [25].

A landmark meta-analysis published in the PNAS by Freeman et al. (2014) clearly showed the superiority of active learning over traditional lecturing across Science, Technology, Engineering, and Mathematics (STEM) disciplines [25]. Analyzing 225 independent studies, the researchers found that active learning increased examination performance by 0.47 standard deviations. This is a metric large enough to raise average grades by half a letter grade across a whole cohort [25]. More strikingly, the meta-analysis revealed that the odds ratio for failing a course under traditional lecturing was 1.95. Simply put, students in passive lecture environments were 55% more likely to fail than their peers in active learning environments [25].

In undergraduate medical education, this overwhelming research evidence has sped up the adoption of the "flipped classroom" model [26,27]. In this model, foundational knowledge acquisition happens asynchronously before class. This is often done through assigned readings, video modules, or increasingly through educational podcasts [27–29]. Podcasting has become a highly regarded, evidence-based teaching method that matches adult learning theory. It offers an effective form of asynchronous passive learning that is not worse than traditional teaching methods for short- and long-term retention [28,29].

Classroom time is then kept for higher-order cognitive tasks, such as clinical case discussions, Team-Based Learning (TBL), and collaborative problem-solving [30]. It is vital to note

that the move to active learning must still respect Cognitive Load Theory [1,2]. Active exercises must be carefully scaffolded and structured rather than leaving students to struggle in unstructured discovery environments. When active learning is combined with deliberate structure, achievement gaps for underrepresented and low-income students are significantly reduced [31,32].

Conclusion

The adoption of teaching based on evidence in medical education is no longer an optional academic pursuit. It is a critical mandate necessary to cope with the exponential growth of medical knowledge and the increasingly complex demands of modern healthcare [1,2]. This full review highlights that successful educational design must fundamentally respect human cognitive architecture [1,2]. By acknowledging the severe limits of working memory, educators can abandon intuitive but ineffective minimal-guidance models in favor of structured, active learning and worked examples [3–7]. At the individual level, self-directed knowledge acquisition must be improved through spaced repetition, retrieval practice, and the discriminative contrast provided by interleaved learning [8,9,11,13,18,20,22]. Finally, transforming the traditional preclinical lecture hall into an active, flipped classroom ensures that foundational knowledge is consolidated and immediately applied to higher-order clinical problem-solving [25–27]. By committing to these rigorous, empirically validated instructional designs, medical education can ensure the development of highly resilient and competent future physicians [1,2].

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Advances, Mechanisms, and Trends in Practical Teaching in Higher Education: A Literature Review with a Focus on Contextual Adaptation to Medical Education in Kazakhstan

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Abstract

As the goals of higher education have increasingly shifted from knowledge transmission toward broader competency development, practical teaching has attracted growing attention across different disciplines. However, practical teaching is not a single instructional method. Rather, it can be understood as an umbrella concept covering pedagogical approaches that connect theoretical knowledge with active application, problem solving, collaboration, reflection, and authentic or simulated practice. This review synthesizes research on major forms of practical teaching in higher education, including problem-based learning (PBL), case-based learning (CBL), team-based learning (TBL), simulation-based learning (SBL), flipped learning, and project-based learning (PjBL). Existing evidence generally indicates favorable associations between these approaches and academic performance, higher-order thinking, collaboration, and professional competencies, although the strength and consistency of findings vary across methods and contexts. Meta-analyses and systematic reviews provide relatively substantial evidence for active learning, simulation, flipped learning, and TBL, while evidence concerning PBL and CBL suggests potential benefits but also considerable methodological and contextual variation. The literature further indicates that learning outcomes depend not only on the instructional model itself but also on cognitive engagement, prior knowledge, instructor scaffolding, feedback, and alignment among learning objectives, learning activities, and assessment. Important limitations remain, including inconsistent conceptualizations of practical teaching, reliance on short-term outcomes and self-reported measures, limited investigation of underlying mechanisms, and insufficient evidence regarding contextual transfer. These issues are particularly relevant to medical education in Kazakhstan, where internationally developed pedagogical approaches need to be adapted to local curricular, institutional, technological, and faculty conditions. Drawing on international evidence and available Kazakhstan-based studies, this review proposes a contextualized framework for practical teaching in medical immunology, integrating CBL, short problem-based activities, flipped learning, simulation, and assessment alignment. Future research should examine not only whether practical teaching is associated with improved learning outcomes, but also how, under what conditions, and for which learners particular approaches produce meaningful and sustainable learning outcomes.

Keywords: practical teaching; active learning; problem-based learning; case-based learning; team-based learning; simulation; medical education; immunology; Kazakhstan

1. Introduction

Higher education has traditionally placed considerable emphasis on systematic knowledge transmission through lectures, textbooks, and examinations. Although these approaches remain important for establishing disciplinary knowledge, the increasing complexity of professional practice has strengthened the need for students to apply knowledge rather than merely recall it. Practical teaching has therefore become an important component of contemporary higher education.

The concept, however, is broader than any single teaching technique. Active learning, for example, has been described as an instructional approach in which students engage cognitively and behaviorally in learning activities rather than simply receiving information through lectures [1]. Research in science, technology, engineering, and mathematics has associated active learning with higher examination and concept-inventory performance and lower failure rates compared with traditional lecturing [2]. At the same time, the literature does not support treating every interactive classroom activity as equivalent. Different approaches involve different levels of authenticity, structure, collaboration, student autonomy, and instructor guidance.

This distinction is particularly important for medical education. Medical students need to integrate basic scientific knowledge with clinical reasoning, communication, decision making, and professional practice. In immunology, for instance, students are expected not only to remember immune mechanisms but also to connect immunological processes with disease manifestations, laboratory findings, diagnosis, and treatment. A recent systematic review of immunology education identified patient-oriented problem solving, case-based learning, e-learning, audiovisual methods, and clinical simulation among the approaches used to support immunology learning, while also noting considerable variation in the available evidence [3].

Accordingly, the purpose of this review is not simply to determine whether practical teaching is “effective.” Instead, it addresses four related questions: (1) how practical teaching is conceptualized in higher education; (2) what major instructional models have been investigated; (3) what learning outcomes and mechanisms are associated with these approaches; and (4) how international evidence can be adapted to medical education, particularly medical immunology, in Kazakhstan.

2. Redefining Practical Teaching: From Hands-on Activities to Contextualized Learning

A central problem in the literature is the lack of a single, consistently applied definition of practical teaching. Prince's review of active learning demonstrated that student engagement can take many forms, including activities undertaken individually, collaboratively, or through structured classroom interaction [1]. More recent conceptual work has shown that even the term “active learning” is defined inconsistently across higher education research. Doolittle and colleagues reviewed 547 Scopus-indexed publications and found substantial variation in how active learning was defined, although student engagement, knowledge construction, and higher-order thinking appeared repeatedly across definitions [4].

This conceptual diversity matters because practical teaching is often used as a broad label for several distinct pedagogical approaches. Experiential learning environments, for example, can involve authentic tasks, reflection, learner agency, structured guidance, and interaction with real or simulated contexts. A scoping review by Duchatelet and colleagues identified cognitive, affective, metacognitive, and socio-communicative outcomes associated with different experiential learning environments, but the heterogeneity of the studies made direct comparison difficult [5].

A similar issue appears in engineering education. Tembrevilla and colleagues reviewed 220 studies of experiential learning and found substantial diversity in the forms of experiential learning used and in the theoretical foundations underpinning those activities [6]. This suggests that practical teaching should not be understood simply as “learning by doing.” Rather, the educational value of practical activity depends on how the activity is designed, what students are expected to learn from it, and how experience is connected to conceptual understanding.

Therefore, in this review, practical teaching is used as an umbrella concept referring to instructional designs that require students to actively apply, integrate, discuss, test, or reflect on disciplinary knowledge through problems, cases, teamwork, projects, simulations, or other structured forms of practice. Under this definition, PBL, CBL, TBL, simulation-based learning, flipped learning, and PjBL can be examined as related but non-identical approaches.

This conceptual clarification also prevents a common analytical problem: treating all active or experiential approaches as if they produced identical outcomes through identical mechanisms.

3. Major Models of Practical Teaching in Higher Education

3.1 Problem-Based Learning

Problem-based learning is one of the most established approaches within practical and active teaching. Hmelo-Silver described PBL as a learner-centered approach in which students work through complex problems while developing knowledge, reasoning, self-directed learning, and collaboration [7].

The theoretical rationale of PBL is particularly relevant to professional education because knowledge is introduced and reorganized around meaningful problems rather than presented exclusively as isolated facts. Students must identify what they know, determine what they need to learn, search for relevant information, and return to the problem with a more developed explanation.

Evidence from medical and nursing education is broadly supportive but should be interpreted cautiously. Ren and colleagues conducted a systematic review and meta-analysis of randomized controlled trials and found that PBL was associated with favorable knowledge and performance outcomes and higher student satisfaction. However, the review also identified high risk of bias in a substantial proportion of the included studies, considerable heterogeneity, and limitations in the overall quality of evidence [8]. Therefore, the available evidence supports the educational potential of PBL but does not justify assuming that PBL will automatically outperform conventional teaching in every setting.

For medical immunology, PBL can be particularly useful when a problem requires students to integrate immunological mechanisms with clinical manifestations. For example, a case involving recurrent infection may require students to connect innate and adaptive immune responses, laboratory findings, and possible immune deficiencies. The value of the activity would depend not only on the problem itself but also on the quality of the questions, information resources, and instructor guidance.

3.2 Case-Based Learning

Case-based learning occupies a related but distinct position. CBL generally organizes learning around carefully constructed cases that allow students to apply theoretical knowledge to realistic situations. Zheng and Mavis describe CBL in health professions education as an approach designed to bridge theory and practice, with potential relevance to knowledge development, critical thinking, clinical reasoning, collaboration, and engagement with real-world scenarios [9].

Compared with PBL, CBL may provide greater structure because the teacher can determine the case, learning objectives, sequence of information, and discussion questions in advance. This can make it particularly suitable for subjects in which students need to connect foundational scientific knowledge with clinical contexts.

This approach is highly relevant to medical immunology. A case involving systemic lupus erythematosus, primary immunodeficiency, autoimmune disease, or vaccine-related immune responses can be used to organize discussion around mechanisms, diagnostic tests, and clinical implications. Rather than asking students to memorize isolated pathways, the case creates a context in which the relationships among those pathways become meaningful.

The immunology education literature also suggests that patient-oriented and case-oriented approaches are among the methods increasingly used to move immunology teaching beyond traditional content delivery [3]. However, the available evidence remains heterogeneous, meaning that positive findings from individual studies should not be generalized to all forms of CBL.

3.3 Team-Based Learning

Team-based learning combines individual preparation, readiness assurance, structured teamwork, and application exercises. It therefore differs from general group work because the learning sequence and accountability mechanisms are more explicitly organized.

A meta-analysis by Liu and Beaujean found positive associations between TBL and academic outcomes, although the magnitude of effects varied across studies [10]. More recent evidence has continued to examine TBL across health professions and tertiary education. Roossien and colleagues reviewed TBL in health professions education and emphasized that outcomes are closely connected with how core conceptual elements of TBL are implemented [11]. A second-order meta-analysis by Kaya and colleagues likewise reported generally favorable academic outcomes associated with TBL while highlighting differences among the underlying meta-analyses and the need to consider contextual variation [12].

Evidence from Kazakhstan provides an additional contextual perspective. Saduakassova and colleagues reported the use of TBL in practical classes for fourth-year general medicine students at Asfendiyarov Kazakh National Medical University. Student feedback indicated that teamwork, discussion, and joint problem solving were perceived as helpful for understanding course material and motivating further independent study [13]. Because this was a local educational implementation rather than a controlled meta-analysis, it should be interpreted as contextual evidence rather than as proof of general effectiveness.

3.4 Simulation-Based Learning

Simulation-based learning provides students with opportunities to practice knowledge, skills, communication, and decision making in controlled environments. Simulation can range from low-technology models and standardized scenarios to virtual patients and sophisticated high-fidelity systems.

A meta-analysis by Chernikova and colleagues found that simulation-based learning in higher education was associated with favorable learning outcomes, while also demonstrating variation across different forms of simulation and learning conditions [14]. This variation is important because simulation is not a single intervention. The educational effect can depend on the realism of the scenario, the amount of guidance, opportunities for repeated practice, and especially the reflection or debriefing that follows the activity.

The Kazakhstan experience also illustrates how simulation can form part of broader curricular transformation. Riklifs and colleagues described the internationalization and transformation of medical education at Karaganda State Medical University, including integrated curricula, PBL, TBL, virtual patient cases, technology-based education, deliberate practice, and simulation [15]. This example demonstrates that practical teaching approaches are often introduced as part of a wider educational reform rather than as isolated interventions.

For medical immunology, simulation may be most useful when students need to interpret laboratory or clinical scenarios rather than simply perform physical procedures. For example, virtual patients can be used to simulate diagnostic reasoning around immune-mediated disease,

while laboratory simulations can provide structured practice in interpreting ELISA or PCR-related results.

3.5 Flipped Classroom and Project-Based Learning

Flipped learning changes the sequence of instruction by moving some content acquisition outside scheduled class time and using classroom time for discussion, application, problem solving, or collaborative activities.

A meta-analysis covering multiple disciplines and education levels found that flipped classroom approaches were associated with improved student performance compared with conventional arrangements [16]. However, flipped learning should not be equated simply with assigning videos before class. Its educational value depends on whether classroom time is subsequently used for meaningful cognitive and practical activity.

Project-based learning provides another route from knowledge acquisition to application. Guo and colleagues reviewed PjBL in higher education and found that studies reported a range of student outcomes, including academic, cognitive, affective, and behavioral outcomes [17]. At the same time, they noted variation in outcome measurement, with self-reported perceptions appearing frequently.

For medical immunology, a project could involve analyzing an immunological disease pathway, preparing a diagnostic algorithm, evaluating a vaccination-related question, or developing a patient education product. Such tasks can connect scientific knowledge with communication and problem-solving skills while also creating an authentic product.

4. Effects of Practical Teaching: From Academic Performance to Broader Competencies

4.1 Knowledge Retention and Academic Performance

The strongest evidence for practical teaching is currently concentrated around broader active-learning approaches rather than one specific method. Freeman and colleagues synthesized 225 studies involving STEM students and found that active learning was associated with higher examination and concept-inventory performance and lower failure rates than traditional lecturing [2].

A later meta-analysis focusing on humanities and social sciences also reported favorable academic achievement outcomes for active learning compared with traditional lecturing [18]. Taken together, these findings suggest that increasing students' active engagement can be associated with improved academic performance across different disciplinary settings.

However, this evidence should not be interpreted as demonstrating that every practical teaching model will produce the same effect. “Active learning” includes many different instructional designs, and the specific mechanisms may vary considerably between, for example, TBL, simulation, and PjBL.

4.2 Higher-Order Thinking and Clinical Reasoning

Practical teaching may be particularly relevant when learning objectives extend beyond factual recall. PBL requires students to identify information needs and reason through complex problems, while CBL encourages students to apply concepts to specific situations. Simulation adds the possibility of practicing decisions and responses in realistic or semi-realistic environments.

The literature on experiential learning also indicates that outcomes can extend beyond academic achievement to metacognitive and socio-communicative domains [5]. In health professions education, the CBL literature emphasizes its potential role in clinical reasoning and the integration of declarative and procedural knowledge [9].

Nevertheless, higher-order thinking is difficult to measure consistently. A study reporting greater student satisfaction or self-perceived confidence cannot automatically be interpreted as evidence of improved clinical reasoning. More robust assessment requires performance-based measures, structured tasks, or longitudinal evaluation.

4.3 Communication, Collaboration, and Professional Competencies

Many practical teaching models require students to explain their reasoning, negotiate with peers, distribute tasks, and present conclusions. These activities may create opportunities for developing communication and collaborative competencies.

TBL provides a particularly explicit structure for teamwork, while CBL and PBL can promote discussion and joint problem solving. Simulation can additionally incorporate communication under time or situational constraints.

However, group work does not automatically produce effective collaboration. Poorly structured group activities may result in unequal participation or superficial discussion. Consequently, collaboration should be treated as an intended learning outcome that requires appropriate task design and assessment rather than as an automatic by-product of placing students into groups.

5. Mechanisms and Conditions Influencing Effectiveness

5.1 Cognitive Engagement and Knowledge Integration

One possible mechanism underlying practical teaching is increased cognitive engagement. When students are required to explain, compare, interpret, solve, or apply information, they must process knowledge more actively than when they simply receive information.

This mechanism helps explain why practical teaching should not be reduced to physical activity. A student may be physically active during a classroom exercise while engaging in relatively little meaningful cognitive processing. Conversely, analyzing a complex clinical case without any laboratory manipulation may constitute highly practical learning if the task requires substantial application and integration of knowledge.

5.2 Prior Knowledge and Cognitive Load

Students do not enter practical activities with identical levels of background knowledge. Complex cases or problems may be productive for students who possess sufficient foundational knowledge but overwhelming for students who lack essential concepts.

This issue helps explain why the same instructional method can generate different outcomes across courses or student groups. In practical teaching, the amount of information presented, complexity of the task, sequence of activities, and degree of instructor support all need to be considered.

For medical immunology, this means that a case involving complement pathways, hypersensitivity, or immune deficiency should normally be preceded by sufficient foundational preparation. Otherwise, students may spend most of the activity trying to recall basic terminology rather than reasoning through the clinical problem.

5.3 Instructor Scaffolding and Feedback

The role of the instructor changes in practical teaching but does not disappear. Instead of functioning primarily as a transmitter of information, the instructor may act as a designer, facilitator, questioner, observer, and provider of feedback.

This is especially important in PBL and simulation. Students may need prompts that redirect discussion without giving away the answer. In simulation, structured debriefing can help students connect their experience with underlying principles.

The literature on experiential learning similarly suggests that learning environments differ in the amount of structure, authenticity, learner agency, and support they provide [5]. Therefore, the effectiveness of practical teaching should be considered partly in relation to the quality of instructional scaffolding.

5.4 Alignment Among Learning Objectives, Activities, and Assessment

Another central mechanism is constructive alignment. If the learning objective is the ability to interpret laboratory findings or reason through a clinical case, a purely recall-based final examination may not adequately capture the intended learning outcome.

Practical teaching therefore requires consistency among three elements:

Learning objectives — what students are expected to know or do;

Learning activities — how students practice those competencies;

Assessment — how achievement of those competencies is evaluated.

For example, if medical immunology teaching aims to develop clinical reasoning, students should have opportunities to analyze cases during learning and should encounter assessment tasks that require similar reasoning. This principle is also consistent with competency-oriented approaches to medical education, where curriculum, learning opportunities, assessment, faculty, and educational resources need to function as an integrated system.

6. Major Limitations in Existing Literature

6.1 Inconsistent Conceptualizations

The first major limitation is conceptual inconsistency. Active learning, experiential learning, practical teaching, problem-based learning, case-based learning, and other terms are sometimes used interchangeably even though they represent different levels of abstraction.

Doolittle and colleagues demonstrated substantial variation in definitions of active learning [4], while Tembrevilla and colleagues identified considerable diversity in experiential learning practices in engineering education [6]. Without clearer conceptual boundaries, comparing studies becomes difficult and meta-analytic findings may combine educational activities that are not genuinely equivalent.

6.2 Short-Term Evaluation and Self-Reported Outcomes

A second limitation concerns outcome measurement. Many studies evaluate immediate examination results, student satisfaction, perceived confidence, or self-reported engagement. These outcomes are useful but do not necessarily demonstrate durable learning or transfer to professional practice.

The review of PjBL by Guo and colleagues illustrates this issue because studies used diverse outcome measures, with self-reported measures appearing frequently [17]. Similar concerns apply to other practical teaching approaches.

Future studies should therefore include delayed post-tests, authentic performance tasks, structured assessments, and, where feasible, longitudinal measures.

6.3 Limited Explanation of Underlying Mechanisms

Many studies ask whether a teaching approach works but provide less information about why it works. For example, a positive outcome associated with TBL does not necessarily demonstrate whether the effect resulted from preparation, peer explanation, accountability, feedback, or increased classroom engagement.

This problem is important because instructional methods are complex interventions. Two institutions may both report using PBL while differing substantially in case design, student preparation, instructor facilitation, assessment, and available resources.

Consequently, future research should move beyond simple method-versus-control comparisons and investigate mediating and moderating mechanisms.

6.4 Limited Evidence on Contextual Transfer

Evidence generated in one educational system cannot automatically be transferred to another. Differences in class size, language, curriculum structure, faculty preparation, student expectations, technological infrastructure, and assessment culture can affect implementation.

The Kazakhstan literature provides an example of why contextual adaptation matters. Riklefs and colleagues described educational transformation at a specific medical university, while Saduakassova and colleagues reported a local TBL implementation at KazNMU [13,15]. These studies demonstrate that international educational models can be implemented locally, but they do not establish that identical implementation conditions exist across all Kazakhstani medical schools.

7. Contextualized Design Strategies for Practical Teaching in Medical Immunology in Kazakhstan

The evidence reviewed above suggests that practical teaching in Kazakhstan should not simply reproduce a model developed elsewhere. Instead, the instructional model should be adapted to course objectives, student preparation, faculty capacity, available technology, and institutional resources.

7.1 Case-Based Learning for Disease-Oriented Teaching

CBL is particularly appropriate for immunology because many immunological concepts become more understandable when linked to recognizable clinical problems.

A teaching unit could begin with a patient case and progressively introduce symptoms, laboratory results, immunological mechanisms, and treatment-related information. Students would then identify relevant mechanisms and explain how these mechanisms account for the observed findings.

This structure can bridge basic immunology and clinical medicine without requiring a fully open-ended PBL process.

7.2 Short Problem-Based Activities

For courses with limited classroom time, short problem-based activities can be used within a conventional course structure. In this review, the term “**micro-PBL**” is used descriptively for short, focused problem-based activities rather than as a claim that micro-PBL represents a standardized pedagogical model.

For example, a 15–20 minute activity could ask students to determine why a patient with a particular immune defect develops a specific infection. Students could first identify the relevant immune pathway, discuss possible explanations, and then compare their reasoning with the instructor's synthesis.

This format may provide some characteristics of PBL while remaining feasible within a larger lecture-based curriculum.

7.3 Flipped Classroom

Flipped learning can be used to move basic content acquisition outside the classroom. Students may review a short lecture recording, reading, diagram, or question set before class. Classroom time can then be devoted to cases, interpretation of laboratory data, and discussion.

For immunology, this is potentially useful because the subject contains substantial terminology and foundational mechanisms that students need to review before they can participate effectively in case analysis.

The important point is that the flipped component should not become simply “watch a video before class.” The classroom component must provide a meaningful reason for students to prepare.

7.4 Simulation and the Separate Role of OSCE

Simulation should be selected according to the learning objective and available resources. It can include virtual patients, laboratory scenarios, standardized cases, or more technologically advanced simulation systems.

In medical education, simulation and OSCE should not be treated as synonyms. Simulation is primarily a learning approach that creates a practice environment, whereas an OSCE is

principally a structured assessment format. An OSCE may incorporate simulated patients or stations, but its primary purpose is evaluation.

Therefore, in medical immunology, simulation could be used during learning to practice diagnostic reasoning or interpretation, while an OSCE station could later assess whether students can apply those competencies independently.

7.5 Assessment Aligned with Practical Learning

Assessment should reflect the competencies developed through practical teaching. If students spend substantial time analyzing cases, assessment should include case interpretation rather than relying entirely on factual multiple-choice questions.

A balanced assessment system might combine:

short-answer questions assessing foundational knowledge;

clinical or laboratory cases assessing application;

group activities assessing collaborative reasoning;

structured practical tasks assessing performance;

reflective questions assessing students' ability to explain their reasoning.

Such alignment would make practical teaching more than an additional classroom activity; it would integrate practical learning into the overall educational system.

8. Future Research Directions

Several directions emerge from the current literature.

First, future studies should adopt clearer definitions of practical teaching and distinguish among PBL, CBL, TBL, simulation, flipped learning, and PjBL rather than combining them into a single category.

Second, research should pay greater attention to mechanisms. Rather than asking only whether a method produces higher scores, studies should examine how preparation, cognitive engagement, peer interaction, feedback, scaffolding, and assessment contribute to learning.

Third, outcome measurement should become more multidimensional. Academic performance should be complemented by measures of reasoning, communication, collaboration, retention, and transfer.

Fourth, more longitudinal studies are needed. Immediate post-intervention outcomes may not demonstrate whether students retain knowledge or transfer it to clinical practice.

Finally, Kazakhstan requires more locally generated evidence. Existing local examples demonstrate that PBL, TBL, simulation, and technology-supported approaches can be incorporated into medical education [13,15], but systematic multicenter research is still needed to determine how these approaches function across different institutions, student populations, and resource conditions.

Medical immunology could serve as a useful research context because it combines foundational biomedical knowledge with clinically relevant reasoning. Future studies could compare different combinations of CBL, PBL, flipped learning, and simulation while examining not only examination performance but also diagnostic reasoning, knowledge retention, and student engagement.

9. Conclusion

Practical teaching in higher education should be understood as a broad pedagogical concept rather than as a single instructional method. The literature reviewed in this study includes active learning, PBL, CBL, TBL, simulation, flipped learning, and PjBL, each of which emphasizes different forms of student engagement and application.

Existing evidence generally indicates favorable relationships between practical and active learning approaches and academic or competency-related outcomes. However, the evidence is

not uniform, and methodological limitations remain. In particular, inconsistent definitions, short-term outcomes, self-reported measures, limited investigation of mechanisms, and insufficient attention to contextual transfer make it difficult to assume that one teaching model will work equally well in all educational settings.

The literature therefore supports a shift from asking which method is “best” toward examining which instructional design is appropriate for a particular learning objective, student population, and educational context. For medical education in Kazakhstan, this means adapting international approaches rather than mechanically reproducing them. In medical immunology, a combination of case-based learning, focused problem-based activities, flipped preparation, appropriate simulation, and aligned assessment may provide a practical framework for connecting foundational knowledge with clinical reasoning.

Future research should consequently focus on the interaction among instructional method, learner characteristics, instructor support, assessment, and institutional context. Such an approach would provide a stronger basis for developing practical teaching that is educationally meaningful, feasible, and responsive to the needs of medical education in Kazakhstan.

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- 19.

Pedagogical Monitoring as a Tool for Optimizing the Educational and Developmental Environment of a Higher Education Institution

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This article examines the theoretical and methodological foundations of pedagogical monitoring as a comprehensive tool for assessing and developing the educational space of higher educational institutions. The key components of the monitoring system, methodological approaches to its organization and implementation are presented. Special attention is paid to the integration of pedagogical monitoring into the structure of educational work, its role in creating a quality educational environment and students' personal development. Practical examples demonstrate the effectiveness of applying monitoring procedures in the context of modern higher education. [1,2,3]

Keywords: pedagogical monitoring, educational space, higher education, educational quality, assessment system, student personal development.

INTRODUCTION

Modern higher education is undergoing a large-scale transformation driven by changing social demands, socio-economic developments, and the challenges of the digital era. Under these conditions, traditional approaches to monitoring and evaluating educational and developmental activities are becoming insufficient, as they primarily focus on final outcomes rather than the dynamics of processes influencing student development. This creates a need for flexible monitoring systems that enable the systematic collection, analysis, and interpretation of data to support informed management decisions, improve the educational and developmental environment, and create conditions for the comprehensive development of students' personalities. [1,2,4]

The aim of this article is to examine pedagogical monitoring as a tool for optimizing the educational and developmental environment of a higher education institution, to explore its theoretical and methodological foundations, and to describe practical approaches to its organization and implementation.

THEORETICAL AND METHODOLOGICAL FOUNDATIONS OF PEDAGOGICAL MONITORING

Unlike traditional episodic control or assessment of students' knowledge, pedagogical monitoring focuses on the educational process and its dynamics rather than solely on measuring final

outcomes. Its distinctive features include continuity, systematic data collection, and the potential to identify trends and inform subsequent pedagogical decisions. [1,2,3]

The key characteristics of pedagogical monitoring include:

- **Systematicity:** regular implementation of diagnostic procedures according to a clearly defined framework.
- **Comprehensiveness:** consideration of the main components and dimensions of the educational and developmental environment.
- **Objectivity:** use of scientifically grounded assessment tools and a combination of quantitative and qualitative indicators.
- **Transformative orientation:** the use of monitoring results to inform the optimization and adjustment of the educational and developmental process. [1,2]

Comparison Parameter	Control	Diagnosis	Monitoring
Main question	What has been achieved?	Why has this result been obtained?	How does the result change over time?
Temporal aspect	Usually a single point in time	Assessment of the current state and its underlying causes	Systematic observation over time
Primary function	Assessment of outcomes	Identification of specific characteristics and causes of difficulties	Tracking dynamics and supporting decision-making
Outcome	Assessment result	Diagnostic conclusion	Data for process correction and improvement

Table 1. Distinction between control, diagnosis, and pedagogical monitoring

Component	Key elements
Academic environment	Curriculum, research activities, teaching culture
Sociocultural environment	Student clubs, volunteering, self-governance
Moral and ethical environment	Values, civic engagement, ethical standards
Information and digital environment	Digital resources, communication platforms, social media
Physical and infrastructural environment	Campus, facilities, sports infrastructure

Table 2. Components of the Educational and Developmental Environment of a Higher Education Institution

INTEGRATION OF PEDAGOGICAL MONITORING INTO THE EDUCATIONAL AND DEVELOPMENTAL ENVIRONMENT

The integration of pedagogical monitoring into the educational and developmental structure of a higher education institution involves a set of interrelated functions:

- **Diagnostic function:** identification of existing problems, risks, and positive trends, as well as the specific factors underlying students' difficulties.
- **Assessment function:** objective assessment of students' educational and developmental outcomes based on relevant quantitative and qualitative indicators.
- **Prognostic function:** identification of potential development trends and formulation of possible scenarios based on observed dynamics.
- **Corrective and managerial function:** development of timely management decisions and adjustment of educational and developmental programs based on monitoring results.
- **Informational function:** provision of feedback among the main participants in the educational process, including students, academic staff, and university administration. [1,2,3]

The comprehensive nature of pedagogical monitoring is therefore reflected in its ability to combine data collection, assessment, interpretation, and feedback into a continuous cycle of educational improvement. In this context, monitoring is not limited to identifying the current state of the educational and developmental environment but serves as a basis for evidence-informed adjustments and the continuous improvement of pedagogical practices. [2,3,7]

PURPOSE OF PEDAGOGICAL MONITORING

The purpose of pedagogical monitoring is to assess students' current level of knowledge and identify factors contributing to learning difficulties. These may include insufficient theoretical knowledge, incorrect application of algorithms, misunderstanding of tasks, or gaps in prerequisite knowledge. [3,7]

Systematic data collection over a defined period makes it possible to track changes in students' performance and identify relevant trends. The results of monitoring can then be used to adjust teaching methods, instructional approaches, and educational programs. [2,3,7]

ORGANIZATION AND STAGES OF IMPLEMENTING THE MONITORING SYSTEM

The process of developing an effective pedagogical monitoring system in a higher education institution involves the sequential implementation of five key stages:

[1. Goal Setting] → [2. Selection of Criteria] → [3. Selection of Methods] → [4. Data Collection] → [5. Analysis and Correction] [1,2]

1. **Goal setting:** clearly defining the objectives (for example, assessing students' level of social engagement or degree of adaptation).
2. **Development of indicators and criteria:** combining quantitative data (the percentage of students involved in extracurricular activities, attendance statistics) and qualitative criteria (the level of *soft skills* development, formation of values). [1,2]
3. **Selection of diagnostic tools:** the use of questionnaires, in-depth interviews, focus groups, participant observation methods, analysis of digital footprints, and student portfolios. [2,6,8]
4. **Data collection and processing:** regular collection and processing of data involving academic advisors, psychological support services, and student self-government bodies. [5,6,9]
5. **Analysis and presentation of results:** interpretation of data using mathematical and statistical methods and preparation of recommendations for university administration and academic departments. [1,2,4]

PRACTICAL EXPERIENCE IN APPLYING PEDAGOGICAL MONITORING

The practical application of pedagogical monitoring in the educational and developmental environment of a higher education institution can be implemented in several key areas:

- **Monitoring student satisfaction:** regular surveys of students from the first to the fourth year can help identify areas of satisfaction and concern in a timely manner, including living conditions in student residences, the psychological climate within academic groups, and the quality of academic advising. [3,9]
- **Assessment of engagement in extracurricular activities:** monitoring changes in students' participation in volunteering, sports activities, student organizations, and research societies makes it possible to assess the dynamics of their involvement in university life. [5,9]
- **Monitoring the development of transferable skills (*soft skills*):** systematic assessment of communication skills, leadership qualities, and teamwork skills can be conducted through project-based activities, group work, and reflective essays. [6,8]

The systematic use of these monitoring areas makes it possible to obtain comprehensive information about students' educational and developmental experiences and identify areas requiring further pedagogical support and organizational improvement. [2,3,6]

CHALLENGES AND PROSPECTS FOR DEVELOPMENT

Among the main challenges associated with the implementation of pedagogical monitoring are the resource-intensive nature of the process, the methodological complexity of measuring qualitative indicators such as students' moral and ethical orientations, as well as formal attitudes toward monitoring or resistance from some members of the academic and administrative staff. [1,4]

Prospects for further development are associated with the digitalization of the educational and developmental environment, including the integration of artificial intelligence algorithms for Big Data analysis, automated collection of students' digital activity data within learning management systems (LMS), and the development of unified digital profiles reflecting students' personal and educational development. [4,5,7,10]

At the same time, the use of digital technologies and artificial intelligence in education requires evidence-based implementation, appropriate governance, and consideration of educational needs and risks associated with excessive reliance on technology. [5,10]

CONCLUSION

Pedagogical monitoring represents a strategic tool for managing and optimizing the educational and developmental environment of a modern higher education institution. Its systematic implementation makes it possible to move from declarative approaches to educational and developmental work toward evidence-informed pedagogy based on reliable data, regular feedback, and consideration of students' individual needs. [1,2,3]

The comprehensive organization of monitoring contributes to improving the quality of the educational environment and creating favorable conditions for the development of students' professional competencies, personal potential, and overall development. [4,6,8]

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Pedagogical Design

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Pedagogical design is the preliminary development of the key details of the upcoming activities of students and educators. The pedagogical process is the primary object of design for the educator.

- A new, developing field of knowledge, a way of interpreting pedagogical reality (A. P. Tryapitsyna)
- An applied scientific field within pedagogy and organized practical activity, aimed at addressing tasks related to the development, transformation, and improvement of modern educational systems, as well as the resolution of contradictions within them (E. S. Zair-Bek)
- a method for standardizing and transmitting pedagogical and research activities (N. A. Masyukova)

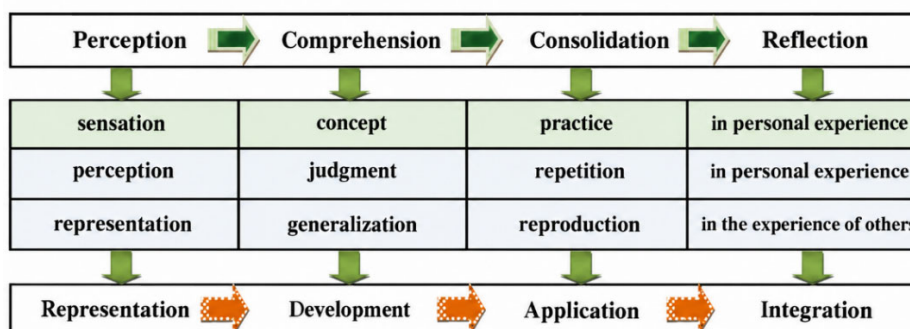
Stages of pedagogical design:

1. Pedagogical modeling (creating a model) involves formulating the goals (the general concept) for establishing pedagogical systems, processes, or situations, as well as the primary means of achieving them; this stage entails selecting the methodological system and instructional technology.
2. Pedagogical design (creating a project) involves further developing the established model and bringing it to the stage of practical application.
3. Pedagogical construction (creating a construct) involves further detailing the project to adapt it for use in specific conditions by the actual participants in the educational process. Structuring educational and pedagogical activities is a methodological task.

The essence of the pedagogical technology lies in executing the procedural sequence of **perception, comprehension, consolidation, and reflection**. This sequence can be implemented in various ways, the most productive of which is the technological approach

TEACHING TECHNOLOGY

THE PROCESS OF COGNITION (LEARNING)



STAGES OF THE METHODOLOGICAL SYSTEM

Knowledge
of representation

Knowledge
of concepts

Knowledge
of skills

Knowledge
of abilities

To perceive information and form a mental model of the object of activity, the student must possess a structured set of current goals established by the time data processing begins. These goals are formed during the initial stage of the learning activity: the conceptualization stage.

The second step (representing the "development" stage of the instructional methodology)—following the determination of data significance for the entity—involves the formation of concepts, judgments, and inferences. These are stored in memory elements linked to the goals established in the preceding step. The aggregate of previously stored and newly acquired data—associated by their storage purpose—is then evaluated to determine whether it is sufficient for selecting actions that move the entity closer to the corresponding goal.

Information templates are used to evaluate the potential outcome of actions aimed at achieving a specific goal, given certain data. The ability to construct dynamic templates depends on an entity's capacity to modify elements of its memory based on past experiences—specifically, which actions, performed with specific information, led to particular results. This process is characteristic of the third stage of learning: application. Performing exercises based on models (templates) and reinforcing the essence of concepts, judgments, and inferences fosters the formation of template models; the learner then uses these models to reproduce information and apply it in altered circumstances and real-life situations. In this way, templates become dynamic and evolve into a means of acquiring new knowledge—specifically, knowledge-based skills—serving as an ideal tool for learning.

If acquired knowledge and skills go unused, they lose their value and may devolve into mere capabilities. The very purpose of the integration stage is to maintain the active status of these skills through a kind of resonant reinforcement—specifically, by creating learning scenarios that compel the student to draw upon their knowledge and skills to solve practical problems in real-life situations.

1.1. Selection of an Educational Module

To select an educational module, it is necessary to analyze the curriculum and the principal literature on the subject, and to identify interdisciplinary and intra-disciplinary connections. Determine:

What are the goals and objectives of the educational module?

What are the main issues that will be studied according to the curriculum of the academic discipline?

Does the curriculum contain basic concepts that the student must master? If so, which ones?

Does this academic discipline involve discussion of controversial issues? If so, which ones?

How will the student's independent work be organized, and what will its content be?

Will students be offered creative assignments while mastering the curriculum of the academic discipline? If so, what kind?

How will ongoing assessment of knowledge acquisition be carried out?

How will the final assessment be conducted?

Which textbooks, teaching aids, and other publications will help the student master the curriculum of the academic discipline (primary and supplementary literature; periodicals)?

1.2. Creating the SLS of the Module

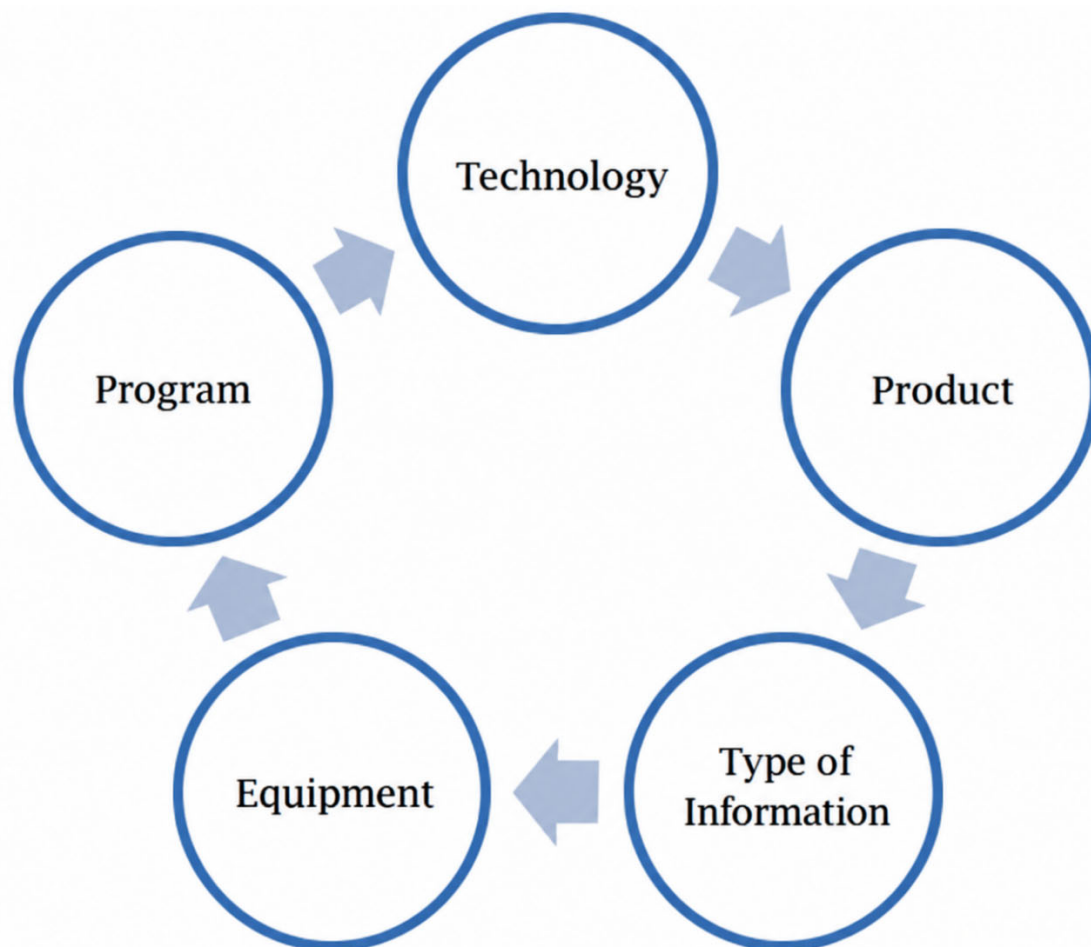
To create the structural-logical scheme (SLS) of a module, it is necessary to:

determine the overall target orientation of the module and its place within the educational-methodological complex (EMC) of the discipline;

identify the logical and didactic connections with supporting and supported modules;

establish connections between the educational module and the educational programs being implemented;

include connections with other teaching aids (reference materials, assignments, instructions) in the structure.



II.1. Basic Concepts

Compile a list for an alphabetical index or reference guide of the basic concepts, terms, and laws presented in the educational material of the module.

II.2. Development of Learning Situations and Creation of Technological Maps

A pedagogical situation is an integral part of the pedagogical process that characterizes its state at a particular time and in a particular space. Situations are always concrete; they are created or arise during a lesson, examination, excursion, and, as a rule, are resolved immediately. The design of pedagogical situations is part of the design of the process.

The significance of pedagogical situations is enormous. In fact, the pedagogical process manifests itself through them. This small unit concentrates all the advantages and shortcomings of the pedagogical process and the subsystem as a whole. Expressed as concrete educational relationships, pedagogical situations realize their possibilities.

The structure of pedagogical situations is outwardly simple. It includes two subjects of activity (the teacher and the learner) and the ways in which they interact. However, this simplicity is deceptive. The interaction of the participants in pedagogical situations is built upon the realization of their complex inner worlds, their upbringing, and their level of learning.

Pedagogical situations may arise spontaneously or be designed in advance. However, even those that arise spontaneously are resolved thoughtfully, with the way out of them designed in advance.

The phenomenon of the pedagogical situation lies in the fact that, although it is integrative in essence, neither a single situation nor even a set of situations can replace either a form or a system in pedagogy. A form cannot be created from situations, just as a pedagogical

system cannot be created from forms. The design of pedagogical situations takes place as a process of “fitting” the pedagogical process to specific people, with operational consideration of the actual situation at its smallest links.

Example of a technological map of a lesson:

Table 1.1. Technology for Programming Educational Activities in the Study of the Fundamentals of Computer Graphics

No.	Goal	Situation title	Teacher's activity	Learner's activity	Teaching aids
1	Develop an understanding of color models and types of computer graphics.	What do we need to know about light and color? “Which graphics are better?”	Demonstrates a presentation on the topic and engages students in a discussion. Justifies the use of various methods for describing color. Formulates scientific definitions of the concepts under consideration.	Express their point of view on the possibilities of using computer graphics in their professional work. Name examples of the use of computer graphics in education and printing.	Presentation “Graphics”

II.3. Selection and Creation of Teaching Aids

The purpose of this stage is to select (adapt to the learning situations) existing teaching aids or create teaching aids that will make it possible to implement the learning situation and the teaching technology as a whole.

III.1. Writing Methodological Guidelines for Learning Situations

The purpose of this stage is to substantiate the choice of means and methods for resolving the learning situation. In this part, the author defends the proposed teaching technology.

identification of common objects of analysis (phenomena, processes, problems, concepts, theories, etc.);

use in teaching aids of a set of problem situations that contribute to the formation of motives for cognitive activity appropriate to the pedagogical goals;

disclosure in teaching aids of ways of mastering the information and educational space available to learners;

use of questions and assignments, as well as other components of teaching aids, to develop the ability to use different types of information sources;

use of the texts of teaching aids, questions, and assignments to develop universal methods of activity and other elements of the cognitive foundation for solving problems;

creation of a unified orientation system in teaching aids (orientation symbols, headers, indexes, methods of structuring, preface, bibliography, table of contents);

use of a unified approach to the design of teaching aids;

use in teaching aids of a unified approach to creating an achievement ladder that allows learners to independently determine their position on this ladder and the level of competence they have achieved.

III.2. Creating a Reference Outline

The reference outline is created in the process of writing the teaching technology. It includes such structural elements as the SLS of knowledge, a glossary of terms, a brief (thesis-style) summary of the educational material, and literature.

The created module is an element of the educational-methodological complex, which minimally includes:

teaching technology for the teacher;
teaching aid for the learner;
teaching aids.

A textbook is a book containing a set of modules within a field of knowledge. Assessment should also be conducted by modules. This provides room for maneuver for teachers and students. If the student's reference outline is regarded as the SLS of their knowledge, skills, and abilities, then the creation of the reference outline is based on the SLS of the subject knowledge of the educational module. The reference outline serves as an auxiliary algorithm executed within limited time frames (a lesson) and forms part of the main algorithm describing the learning situation as a whole.

Let us try to define the basic rules (axioms) for creating a reference outline from a structural-logical scheme of knowledge.

1. Graph language.
2. Symbols used to form reference signals (visual sequence): pointer arrows, smileys, signs and symbols, comics, anecdotes, sayings, etc.
3. A thesaurus for learners.
4. The reference outline is created as part of a set of teaching aids and meets the didactic requirements for teaching aids.
5. The reference outline is created individually for each learning situation.
6. The reference (block) outline contains: the SLS, methodological recommendations for studying the educational module, a thesaurus, lecture theses, practical assignments, programmed assignments, and problems for independent solution.
7. It reveals the content of the educational module and provides a methodology for mastering it. It contains exhaustive information for the learner. It contains educational standards, i.e. defined ways of performing activities or abilities.
8. It contains assignments for independent creative activity: "They did not assign this to us; we did not cover this."
9. It contains one specific learning objective for a lesson. All pedagogical theories with their threefold goal and seven stages of cognitive activity are pure theory with which a teacher cannot work!
10. The minimum number of learning situations in a module equals the number of stages of the methodological system. Each element of the methodological system determines a learning situation (they do not need to be invented!!!). As a rule, more learning situations are allocated to the stage of materialization of knowledge (integration).

Recommendations for Creating an Orientation System and for Publication Style

In order for the reader to work conveniently with the publication, take care to provide an appropriate orientation system.

The publication should enable the reader to quickly and accurately find the material they need, establish its connection with other sources of information, and actively use all elements of the book intended for them. Therefore, include a preface, table of contents, sectioning, indexes, bibliography, orientation symbols, and headers.

In the preface, try to provide as much information as possible about the publication and its structure, explain the system of conventional symbols and forms of emphasis, and explain how

to use appendices, including indexes and the bibliography, as well as other textual and non-textual components.

Use a minimum number of styles. This will make it possible to create a clear document structure: part — section — chapter — paragraph — subparagraph. Use text color, bold, and italics to emphasize objects, but not underlining, since underlining will indicate the presence of a link. Use the capabilities of hypertext. The more varied the designations, the easier it is to navigate the text.

Graphics should be consistent: all pointers, figures, tables, callouts and comments, and organizational diagrams should be executed in a unified style. Repeated elements should have the same graphic expression and evoke analogous associations.

Materials presented in tables also facilitate perception (however, it is undesirable to have more than 4 columns of text in a table).

The material should be written in clear, lively language. Where possible, avoid long sentences (7–10 words) and a significant number of adverbial participial constructions in a single sentence.

Break the text into small sections, devoting each to a particular aspect of the problem under consideration. Give each section a heading. Such a text structure facilitates perception.

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Art History

HUMAN-AI CO-CREATION AS A NEW AESTHETIC PHENOMENON IN CONTEMPORARY GRAPHIC DESIGN

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Introduction

The development of artificial intelligence has become one of the most influential technological and cultural processes affecting contemporary visual culture. Generative artificial intelligence systems have moved beyond the automation of technical operations and entered areas traditionally associated with human creativity, including illustration, photography, advertising, visual communication, digital art, and graphic design.

Contemporary generative systems allow designers to produce visual interpretations from textual descriptions, transform existing images, explore alternative styles, combine heterogeneous visual references, and rapidly generate multiple variations of a single concept. Consequently, the creative process is increasingly characterised by continuous interaction between human intention and algorithmic generation.

This development raises an important question for contemporary art and design theory: should artificial intelligence be understood merely as another technological instrument in the historical development of graphic design, or does human interaction with generative systems constitute a qualitatively new form of creative practice?

The question is particularly relevant because graphic design has always developed in close connection with technological transformation. Printing technologies, photography, photomontage, offset printing, desktop publishing, digital imaging, and professional graphic software each changed the possibilities of visual communication. Nevertheless, generative artificial intelligence introduces a different type of transformation. Instead of merely extending the designer's technical capacity to manipulate visual elements, generative systems can participate in the production of visual alternatives themselves.

The designer can provide a conceptual direction, verbal prompt, reference image, compositional requirement, stylistic constraint, or other input, while the generative system produces visual interpretations that may subsequently influence the designer's original intention. The creative process therefore becomes iterative: intention generates an algorithmic response, the response stimulates interpretation, and human evaluation produces further modification.

The aim of this study is to examine human–AI co-creation as a new aesthetic phenomenon in contemporary graphic design and to identify how this interaction influences visual language, aesthetic decision-making, authorship, and the professional role of the graphic designer.

The following research questions guide the study:

1. How does generative artificial intelligence transform the visual and aesthetic language of contemporary graphic design?
2. What forms of creative interaction emerge between the designer and generative AI?

3. How does human–AI co-creation influence concepts of authorship and originality?
4. What remains specifically human within AI-assisted graphic design?

Human–AI Co-Creation in Contemporary Design

The concept of human–AI co-creation describes a creative process in which human and computational contributions interact across multiple stages of idea generation, visual exploration, evaluation, and refinement.

Traditional digital graphic design is largely based on direct manipulation. The designer selects colours, constructs compositions, modifies typography, creates vector forms, edits photographs, and controls the relationships among visual elements. Software operates primarily as an instrument that executes intentional commands.

Generative artificial intelligence changes this relationship.

The designer no longer necessarily determines every visual element directly. Instead, the designer may establish a conceptual and aesthetic framework and allow the generative system to produce alternative interpretations. These outputs can contain unexpected combinations of forms, textures, colours, spatial relationships, and stylistic characteristics.

The process may be represented conceptually as:

Human intention → prompt/reference → AI generation → aesthetic evaluation → human selection → modification → new generation → professional refinement → final visual solution.

This structure is important because it demonstrates that human–AI co-creation is not equivalent to pressing a button and accepting an automatically generated image. Meaningful co-creation involves repeated acts of human judgement.

The designer defines the communication problem, establishes the conceptual direction, evaluates visual alternatives, identifies aesthetically meaningful elements, rejects unsuitable results, corrects inconsistencies, and integrates selected material into a coherent design system.

AI therefore introduces a new form of visual dialogue. Algorithmic unpredictability can provide the designer with visual propositions that might not have emerged through conventional sketching or software-based processes. Human creativity, in turn, provides cultural interpretation, purpose, hierarchy, and meaning.

The aesthetic result emerges from the interaction between these two components rather than exclusively from either one.

Transformation of Visual and Aesthetic Language

One of the most important consequences of generative artificial intelligence is the expansion of visual variability.

Traditional graphic design requires the designer to develop visual alternatives individually. Although digital software significantly accelerated this process, the production of each meaningful alternative still demanded deliberate manipulation.

Generative systems can produce numerous variations within seconds. This changes the scale of visual experimentation.

A designer can investigate alternative compositions, colour relationships, illustration styles, textures, lighting conditions, visual metaphors, and representational strategies before selecting a particular direction.

However, quantity does not automatically produce aesthetic quality.

A generated image may be technically impressive while remaining conceptually superficial. It may contain visually attractive details but lack hierarchy, communicative clarity, cultural relevance, or stylistic consistency. Graphic design cannot therefore be reduced to image generation.

The aesthetic quality of graphic design depends on relationships among form, content, context, and communication.

From an art-historical perspective, AI-assisted design can be understood as contributing to several transformations of contemporary visual language.

First, it encourages **stylistic hybridity**. Generative systems can combine characteristics associated with different artistic periods, visual genres, media, and cultural traditions. This produces hybrid visual forms that challenge conventional stylistic categories.

Second, AI promotes **rapid aesthetic variation**. A single conceptual idea can be interpreted through numerous visual languages, making experimentation a continuous component of the design process.

Third, generative systems introduce **algorithmic unpredictability**. Unexpected visual outcomes may function similarly to accidental discoveries within artistic practice, providing new directions for subsequent human interpretation.

Fourth, AI increases the importance of **selection as a creative act**. When hundreds of visual possibilities can be generated, the ability to recognise which solution communicates meaning effectively becomes more significant.

Consequently, aesthetic judgement does not disappear in AI-assisted design. On the contrary, it becomes one of the designer's central professional competencies.

From Tool to Creative Partner

The traditional understanding of digital technology defines software primarily as an instrument controlled by the designer. Generative AI complicates this model because its output is not completely predictable.

A designer may formulate a detailed prompt and still receive an unexpected interpretation. The generated result may then influence the subsequent development of the concept.

This feedback loop creates a form of co-creative interaction.

However, describing AI as a “creative partner” requires conceptual caution. Artificial intelligence does not possess human cultural experience, biography, emotion, social responsibility, or artistic intention in the same sense as a human creator.

Its contribution is based on computational processing and probabilistic generation derived from learned patterns.

Therefore, human–AI co-creation should not necessarily imply an equal relationship between two equivalent creative subjects.

A more appropriate interpretation is that AI introduces a generative agency into the creative process while human beings retain intentional and contextual agency.

The distinction is significant.

AI can generate.

The designer must interpret.

AI can produce alternatives.

The designer must evaluate them.

AI can imitate or combine visual characteristics.

The designer must determine whether those characteristics are culturally, aesthetically, and communicatively appropriate.

AI can increase the range of possibilities.

The designer must transform possibility into meaning.

Human–AI co-creation therefore emerges from the interaction between **algorithmic possibility and human intentionality**.

Authorship and Creative Agency

The emergence of AI-generated visual content challenges traditional concepts of authorship.

In conventional graphic design, authorship is generally associated with the individual or team responsible for developing the concept and executing the visual solution. Generative

systems complicate this relationship because some visible components of the final work may originate from computational generation rather than direct manual construction.

This raises a fundamental question: who is the author of an AI-assisted graphic work?

A purely technological interpretation could attribute substantial creative importance to the generative system because it produces visible visual material. An opposing interpretation could consider AI only an advanced tool because it cannot independently establish the cultural purpose of the work.

Human–AI co-creation suggests a more nuanced model.

Authorship can be understood as a process involving different levels of creative agency. The designer may establish the problem, conceptual framework, aesthetic criteria, prompts, references, selection procedures, modifications, typography, layout, and final contextualisation. The generative system contributes visual alternatives within this framework.

The significance of human authorship therefore depends not merely on whether AI was used but on the extent and quality of human creative intervention.

This leads to the concept of **distributed creative production**, while not necessarily implying equal authorship.

The designer's authorship is particularly visible in five stages:

Conceptualisation — defining the idea, message, audience, and cultural context.

Direction — establishing visual and aesthetic parameters.

Selection — evaluating generated alternatives.

Transformation — modifying and combining generated materials.

Contextualisation — integrating the result into a meaningful system of visual communication.

These stages demonstrate why prompt writing alone cannot constitute the complete professional process of graphic design.

Comparative Visual Analysis

To understand the aesthetic characteristics of human–AI co-creation, it is useful to compare three models of visual production:

Human-led traditional design, AI-generated design, and human–AI co-created design.

In human-led design, the designer exercises a high degree of direct formal control. Composition, typography, colour, hierarchy, and imagery are intentionally constructed according to a defined communication objective. The strength of this model lies in conceptual coherence and contextual awareness, although visual exploration may require considerable time.

In predominantly AI-generated production, visual variability and speed increase significantly. Generative systems can rapidly create sophisticated imagery and unexpected stylistic combinations. Nevertheless, the resulting work may demonstrate inconsistencies in typography, symbolic meaning, visual hierarchy, cultural interpretation, or brand-specific communication.

Human–AI co-creation combines elements of both processes.

The generative system is used for visual exploration, ideation, stylistic experimentation, image synthesis, or the development of alternative compositions. The designer subsequently evaluates and transforms these materials according to professional principles.

From an aesthetic perspective, the third model has particular significance because it creates a dynamic relationship between unpredictability and control.

Algorithmic generation introduces variation.

Human judgement introduces hierarchy.

Algorithmic generation introduces unexpected associations.

Human interpretation establishes meaning.

Algorithmic generation accelerates experimentation.

Human authorship establishes cultural and communicative relevance.

The aesthetic character of human–AI co-created design therefore emerges not from automation itself but from the tension and interaction between computational variability and intentional design.

Methodology

This research applies a qualitative theoretical methodology grounded in art-historical and design analysis.

The methodological framework combines three approaches.

First, a **literature review** is used to examine contemporary academic discussions concerning artificial intelligence, creativity, human–AI co-creation, authorship, and generative design.

Second, **comparative visual analysis** is applied to distinguish aesthetic and procedural characteristics of human-led, AI-generated, and human–AI co-created graphic design.

The comparative criteria include:

- composition and visual hierarchy;
- colour relationships;
- stylistic coherence;
- originality and visual variation;
- artistic imagery;
- contextual relevance;
- communicative clarity;
- degree of human creative control.

Third, an **art-historical interpretative approach** is employed to position generative AI within the broader history of technological transformations in visual communication.

This methodological combination allows AI-assisted graphic design to be examined not merely as a technological development but as a transformation of artistic practice and aesthetic experience.

Discussion

The analysis indicates that the significance of generative AI in graphic design extends beyond improvements in efficiency.

Its more fundamental impact concerns the changing structure of creative activity.

For much of the history of graphic design, technological innovation expanded the designer's capacity to produce and manipulate visual form. Generative AI expands something different: the capacity to generate alternative visual possibilities before the designer has fully determined their formal characteristics.

This changes the relationship between intention and result.

In traditional practice, intention generally precedes execution. In human–AI co-creation, intention and execution can influence each other recursively.

The designer formulates an intention; AI interprets it; the generated image changes the designer's perception of the problem; the designer reformulates the intention; another generation follows.

Creativity therefore becomes increasingly iterative and dialogical.

At the same time, several aesthetic risks should be recognised.

Generative systems may reproduce stylistic conventions present in training data, potentially encouraging visual homogenisation. Easily generated spectacular imagery can also shift attention from conceptual depth toward surface aesthetics. Furthermore, insufficient understanding of cultural symbols may result in visually convincing but contextually inappropriate representations.

These limitations reinforce rather than diminish the role of the professional designer.

As the technical production of visual alternatives becomes easier, the ability to make meaningful aesthetic decisions becomes more important.

The designer's professional identity consequently shifts from “the person who produces images” toward “the person who constructs visual meaning.”

This distinction may become one of the defining characteristics of graphic design in the age of generative artificial intelligence.

Human Creativity in the Age of Generative AI

The increasing capabilities of generative systems inevitably raise concerns about whether artificial intelligence could replace graphic designers.

From the perspective developed in this article, this question is overly simplistic.

Graphic design is not merely the production of visually attractive images. It is a cultural and communicative practice involving interpretation, empathy, symbolic thinking, historical awareness, ethical judgement, and understanding of social context.

AI can participate effectively in formal experimentation and visual generation. Nevertheless, the designer remains responsible for deciding why an image should exist, what it should communicate, whom it addresses, what cultural meanings it activates, and whether its visual language is appropriate.

These dimensions constitute the human foundation of design.

The future of graphic design therefore may not be defined by competition between humans and artificial intelligence. It is more likely to be characterised by different configurations of collaboration.

In this context, the most significant professional quality will not simply be the technical ability to operate AI systems. It will be the ability to preserve creative intentionality while using algorithmic generation critically and selectively.

Conclusion

Generative artificial intelligence is contributing to a significant transformation of contemporary graphic design. Its influence extends beyond workflow automation and introduces new relationships among visual generation, aesthetic judgement, authorship, and creative agency.

Human–AI co-creation can be considered a new aesthetic phenomenon because it changes the mechanism through which visual form emerges. Instead of a linear transition from human intention to technical execution, the creative process increasingly develops through iterative interaction between human direction and algorithmic generation.

Artificial intelligence contributes speed, variability, unexpected visual combinations, and extensive possibilities for stylistic experimentation. Human creativity contributes intention, cultural interpretation, aesthetic judgement, conceptual coherence, ethical responsibility, and communicative meaning.

The aesthetic value of human–AI co-created graphic design therefore emerges at the intersection of these two forms of contribution.

This transformation also changes the professional role of the graphic designer. The designer increasingly functions not only as the producer of visual form but also as a director, selector, interpreter, curator, and critical evaluator of algorithmically generated possibilities.

At the same time, the development of generative technologies does not eliminate fundamental principles of graphic design. Composition, typography, colour, visual hierarchy, cultural context, and conceptual thinking remain essential because they provide the criteria through which generated visual material can be transformed into meaningful design.

Human–AI co-creation should therefore be understood neither as the replacement of human creativity nor as simple technological automation. It represents an emerging model of artistic production in which computational generation expands the space of visual possibility while human intentionality determines aesthetic and cultural significance.

Further research should examine specific examples of AI-assisted graphic design through systematic visual analysis and investigate how different levels of human intervention influence aesthetic quality, originality, cultural representation, and perceptions of authorship.

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Philological Sciences

THE TRAVEL POETRY IN LITERATURE OF KAZAKHSTAN ON THE EXAMPLE OF THE CREATIVE WRITINGS OF F. BAIGELDINOV AND F. TAMENDAROV

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Contemporary literature of Kazakhstan is characterized by a variety of artistic ways of understanding space and human experience. One of the productive directions of such understanding is the poetry of travel, where geographical movement gains the significance of aesthetic, cultural, and spiritual experience. Travel allows the lyrical hero to go beyond familiar spaces, see other countries and cities, connect with the history and culture of different peoples, and at the same time feel their own connection to their homeland in a new way. In this regard, the poems of Kazakhstani poets Farid Baigeldinov, included into the collection "Astral Gaze" (2006) [1], and Farhat Tamendarov in the collection "The Moment of Inspiration" (2010) are of particular interest [2].

Both poets' appeal to traveling is naturally connected to the biographical and cultural experience of a person at the turn of the XX-XXI centuries. However, their artistic approaches to travel differ significantly. F. Baigeldinov mainly focuses on the European cultural space – Paris, Berlin, Amsterdam, Brussels, Venice, Rome. His travel becomes a way of encountering history and art, and the cities he sees turn into a kind of cultural text. F. Tamendarov uses a much broader geographic range: Egypt, Dubai, Mauritius, Shanghai, Rome, London, the Maldives. His lyrical character finds himself in various parts of the world, experiencing space through direct impressions, movement, and sensory and visual details.

In F. Baigeldinov's poems, travel is portrayed as a crucial part of life experience. In a text about Europe, the character says that he has 'traveled across Europe / ... from top to bottom' [1, p. 86]. At the same time, the journey is connected with a challenge: the path is taken 'on the edge of human strength', and the hero calls himself a "Nomad / Among the seven winds of Europe". In this case, the word 'nomad' carries a special artistic meaning. It not only describes a person who is constantly on the move, but also brings to mind the cultural memory associated with the image of the nomadic world. The hero from Kazakhstan finds himself in European space, yet his identity does not disappear; on the contrary, it becomes especially noticeable precisely in the situation of being away from his homeland.

F. Baigeldinov's journey has a clearly pronounced cultural focus. The lyrical hero perceives Europe not just as a collection of geographical objects, but above all as a space of art. He talks about 'ancient' Europe and its art, which seems to become an object of direct spiritual consumption: the hero soaks up cultural impressions 'by the handful'. In this way, the journey becomes a form of aesthetic knowledge of the world.

This feature is particularly clear in the poem "Streets of Paris". Paris is depicted here as a living organism: the subway lines remind the lyrical hero of a "scheme of veins and arteries", and

life pulses through the "veins and arteries of Paris" [1, p. 87]. Such a metaphorization of the city allows to move away from a static depiction. Paris becomes a living being, where the present and the past, life and death, art and tragedy coexist.

The urban space in the poem is filled with historical and cultural symbols. The streets of Paris hold memories of victories and defeats, revolutions, violence, and human tragedies. Notre-Dame, the Louvre, the Eiffel Tower, Montmartre, the Tuileries, Rodin's sculptures, and the works of Van Gogh, Modigliani, and Toulouse-Lautrec form a single cultural field. In this way, the hero's journey turns out to be simultaneously a journey through the history of European culture.

It's worth noting that F. Baigeldinov doesn't just list the sights. Each place is given an emotional and associative meaning. For example, Pigalle Square in Paris, the music of Yves Montand and Édith Piaf, the accordion, and artists' works all become part of a single image of the city. The space of Paris is perceived as a whole: visual, sound, and emotional impressions blend together. That's why F. Baigeldinov's travel poetry is built less on describing what he sees and more on experiencing it artistically.

The theme of parting plays a special role. In the finale of 'Streets of Paris', the hero, saying goodbye to the city, wants to whisper his love confession to its streets, quays, and bridges. Moreover, he mentally sets up a new meeting with Paris – "in this life or another". The journey doesn't end with a physical departure. The space he's seen continues to exist in memory and becomes part of a person's inner world.

This connection between travel and memory is especially noticeable in the poem "Berlin". The perception of the city is organized through a shift in time perspectives: before the character's eyes appear ruins and memories of the war, and then the modern Berlin with the Spree embankments, the Museum Island, and Pushkin Alley. The city is presented as a space where historical layers coexist. Modernity does not erase the memory of the past but engages in a dialogue with it.

The most important outcome of the journey is the emotional appropriation of foreign space. Berlin gradually becomes for the protagonist no less familiar and lyrically significant than Paris. At the end of the poem, the love for the city gets a personal explanation: Berlin is connected to the memory of a loved one, whose smile seems to light up the city. Therefore, the geographical space turns into a space of memory. The city becomes dear not only because of its historical and cultural landmarks but also because of the protagonist's personal experiences.

A different tone is characteristic of F. Tamendarov's poems. Even the sheer variety of geographical locations – Egypt, Dubai, Mauritius, Shanghai, Rome, London, Maldives – shows the poet's desire to embrace a wide world of travel. At the same time, the lyrical hero maintains a clear connection to Kazakhstan. In the poem "In Egypt", sunny Egypt is contrasted with distant, winter Kazakhstan: "somewhere a snowstorm rages, / Far away is my beloved Kazakhstan" [2, p. 28]. As a result, foreign lands are experienced as both appealing and far from home.

In the Egyptian cycle, the journey acquires the character of an encounter with ancient culture. The pyramids, Tutankhamun, Anubis, Sphinx, Khufu, Nefertiti, papyrus all become elements of a poetic space. However, F. Tamendarov does not turn the poem into a historical reconstruction. He is interested in the emotional reaction of a modern person who gets the chance to directly touch the cultural heritage of the past. That's why the motif of the journey is combined with the motif of fulfilling a dream: the hero feels like someone who has managed to make their way and see one of the great wonders of the world.

In the poem "Dubai", the approach to depiction is different. The historical and cultural perspective is practically absent; bodily sensations come to the forefront. The white sun, tropical heat, hot water, foam, and the touch of water on the body create an image of space experienced directly through physical feeling. The journey turns out to be a way to live the fullness of the

present moment. This aligns with the poet's general focus on capturing the instant, which is particularly expressive in relation to the title of the collection 'A Moment of Breath.'

In "Mauritius" the exotic setting is also built on sensory details: white sand, emerald palms, the ocean, coral, birds, fish, flowers, and sunrises. However, the poet deliberately introduces elements of humor and everyday tone into this idyllic image. The biblical story of Adam and Eve becomes the basis for a playful interpretation of the paradise island. Thanks to this, the journey acquires the nature of a light, carefree game with cultural associations.

The image of Shanghai is especially interesting in the context of travel poetry. The lyrical hero enters the Chinese space with a sense of direct physical contact: he breathes in the air of China 'with his whole chest'. The advertising characters, the movement of cars, skyscrapers, rainy fog, the Yangtze River appear before him. The city space is perceived dynamically, through movement and changing impressions.

However, the climax of the poem is not tied to Shanghai itself, but to the unexpected return to the native world. From the height of the city, the hero sees the "Eastern Paris" and then mentally moves back to his native Tengri. This episode is fundamentally important for understanding F. Tamendarov's artistic model of travel: the farther the hero moves away from Kazakhstan, the more significant the image of his homeland becomes. The journey doesn't break the connection to his homeland; it strengthens it.

In the poem "Rome" the foreign city acquires human-like traits. The protagonist addresses it as if it were a living companion: "Well, hello, eternal city!" [2, p. 34] and invites it to go for a walk together. Rome turns out to be not a museum object, but a kind of partner for the lyrical hero. The Colosseum, the Pantheon, the Sistine Chapel, Verdi's music, and the atmosphere of the Italian city all become part of the hero's personal experience.

This way of depicting things distinguishes F. Tamendarov from F. Baigeldinov. While for the latter, the city is more often seen as a complex cultural and historical text that needs to be thought over, for F. Tamendarov it becomes a space for friendly meetings, walks, and personal impressions. His lyrical hero finds it easier to get in direct contact with the foreign world.

This trend is especially noticeable in the poem "London". Here, London acquires human characteristics: it is "restrained, like a prim lord" [2, p. 37], yet at the same time, a free wind can be felt in its 'veins'. The city's image includes Hyde Park, Kensington, Buckingham Palace, Trafalgar Square, the gallery, Big Ben, and Baker Street. But the cultural and tourist symbols don't overshadow the personal aspect. The protagonist has a sort of dialogue with the city and at the end playfully admits being ready to stay in it.

F. Tamendarov mainly creates a dynamic model of a journey. The world in his poems changes quickly, and the lyrical hero moves from one point to another. Important tools include listing, visual detail, conversational tone, humor, anthropomorphizing cities, and immediate emotional reactions. Geographic names not only indicate a location but also become kind of signs of the cultural space.

When comparing the two poets, the question of the relationship between the "foreign" and the "own" turns out to be especially important. Both authors constantly take the reader beyond Kazakhstan, but the foreign space doesn't exist in isolation for them. For F. Baigeldinov, Europe becomes a part of his personal biography and memory, while for F. Tamendarov, exotic and European countries are constantly related to Kazakhstan.

In F. Baigeldinov's work, this connection is expressed more indirectly. His lyrical hero acts as a nomad, moving around Europe but keeping his own cultural identity. It's especially revealing that the poem about Berlin ends with the line "Berlin – Alma-Ata", meaning that a foreign place is directly linked to his hometown. The very mention of this geographic pair becomes an artistic symbol of dual belonging: the hero is physically in one place, but his memory and emotional experience connect different parts of the world.

F. Tamendarov's connection to Kazakhstan is expressed more directly. In "Egypt", alongside the image of an ancient civilization, his beloved Kazakhstan appears; in "Shanghai" among impressions of the huge Chinese metropolis, the image of his native Tengri comes up. Travel here becomes a way to see his homeland from a distance.

It is also significant that both poets use the road as a way to structure the lyrical plot. In F. Baigeldinov's poems, movement between cities creates a kind of European map: Paris, Berlin, Amsterdam, Brussels, Venice, and other cities form a sequence of personal impressions. In F. Tamendarov's poems, the world's map is even broader: Europe, Asia, Africa, and the island spaces of the Indian Ocean. But in both cases, geography is subordinated to lyrical logic: what matters is not the mere fact of visiting a country, but the inner state that arises as a result of encountering it.

Differences also show up in their attitude toward time. For F. Baigeldinov, the present almost constantly interacts with the past. Paris exists both as a modern city and as a space of revolutions, art, music, and historical memory; Berlin combines the memory of the war with the image of a contemporary city. Venice is also depicted through the layering of different time periods: carnival culture, medieval atmosphere, love, and legends come together to create a complex picture of the city.

In F. Tamendarov's work, even where ancient civilizations appear, as in the poem "In Egypt", the past rather serves as a vivid cultural backdrop for the experiences of a modern traveler. The main value of traveling is connected to experiencing the present – having the chance to see, feel, breathe in the air of a new place, and enjoy the joy of discovery. In this respect, the poem titles are telling, directly marking geographical points: "In Egypt", "Dubai", "Mauritius", "Shanghai", "Rome", "London", "Maldives". This kind of nomination gives the cycle the feel of a kind of poetic travel album. Each poem captures a separate travel moment, a separate impression.

The emotional tone of the works also differs. F. Tamendarov's works are characterized by lightness, optimism, a playful spirit, and sensual spontaneity. The journey is associated with fulfilling desires, relaxation, love, and enjoyment of the world's beauty. In the poem about the Maldives, the flight over the Himalayas and the subsequent arrival on the island end with the realization that for happiness, the hero needs to be there with their loved one.

For F. Baigeldinov, travel is often accompanied by shades of melancholy, nostalgia, and farewell. Amsterdam is associated with loneliness and a 'distant path', Brussels appears in a state of nostalgic dreaming, and saying goodbye to Paris is filled with love and sadness.

Thus, comparison of the poems of F. Baigeldinov from "Astral Gaze" and F. Tamendarov from "The Moment of Inspiration" allows to highlight two different, yet complementary, models of travel poetry in Kazakh literature. F. Baigeldinov is characterized by an intellectual-historical and cultural approach to space: Europe is perceived as a vast text of art and history, and the journey is seen as a return to cultural memory while also being a part of personal biography. F. Tamendarov, on the other hand, is more associated with the immediacy of impressions, sensory vividness, movement dynamics, humor, and a playful spirit. His character engages with the world's diversity with open curiosity, turning the journey into a series of vivid moments. Despite their differences, both poets share a fundamentally important trait: traveling does not mean losing connection with one's homeland. On the contrary, encountering other countries allows one to feel their own cultural space more strongly.

The poetry of travel in the presented collections, therefore, comes across as the poetry of a person encountering foreign culture, history, the beauty of the world, and, ultimately, with oneself. This is exactly what makes it important for contemporary Kazakh literature: while opening up the space of the world, it simultaneously brings the lyrical hero back to questions about their own cultural and spiritual coordinates.

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From Social Media to the Mind: The Influence of English-Language Content on Kazakh Adolescents

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The rapid expansion of English-language content on globally popular social media platforms has become a defining feature of adolescent life in Kazakhstan, a multilingual post-Soviet nation where Kazakh, Russian, and English coexist within a shifting linguistic hierarchy. This article presents a systematic narrative review examining how sustained exposure to English-language social media content shapes the linguistic repertoires, cognitive processing, and psychosocial development of Kazakh adolescents. Drawing on scholarship in second language acquisition, sociolinguistics, digital literacy, and developmental psychology, the review synthesizes findings from studies conducted in Kazakhstan and in comparable multilingual English-as-a-foreign-language contexts, including Thailand, Mongolia, and other post-Soviet settings. The review was guided by three research questions: first, how does English-language social media content function as an informal language-learning environment for Kazakh adolescents; second, what cognitive and psycholinguistic mechanisms underlie the incorporation of English lexical and discursive patterns into adolescents' everyday Kazakh-Russian bilingual speech; and third, what psychological and identity-related consequences of this exposure have been documented in the literature. Findings indicate that English-language content functions simultaneously as a vocabulary-building resource, a marker of social prestige, and a trigger for code-switching behavior that reshapes adolescents' trilingual repertoires. The review further identifies documented associations between heavy screen-mediated engagement and declines in adolescent psychological well-being, alongside a persistent shortage of Kazakhstan-specific empirical research that isolates English-language content from broader digital media use. The article concludes with a proposed research agenda and pedagogical recommendations for embedding critical digital literacy within Kazakhstani English-language education, emphasizing the need for longitudinal, mixed-methods studies grounded in local trilingual realities.

Keywords: English-language social media, adolescent bilingualism, Kazakh youth, code-switching, digital literacy, second language acquisition, psychological well-being, trilingual education

Introduction

Over the past decade, the linguistic environment inhabited by Kazakhstani adolescents has been transformed by the near-universal availability of smartphones and social media platforms such as Instagram, TikTok, and YouTube. Whereas earlier generations of Kazakh youth encountered English primarily through classroom instruction and printed textbooks, today's adolescents are exposed to English several hours a day through algorithmically curated video, music, gaming communities, and peer conversation conducted partly or wholly in English. This shift occurs within a distinctive sociolinguistic setting: Kazakhstan's constitutionally trilingual policy positions Kazakh as the state language, Russian as a language of interethnic communication, and English as the language of international integration and the knowledge economy. Adolescents therefore navigate three languages simultaneously, and the informal, unsupervised nature of social media use means that English increasingly enters this trilingual repertoire outside any pedagogical framework.

The pedagogical literature has long recognized social media as an informal second-language-acquisition environment, capable of expanding vocabulary, increasing exposure to authentic discourse, and raising learner motivation. At the same time, developmental psychology has documented associations between heavy adolescent screen use and shifts in mood, self-esteem, and attentional regulation. What remains comparatively underexamined is the intersection of these two literatures within a specific multilingual post-Soviet context such as Kazakhstan, where English is not a heritage or majority language but a prestige code entering an already complex Kazakh-Russian bilingual landscape. Existing Kazakhstani sociolinguistic scholarship has documented the symbolic prestige attached to English among Kazakh youth and has traced patterns of Kazakh-Russian code-switching in considerable detail, yet few studies have systematically connected these findings to the specific mechanism of English-language social media consumption, or to its cognitive and psychological correlates.

This article addresses that gap through a systematic narrative review of the international and Kazakhstani literature. The purpose of the review is threefold: to characterize how English-language social media content functions as an informal linguistic input source for Kazakh adolescents; to examine the psycholinguistic and cognitive mechanisms through which this input is incorporated into adolescents' existing trilingual repertoires, including code-switching and lexical borrowing; and to assess what is currently known about the psychological and identity-related consequences of sustained engagement with English-language digital content. Because Kazakhstan-specific empirical studies addressing all three dimensions simultaneously remain scarce, the review deliberately triangulates Kazakhstani sociolinguistic research with international scholarship on social media, second language acquisition, and adolescent digital well-being. The resulting synthesis is intended to inform both future empirical research and the practical work of English-language educators operating within Kazakhstan's trilingual education system, including the training of pre-service teachers who will need to address informally acquired, socially prestigious, and sometimes non-standard English forms already present in their students' speech before formal instruction begins.

The remainder of the article proceeds as follows. The literature review situates the present inquiry within four bodies of scholarship: research on social media as an informal language-learning environment, internet linguistics, Kazakhstani sociolinguistics, and developmental psychology of adolescent media use. The methods section describes the systematic narrative review procedure adopted to synthesize this heterogeneous literature. The results and discussion section presents four interrelated themes emerging from the synthesis, and the conclusion translates these themes into a concrete agenda for future empirical research and classroom practice within the Kazakhstani context.

Literature Review

Research on social media as a site of informal second language acquisition has grown substantially over the past decade. Reinhardt's influential review of blogs, wikis, and social networking in language teaching established that platforms offering authentic audiences and interactive feedback loops can meaningfully extend classroom-based instruction, particularly for vocabulary and pragmatic competence. Barrot's systematic review of social-media-mediated language learning between 2008 and 2019 similarly concluded that exposure to user-generated English content correlates with gains in vocabulary, motivation, and willingness to communicate, while also flagging risks of exposure to non-standard or informal registers. More recent qualitative work, such as Apridayani and Sompuwet's interpretive study of Thai adolescents, extends this line of research by showing that teenagers actively and strategically use platforms including TikTok and Instagram to build vocabulary and intercultural awareness, while simultaneously reporting difficulty separating informal digital registers from the academic English required in school settings.

A parallel body of scholarship, associated with the field of internet linguistics, examines how digitally mediated communication reshapes language itself. Crystal's foundational account of internet linguistics argues that computer-mediated communication constitutes a distinct linguistic register, blending features of speech and writing, and that this register exerts a measurable influence on users' broader linguistic behavior, including in second-language contexts. This theoretical framing is important for understanding Kazakh adolescents' English exposure, because the English they encounter on social media is rarely standard, edited prose; it is typically informal, abbreviated, and highly vernacular, characteristics that appear to accelerate uptake of certain lexical items while also complicating adolescents' command of formal registers.

Within Kazakhstan itself, sociolinguistic scholarship has focused primarily on the Kazakh-Russian dynamic, though English increasingly appears within it. Baimurzina and colleagues documented the continued functional dominance of Russian among Kazakh student youth, while more recent survey research by Khamit and colleagues found that Kazakh youth increasingly symbolize the Kazakh language as an identity marker even as Russian retains instrumental value. Zharkynbekova and colleagues, analyzing ethno-linguistic identity among Kazakhstani student youth in a large, recent multi-regional survey, describe a linguistic landscape in active transition, shaped strongly by education and family language policy, into which English is increasingly inserted as a marker of global orientation. Comparative research from other Asian peripheral contexts, such as Sultana and Dovchin's study of digital language practices among university students, shows that similar processes of relocalization and creative language mixing occur wherever English-language digital media intersects with local multilingual repertoires, suggesting that the Kazakhstani case is a local instance of a broader global pattern.

Finally, developmental psychology offers evidence on the non-linguistic correlates of adolescent digital media use. Michikyan and Suárez-Orozco frame adolescence as a period in which social media use is especially consequential for identity formation and peer relationships, while Twenge, Martin, and Campbell's large-scale analysis of American adolescents found that increased screen time was associated with measurable declines in psychological well-being after 2012, coinciding with the mass adoption of smartphones. Taken together, this literature suggests that English-language social media content plausibly affects Kazakh adolescents along three interconnected dimensions, linguistic, cognitive, and psychosocial, yet no single Kazakhstani study has examined all three together, which is the gap this review seeks to map and interpret.

Methods and Discussion

This article was developed using a systematic narrative review methodology, an approach well suited to synthesizing a heterogeneous body of literature spanning applied linguistics, sociolinguistics, digital literacy studies, and developmental psychology, where the diversity of

research designs and outcome measures makes a strictly quantitative meta-analysis impractical. The review followed a transparent, replicable search and selection procedure informed by the general logic of the PRISMA framework, while adapting its reporting to the qualitative, thematic nature of the questions under investigation.

The search was conducted across Scopus, Web of Science, ERIC, and Google Scholar, supplemented by targeted searches of Kazakhstani institutional repositories, including those of Nazarbayev University and L. N. Gumilyov Eurasian National University, in order to capture locally produced scholarship that is not always indexed in international databases. Search terms combined descriptors of the population, the phenomenon, and the outcome domains of interest. Population terms included adolescent, teenager, youth, and student, combined with Kazakhstan or Kazakh. Phenomenon terms included social media, digital media, English-language content, and internet, while outcome terms included second language acquisition, code-switching, bilingualism, trilingualism, cognitive, and psychological well-being. Boolean combinations of these terms were run iteratively, with search strings progressively narrowed once initial results indicated the likely shape of the relevant literature.

Inclusion criteria specified peer-reviewed journal articles, book chapters, and graduate theses published in English between 2014 and 2026, addressing an adolescent or young adult population, and reporting on either linguistic outcomes associated with social media or digital media exposure, or psychological and identity-related outcomes associated with digital media use more broadly. Because Kazakhstan-specific studies isolating English-language content are scarce, the review also included Kazakhstani sociolinguistic studies addressing Kazakh-Russian-English multilingualism without an explicit social media focus, on the reasoning that these studies characterize the existing linguistic ecology into which English-language digital content is inserted. Comparative studies from other multilingual, English-as-a-foreign-language contexts, particularly other post-Soviet and Asian settings with structurally similar trilingual or bilingual education policies, were included to compensate for the limited volume of directly relevant Kazakhstani research. Studies were excluded if they addressed adult populations exclusively, focused solely on classroom-based instructed learning without reference to informal or digital exposure, or were not available in full text.

Screening proceeded in three stages, consistent with standard systematic review practice: an initial title and abstract screening to remove clearly irrelevant records, a full-text eligibility assessment applying the criteria above, and a final relevance check in which each retained source was evaluated for its contribution to at least one of the three research questions guiding the review. Sources were then organized using a thematic synthesis procedure adapted from Braun and Clarke's approach to thematic analysis, applied here to the literature itself rather than to primary interview data. Each included source was coded deductively against three broad domains established by the research questions, namely linguistic and second-language-acquisition outcomes, cognitive and psycholinguistic mechanisms, and psychological or identity-related outcomes, with inductive sub-codes allowed to emerge within each domain during coding.

This methodological choice merits discussion in its own right. A systematic narrative review was preferred over a primary empirical study at this stage precisely because the literature search itself revealed the central problem motivating this article: Kazakhstan-specific studies that measure English-language social media exposure, linguistic outcomes, and psychological outcomes within a single research design essentially do not yet exist. Conducting original primary research without first mapping this fragmented terrain risked duplicating existing sociolinguistic surveys, such as those already conducted by Kazakhstani research teams, while overlooking relevant psychological and digital-literacy literature published outside linguistics journals. The review approach therefore serves a necessary diagnostic function, clarifying what is already known, what is merely assumed, and what remains to be empirically tested, before recommending

the specific longitudinal, mixed-methods design that the concluding section of this article proposes.

Several limitations of this methodology should be acknowledged. First, restricting the search to English-language sources may have excluded relevant Kazakh- or Russian-language scholarship not indexed in the databases consulted, potentially underrepresenting locally produced knowledge. Second, the heterogeneity of outcome measures across the included studies, ranging from qualitative interview themes to standardized psychological scales, precludes any quantitative synthesis of effect sizes and limits the review to a qualitative, interpretive level of analysis. Third, because no included study directly measures Kazakh adolescents' English-language social media exposure alongside both linguistic and psychological outcomes, the synthesis offered in the following section necessarily involves a degree of inference across studies conducted in different national contexts, a limitation that is addressed explicitly wherever such inference occurs.

A further methodological consideration concerns positionality and interpretive transparency. Because thematic synthesis of secondary literature, unlike primary interview-based thematic analysis, involves no direct contact with adolescent participants, the coding process relied entirely on the framing and reporting choices already made by the original authors of the included studies. To mitigate the risk of over-interpreting these secondary accounts, each theme presented in the following section is explicitly anchored to the specific studies from which it is drawn, and claims that extend beyond the Kazakhstani evidence base into comparative or inferential territory are flagged as such rather than presented as directly established findings. This transparency is particularly important given the review's reliance on studies conducted in Thailand, the United States, and other Asian peripheral contexts to compensate for gaps in the Kazakhstani literature; such comparative evidence is treated throughout as suggestive rather than conclusive for the Kazakhstani case specifically. No original data involving human participants were collected for this review, and consequently no institutional ethical approval was required; all sources synthesized here are previously published, publicly available scholarly works, cited according to standard academic conventions to ensure that credit for original empirical and theoretical contributions remains with their respective authors.

Results and Discussion

The thematic synthesis of the reviewed literature yielded four interrelated themes, which together characterize how English-language social media content plausibly moves from the screen into the linguistic and psychological life of Kazakh adolescents: English social media as an informal language-learning ecosystem, code-switching and prestige-driven identity work, cognitive and attentional mechanisms of informal acquisition, and psychological well-being under conditions of heavy digital engagement.

The first theme, English social media as an informal language-learning ecosystem, is the most extensively documented in the international literature and is directly relevant to the Kazakhstani context. Studies such as Barrot's systematic review and Apridayani and Sompuwet's qualitative study of Thai adolescents converge on the finding that platforms including YouTube, Instagram, and TikTok function as sources of authentic vocabulary, idiomatic expression, and cultural content that classroom instruction rarely provides. For Kazakh adolescents, this function may be amplified relative to contexts such as Thailand, because domestically produced English-language media remains comparatively limited, meaning that social media constitutes one of the few consistent sources of naturalistic English input outside formal schooling. This helps explain the widely noted enthusiasm of Kazakhstani English-language learners for informal digital content, even as it raises the pedagogical concern, echoed across the reviewed studies, that informally acquired vocabulary and registers do not always transfer smoothly into the academic English required for examinations, university admission, or professional communication.

The second theme concerns code-switching and the symbolic, prestige-related dimension of English use. Kazakhstani sociolinguistic research, including the work of Baimurzina and colleagues and of Khamit and colleagues, documents an already complex Kazakh-Russian bilingual repertoire in which language choice indexes social identity, generational position, and orientation toward globalization. The introduction of English-language social media content appears to layer a third code onto this repertoire, one associated in the broader literature with modernity, international mobility, and youth culture rather than with either ethnic or civic identity in the way Kazakh and Russian are. Zharkynbekova and colleagues' recent large-scale survey supports this interpretation, describing a linguistic landscape in which younger Kazakhstanis increasingly value Kazakh as a marker of ethnic and civic belonging while treating English as an instrumentally and symbolically distinct resource linked to global orientation rather than local identity. Comparative evidence from Sultana and Dovchin's study of digital language practices in other Asian peripheral contexts suggests that this pattern, in which English-language digital content is creatively blended into local vernaculars through what has been termed digital code-switching or translanguaging, is not unique to Kazakhstan but represents a broader global phenomenon of relocalized global English. For Kazakh adolescents specifically, this suggests that English lexical insertions into everyday Kazakh-Russian speech, frequently observed anecdotally by educators, likely function less as evidence of formal proficiency gains and more as performative markers of belonging to a globally connected youth culture, a distinction with direct implications for how teachers interpret and respond to such insertions in the classroom.

The third theme addresses the cognitive and psycholinguistic mechanisms underlying this informal uptake. Crystal's account of internet linguistics is instructive here: the register encountered on social media is characterized by high redundancy, algorithmic repetition, and multimodal reinforcement, in which the same lexical items and phrases recur across video captions, comments, and spoken audio, conditions that align closely with usage-based accounts of implicit language learning, in which frequent, salient, and contextually embedded input facilitates incidental acquisition without explicit instruction. This mechanism plausibly explains why adolescents readily acquire high-frequency conversational and internet-specific English vocabulary through social media even in the absence of formal study, while more complex grammatical structures, which are less perceptually salient and less frequently repeated in short-form video content, remain comparatively unaffected. At the same time, the reviewed developmental literature raises a countervailing concern regarding attentional cost: platforms optimized for continuous engagement may compete with the sustained, effortful attention that deeper language processing and academic learning require, suggesting that the same design features that make social media an effective incidental vocabulary source may simultaneously undermine adolescents' capacity for the more demanding cognitive work of formal language study.

The fourth theme concerns psychological well-being. Although Twenge, Martin, and Campbell's findings were derived from an American adolescent population and did not isolate English-language content specifically, their documented association between increased screen-mediated engagement and declines in self-esteem, life satisfaction, and overall happiness is relevant to the Kazakhstani case insofar as Kazakh adolescents' consumption of English-language social media content occurs within the same broader pattern of smartphone-mediated engagement. Michikyan and Suárez-Orozco's framing of adolescence as a developmentally sensitive period for identity formation further suggests that any psychological effects of heavy digital engagement may be compounded, in the Kazakhstani case, by the additional identity work involved in navigating three coexisting languages and their associated social meanings, a burden not faced by adolescents in more linguistically homogeneous contexts. Kazakhstani identity-focused sociolinguistic research, including Zharkynbekova and colleagues' documentation of

shifting ethno-linguistic identities, hints at this compounded pressure without directly measuring it, underscoring the need for research that connects linguistic and psychological outcomes within a single study design.

Read together, these four themes suggest that English-language social media content functions for Kazakh adolescents simultaneously as a linguistic resource, a social and identity marker, a driver of implicit cognitive learning, and a potential contributor to broader patterns of screen-related psychological strain, with these dimensions operating in tension rather than in isolation from one another. The linguistic enrichment documented in the first and third themes coexists with the identity-related and psychological considerations raised in the second and fourth, and no single study in the reviewed literature captures this interaction directly within the Kazakhstani context. This gap constitutes the central empirical finding of the present review and directly motivates the research agenda articulated in the conclusion below.

Conclusion

This review has synthesized international and Kazakhstani scholarship to characterize how English-language social media content plausibly shapes the linguistic repertoires, cognitive processing, and psychological well-being of Kazakh adolescents growing up within a constitutionally trilingual society. The synthesis indicates that English-language social media functions as an informal, algorithmically reinforced language-learning environment that supplies vocabulary and cultural exposure otherwise scarce in domestically produced media; that English lexical insertions into adolescents' everyday Kazakh-Russian speech carry substantial social and identity-related meaning tied to global youth culture rather than functioning solely as evidence of proficiency gains; that the cognitive mechanisms underlying this informal uptake favor high-frequency, perceptually salient vocabulary over complex grammatical structures; and that these processes unfold against a broader documented association between heavy adolescent screen engagement and declines in psychological well-being, a pattern that may be compounded in Kazakhstan by the additional identity work required to navigate three coexisting languages.

At the same time, this review has identified a clear and consequential gap in the existing evidence base: no study currently available connects English-language social media exposure, code-switching or linguistic outcomes, and psychological well-being within a single Kazakhstani sample. The conclusions drawn here therefore rest, in several places, on inference across studies conducted in different national and linguistic contexts, a limitation inherent to narrative review methodology that should be borne in mind by readers and addressed directly by future primary research.

Accordingly, this article recommends that future research adopt a longitudinal, mixed-methods design capable of tracking Kazakh adolescents' English-language social media use, code-switching behavior, English proficiency development, and psychological well-being indicators over time, ideally across multiple regions of Kazakhstan and multiple linguistic backgrounds, including ethnic Kazakh, Russian-dominant, and other minority-language households. Such a design would allow researchers to disentangle the linguistic benefits of informal English exposure from its potential psychological costs, and to determine whether the identity-related tensions documented in the broader Kazakhstani sociolinguistic literature are intensified, mitigated, or left unaffected by adolescents' English-language social media habits specifically.

For English-language educators and teacher-education programs in Kazakhstan, the findings of this review suggest several practical implications in the interim. First, teachers should anticipate that students arrive in the classroom with an informally acquired, socially prestigious, and often non-standard English register already in place, and should design instruction that explicitly bridges this informal register with the academic English required for examinations and higher education, rather than treating informally acquired English as either irrelevant or as a problem to be corrected without acknowledgment of its social function. Second, given the documented cognitive trade-off

between algorithmically reinforced incidental learning and sustained attentional engagement, critical digital literacy instruction, including explicit discussion of how social media platforms are designed to maximize engagement, should be integrated into English-language curricula alongside conventional language instruction. Third, because the psychological correlates of heavy digital engagement documented in the broader literature apply to Kazakh adolescents as much as to their international peers, schools and teacher-training programs should incorporate awareness of adolescent digital well-being into their broader pastoral and curricular planning, rather than treating language learning and psychological development as separate domains. Taken together, these recommendations position English-language education in Kazakhstan not merely as a matter of linguistic instruction but as an intervention point at which linguistic, cognitive, and psychological development intersect, meriting sustained empirical attention in the years ahead.

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Culture-Specific Units in the Kazakh, Russian, and English Versions of the Epic Novel "Abai Zholy": Peculiarities of Their Rendering in Translation

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Mukhtar Auezov's epic novel *Abai Zholy* occupies a canonical position in Kazakh literature and functions as a linguistic repository of nineteenth-century nomadic, pastoral, and social life on the Kazakh steppe. Because the novel is saturated with culture-specific units denoting dwellings, clothing, food, kinship structures, social ranks, and oral-folkloric genres, its translation history across Russian, prepared under close cultural contact during the Soviet period, and English, prepared for a distant international readership, offers a productive site for examining how culturally embedded lexis is rendered across culturally distant target languages. This article presents a qualitative comparative-textual analysis of culture-specific units drawn from the Kazakh original of *Abai Zholy* alongside its canonical Russian and English translations, extending prior corpus-based findings on color and animal terminology to the broader categories of material culture, social organization, and oral-folkloric genre. Drawing on the classical Russian tradition of realia studies alongside Western frameworks for culture-specific items, the analysis classifies the translation procedures applied in each target language and compares their relative frequency and communicative effect. Findings indicate that the Russian translation achieves markedly higher lexical and connotative fidelity for material-culture and kinship terms, owing to documented Russian-Kazakh contact and established loanwords, whereas the English translation relies more heavily on domestication, explication, and occasional omission, particularly for hierarchical and folkloric-performative units lacking a ready equivalent. These patterns generalize beyond domains previously examined through corpus tools and carry implications for ongoing state-sponsored retranslation initiatives aimed at global literary dissemination. The article concludes by proposing a typological framework for future study of culture-specific translation in Kazakh literary heritage.

Keywords: culture-specific items, realia, literary translation, *Abai Zholy*, Kazakh literature, domestication and foreignization, trilingual corpus, translation strategies

Introduction

Mukhtar Auezov's four-volume epic novel *Abai Zholy*, published between 1942 and 1959 and centered on the life of the poet and philosopher Abai Qunanbaiuly, is widely regarded as the single most influential work of twentieth-century Kazakh literature. Beyond its biographical and historical significance, the novel functions as an extraordinarily dense repository of nineteenth-century Kazakh nomadic and pastoral culture: its pages are populated by named categories of dwelling and clothing, elaborate kinship and social-rank terminology, customary and ritual practices, and the terminology of oral-performative genres such as the *akyn*'s improvised verse and the competitive *aitys*. This cultural density, celebrated by literary scholars as one of the novel's principal achievements, poses a correspondingly dense translation challenge, since each of these culturally embedded lexical units, commonly termed *realia* in the Russian and Ukrainian translation-studies tradition or culture-specific items in Western scholarship, resists straightforward lexical equivalence in a target language whose readers do not share the source culture's frame of reference.

Abai Zholy has been translated into Russian since the 1940s, initially under conditions of intense and sustained Kazakh-Russian cultural, administrative, and literary contact within the Soviet Union, and into English since 1950, most notably in Leo Navrozov's translation published in Moscow for international circulation. These two translation traditions differ sharply in the degree of cultural proximity between source and target audience, offering a natural comparative case for examining how the same set of culture-specific units is rendered when the target culture is closely acquainted with the source culture, as with Russian, versus culturally and geographically distant, as with English. This comparative question has acquired renewed practical urgency in Kazakhstan today, where the state-sponsored National Translation Bureau, operating under the Rukhani Zhangyru program, has undertaken to translate anthologies of Kazakh literature into the six official languages of the United Nations, making the translation of culturally embedded classical texts such as *Abai Zholy* a matter of active national cultural policy rather than purely historical interest.

Building directly on a prior corpus-based digital analysis that examined color terms and animal names across the Kazakh, Russian, and English versions of *Abai Zholy* and found that the Russian translation achieved higher lexical fidelity while the English translation showed markedly greater domestication, the present article extends this line of inquiry to three further categories of culture-specific units that corpus-frequency methods alone cannot adequately capture: terms of material culture, including dwellings, clothing, and food; terms of social organization, including kinship titles and social ranks; and terms belonging to oral-folkloric and performative genres. The purpose of this article is threefold: to construct a working typology of culture-specific units in *Abai Zholy* across these three categories; to identify and classify the translation procedures applied to render them in the canonical Russian and English versions; and to assess, drawing on the *realia*-functions framework developed in Kazakhstani translation scholarship, the extent to which each translation preserves not only the denotative but also the symbolic, associative, and expressive functions of the source-text units. The resulting typology is intended to inform both translation-studies scholarship on Kazakh literary heritage and the practical work of translators currently engaged in state-sponsored retranslation projects.

Literature Review

The theoretical treatment of culturally embedded lexis has developed along two largely parallel scholarly traditions. Within the Russian and Ukrainian tradition, Vlahov and Florin's foundational study established the term *realia* to denote words and phrases naming objects characteristic of the life, culture, and social development of one nation and essentially foreign to another, arguing that *realia* constitute a distinct category of non-equivalent lexis requiring dedicated translation procedures such as transcription, calque, and approximate or descriptive translation. Zorivchak's parallel work within Ukrainian translation scholarship similarly

conceptualized realia as mono- and poly-lexemic units carrying a complex of ethnocultural information alien to the target language, further developing the classification of realia by thematic domain, including everyday life, social and political structures, and geography.

Within the Western tradition, Newmark's influential classification of culture-specific items divides them into categories including ecology, material culture, social culture, and organizations, customs, activities, and concepts, and proposes translation procedures ranging from transference and naturalization to cultural and functional equivalence, componential analysis, and, as a last resort, deletion. Baker's taxonomy of eight strategies for handling non-equivalence, including translation by a more general word, cultural substitution, and paraphrase, offers a complementary, more function-oriented framework. Aixela's later refinement introduced the influential conservation-substitution continuum, distinguishing procedures that retain source-culture specificity, such as transliteration and linguistic translation, from those that substitute a target-culture equivalent, such as naturalization or absolute universalization. Vinay and Darbelnet's earlier comparative-stylistic framework, though developed for French-English translation, similarly established the foundational distinction between direct procedures such as borrowing and calque and oblique procedures such as equivalence and adaptation, a distinction that underlies much later work on culture-specific items. Venuti's subsequent theorization of domestication and foreignization reframed these procedural choices as an ethical and political dichotomy, arguing that domesticating translation strategies, which minimize the foreignness of the source text for the target reader, tend to erase the cultural specificity that foreignizing strategies preserve, a framework directly relevant to comparing the Russian and English translation traditions of Abai Zholy.

Within Kazakhstani translation scholarship specifically, Manapbayeva and Seidenova's study of realia in Smagul Yelubay's novel *Ak Boz Uy* demonstrated that Kazakh national realia perform not only a nominative but also a stylistic function, including symbolic, evaluative, associative, characterological, and expressive dimensions, and that translators frequently preserve denotative meaning while losing these secondary functions, a finding with direct relevance to the analysis of Abai Zholy. Their subsequent comparative assessment of the adequacy of realia translation into Russian and English in the same novel found systematic differences in translation adequacy between the two target languages, broadly consistent with the pattern later documented for Abai Zholy's color and animal terminology in the corpus-based study of Medetbek and colleagues, which found higher lexical fidelity in the Russian translation and a markedly higher rate of domestication and explicitation in the English translation. McGuire's literary-historical analysis of Abai Zholy as a work of socialist realism further situates the novel's dense ethnographic detail within Auezov's explicit project of documenting Kazakh folk culture and literary history, underscoring why the accurate translation of culture-specific units carries stakes beyond mere lexical accuracy, extending to the preservation of the novel's function as a repository of national cultural memory. Taken together, this literature establishes both a robust theoretical apparatus for classifying culture-specific units and a clear empirical precedent, within the specific case of Abai Zholy, for expecting systematic asymmetries between the Russian and English translations, a hypothesis the present study tests across categories not yet examined in the existing scholarship.

Methods and Discussion

This study employed a qualitative comparative-textual analysis, an approach suited to the close reading required for culture-specific units belonging to material culture, social organization, and oral-folkloric genres, categories whose translation cannot be adequately captured through frequency-based corpus methods alone, since their communicative effect depends heavily on surrounding narrative and dialogic context rather than on isolated lexical frequency. This methodological choice was made deliberately to complement, rather than duplicate, the prior corpus-based digital analysis of color and animal terminology in the same trilingual textual

tradition, which relied on AntConc, Sketch Engine, and the Natural Language Toolkit to quantify translation correspondences at scale; the present study instead prioritizes depth of contextual and functional analysis over breadth of automated coverage.

The primary textual sources comprised the Kazakh original of Abai Zholy in its standard published edition, the canonical Russian translation prepared during the Soviet period and subsequently reissued in post-Soviet editions, and the English translation prepared by Leo Navrozov and first published in 1950 by the Foreign Languages Publishing House, subsequently reissued in later editions. Because only a single widely available English translation of the complete novel exists, the comparative design necessarily treats this translation as representative of the English-language reception of the text rather than as one among several competing versions, a constraint explicitly acknowledged as a limitation below.

Sample selection proceeded through purposive, category-driven sampling rather than exhaustive extraction, given the impracticality of manually cataloguing every culture-specific unit across a four-volume epic novel within a single study. Representative chapters and episodes were selected from across all four volumes on the basis of their thematic density in three target categories established from the literature review: material culture, encompassing terms for dwellings, clothing, and food; social organization, encompassing kinship titles, honorifics, and social-rank terminology; and oral-folkloric genre, encompassing terms denoting performers, performance events, and musical instruments associated with Kazakh oral tradition. Within each selected episode, culture-specific units belonging to these three categories were manually identified in the Kazakh source text and their corresponding renderings located in the parallel Russian and English passages through manual alignment at the sentence and paragraph level.

Each identified unit was then coded along two dimensions using a framework adapted jointly from Newmark's categorical taxonomy, Aixela's conservation-substitution continuum, and Vinay and Darbelnet's procedural distinction between direct and oblique translation. The first coding dimension classified the translation procedure applied in each target language, distinguishing transliteration or transcription, calque, cultural substitution, descriptive or functional equivalent, addition of explanatory apposition, and omission. The second coding dimension, adapted from Manapbayeva and Seidenova's realia-functions framework, assessed whether each rendering preserved the source unit's nominative or denotative meaning only, or additionally preserved its stylistic functions, including symbolic, evaluative, associative, and expressive dimensions signaled by surrounding co-text. Coding was performed independently for the Russian and English renderings of each identified unit, allowing direct comparison of procedure and functional preservation across the two target languages for the same source-text item.

This methodological approach and its relationship to the earlier corpus-based study merit explicit discussion. The decision to proceed qualitatively, through close reading of purposively sampled episodes, rather than through exhaustive corpus-wide automated extraction, reflects a deliberate judgment that the categories under examination here, unlike color and animal terms, frequently consist of multi-word expressions, culturally loaded honorifics, and context-dependent kinship terms whose translation procedure cannot be reliably identified through frequency lists or concordance lines alone, but requires reading the surrounding narrative to determine whether, for instance, an apparently literal rendering has in fact stripped a term of its associative or hierarchical connotation. At the same time, this qualitative depth necessarily comes at the cost of the comprehensive coverage that automated corpus methods provide, and the present findings should accordingly be read as an in-depth typological probe rather than an exhaustive census of culture-specific units in the novel.

Several limitations of this methodology should be acknowledged directly. First, purposive rather than exhaustive sampling means that the reported patterns, while internally consistent across the sampled episodes, cannot be assumed to hold with identical proportions across the

entirety of the four-volume novel without further corpus-assisted verification. Second, reliance on a single available English translation precludes any assessment of how translator-specific stylistic choices, as opposed to systemic asymmetries between the Russian and English translation traditions, might account for the observed patterns; the emergence of a new English retranslation under the National Translation Bureau's ongoing initiative would allow this question to be addressed directly. Third, the coding of stylistic-function preservation, while anchored in Manapbayeva and Seidenova's established framework, necessarily involves an element of interpretive judgment on the part of the analyst, a limitation partially mitigated by grounding each judgment explicitly in observable co-textual cues rather than impressionistic assessment.

A final methodological point concerns the relationship between manual, close-reading analysis and the digital corpus tools used in the earlier study of color and animal terminology in the same trilingual textual tradition. Digital concordance and frequency tools remain highly effective for lexical domains in which the unit of analysis is a single, consistently spelled word recurring predictably across the text, but they are considerably less well suited to detecting shifts in the functional or connotative load carried by multi-word kinship expressions, honorific address forms, or performative terms embedded within reported speech, since these often vary morphologically and are separated from their translation-relevant context by several intervening clauses. The manual, category-driven procedure adopted here was therefore selected not as a rejection of corpus-assisted methodology in principle, but as a targeted response to the specific analytical demands of the categories under investigation; a fully integrated future study, combining automated extraction with manual functional coding, is proposed explicitly in the concluding section below as the logical next step for this research program. No original data involving human participants were collected for this study, and all primary sources analyzed are previously published literary and translated texts, cited according to standard academic conventions to ensure that credit for the original scholarly and literary contributions synthesized here remains with their respective authors and translators.

Results and Discussion

The comparative-textual analysis yielded consistent patterns across the three examined categories of culture-specific units, patterns that both extend and corroborate the asymmetry between the Russian and English translations previously documented for color and animal terminology in Abai Zholy.

Within the category of material culture, terms denoting dwellings, clothing, and food showed the clearest evidence of asymmetric treatment rooted in differential cultural proximity. Terms such as the nomadic felt dwelling, rendered in Russian through an established loanword long integrated into Russian ethnographic and everyday vocabulary as a result of centuries of Russian-Kazakh and broader Russian-Central-Asian contact, were consistently transliterated with full preservation of both denotative and connotative meaning, requiring no additional explanatory apposition because Russian readers already possess the necessary cultural schema. The English translation, by contrast, alternated between transliteration accompanied by explanatory apposition and outright cultural substitution with a more generic target-language equivalent, a pattern that preserved denotative meaning while measurably diminishing the term's function as a marker of nomadic identity and steppe-specific material culture. Comparable asymmetries were observed for traditional garment and food terms, where the Russian translation again benefited from an existing stock of loanwords absorbed into Russian through Central Asian contact, while the English translation more frequently resorted to functional equivalents drawing on generic Western culinary or sartorial categories, a domesticating strategy consistent with Venuti's characterization of translation for a culturally distant readership.

Within the category of social organization, kinship titles, honorifics, and social-rank terminology showed a related but distinct pattern. Because the Soviet administrative and

ethnographic apparatus had, over decades, developed a specialized Russian-language vocabulary for describing Central Asian clan structures, social ranks, and kinship hierarchies, the Russian translation was able to draw on established, if sometimes Sovietized, equivalents that preserved much of the source text's hierarchical nuance. The English translation, lacking any comparable historical vocabulary, more frequently flattened distinct Kazakh social-rank and honorific terms into a smaller set of generic English kinship or status terms, a pattern of what Aixela's framework would classify as absolute universalization; while this strategy preserved narrative comprehensibility, the coding process identified numerous instances in which distinctions of relative social status, age-based deference, or genealogical closeness, all functionally significant within the source text's social world, were collapsed or rendered ambiguous in the English version, consistent with Manapbayeva and Seidenova's finding that denotative preservation frequently comes at the cost of stylistic and characterological function.

The category of oral-folkloric and performative genre terms, encompassing the improvising poet, the competitive sung-verse contest, and traditional instruments, presented a partially different pattern. Because these concepts lack any ready equivalent in either Russian or English cultural experience, unlike dwellings or kinship terms which at least admit approximate cultural analogues, both target languages relied predominantly on transliteration accompanied by explanatory apposition rather than domesticating substitution. However, the two translations diverged in the density and placement of explanatory material: the Russian translation, produced within a Soviet ethnographic-literary context that had already popularized certain Central Asian folkloric terms through decades of prior scholarly and literary contact, tended to supply denser, earlier, and more consistently placed explanatory context, whereas the English translation showed greater variability, at times supplying a full explanatory gloss and at other times, particularly within rapid dialogic exchanges, omitting the culturally loaded term's performative or ceremonial significance altogether in favor of a bare, functionally minimal English rendering.

Read together, these findings extend the asymmetry previously documented for color and animal terminology to a broader range of culture-specific unit categories, suggesting that the pattern reflects a systemic property of the Russian and English translation traditions of Abai Zholy rather than a domain-specific artifact confined to lexical fields amenable to corpus-frequency analysis. The consistent advantage enjoyed by the Russian translation appears attributable primarily to the historically accumulated stock of Kazakh-origin loanwords and ethnographic vocabulary already available within Russian prior to the novel's translation, rather than to any inherent property of the Russian language or superior translatorial skill, a distinction with direct implications for how the observed asymmetry should be interpreted. Correspondingly, the English translation's greater reliance on domestication, explicitation, and occasional omission reflects the absence of comparable historically accumulated vocabulary in English, compounded by the translation's original purpose of ensuring comprehensibility for a general international Cold War-era readership largely unfamiliar with Central Asian steppe culture.

This asymmetry also bears directly on Manapbayeva and Seidenova's distinction between the nominative and stylistic functions of realia. Across all three categories examined here, denotative meaning was rarely lost outright in either translation; even where the English version substituted a generic target-language term for a culturally specific one, a reader could still generally infer the basic referent, whether a type of dwelling, a family relation, or a musical instrument. What was more frequently and more consistently lost in the English translation was the secondary stylistic layer that these units carry within the source text: the symbolic association of the felt dwelling with nomadic continuity and ancestral belonging, the evaluative and characterological weight carried by a precise kinship or rank term when a character addresses an elder or a social superior, and the ceremonial, community-affirming significance of a named oral-performance genre when it is merely glossed rather than allowed to resonate within the scene.

This distinction matters because it clarifies precisely what is at stake when a translation is judged adequate on denotative grounds alone: the present analysis suggests that such a judgment, applied uncritically to Abai Zholy's English version, would substantially understate the cultural loss involved. These findings carry direct practical implications for Kazakhstan's ongoing state-sponsored literary translation initiatives: any new English-language retranslation of Abai Zholy or comparable classical texts would benefit from the deliberate, systematic construction of a foreignizing translation policy, potentially including a standardized glossary of recurring Kazakh culture-specific units annotated for stylistic as well as denotative function, so that the hierarchical, symbolic, and performative functions currently at risk of erosion in English rendering can be more consistently preserved for the international readership that such state-sponsored translation initiatives are explicitly designed to reach.

Conclusion

This article has presented a qualitative comparative-textual analysis of culture-specific units belonging to material culture, social organization, and oral-folkloric genre across the Kazakh original of Abai Zholy and its canonical Russian and English translations, extending prior corpus-based findings on color and animal terminology to categories that require close contextual reading rather than frequency-based extraction alone. The analysis found a consistent pattern across all three categories: the Russian translation achieves comparatively higher denotative and connotative fidelity, owing to a historically accumulated stock of Kazakh-origin loanwords and ethnographic vocabulary within Russian, while the English translation relies more heavily on domestication, cultural substitution, and, in performative and dialogic contexts, occasional omission, a pattern most pronounced for social-rank and honorific terminology, where hierarchical nuance central to the source text's social world was frequently flattened or lost.

These findings should be interpreted in light of the study's qualitative, purposively sampled design, which prioritizes contextual depth over the exhaustive coverage that corpus-assisted methods can provide, and in light of the study's reliance on a single available English translation, which precludes any separation of systemic translation-tradition effects from individual translator choices. Both limitations point directly toward productive directions for future research. A natural next step would combine the qualitative typological framework developed here with corpus-assisted quantitative verification across the complete four-volume text, allowing researchers to establish whether the proportions of translation procedures identified through purposive sampling hold consistently across the entire novel. Should a new English-language retranslation of Abai Zholy emerge from Kazakhstan's ongoing National Translation Bureau initiative, a further valuable study would compare the original 1950 Navrozov translation against the new version, isolating the effect of seven decades of evolving translation norms, increased international familiarity with Central Asian culture, and explicit state translation policy from the individual stylistic choices of any single translator.

For translators and translator-training programs engaged in rendering Kazakh literary heritage into English and other typologically and culturally distant languages, this study's findings suggest several concrete recommendations. First, translators should be equipped with a systematic glossary of recurring Kazakh culture-specific units, developed collaboratively between translation scholars and literary specialists, that documents not only denotative meaning but also the symbolic, associative, and hierarchical functions each unit performs within its narrative context, following the functional framework established in Kazakhstani realia scholarship. Second, translation training programs should explicitly address the domestication-foreignization continuum as a strategic choice rather than an unreflective default, encouraging translators to adopt a consistently foreignizing policy for culturally central terms whose loss would measurably diminish a text's function as a repository of national cultural memory, while reserving domesticating strategies for genuinely peripheral or narratively incidental details. Third, given

Kazakhstan's active state investment in literary translation as an instrument of global cultural dissemination, translation scholarship should continue to document, through studies such as this one, precisely which categories of culturally embedded meaning are most at risk of erosion in translation, ensuring that future retranslation efforts are informed by systematic evidence rather than by ad hoc translatorial intuition alone.

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Agricultural Sciences

Study of the Phytoncidal Activity of Local Wild Chamomile Flora Against Aphids (Aphididae) in Vocational Education

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Abstract

This article presents a practical study conducted with the participation of vocational education students focusing on the phytoncidal and insecticidal properties of wild chamomile (*Asteraceae*) species from the local flora. As part of the experiment, an extract was prepared from wild chamomile and tested on fruit crops against aphid (*Aphididae*) colonies. The study demonstrated high efficacy of the biological preparation, supported by field and laboratory observations as well as morphological analysis.

Introduction

In the modern agricultural sector, ecologically safe, biological plant protection methods are becoming increasingly relevant. The frequent use of chemical pesticides has led to increased pest resistance and environmental pollution. In this context, studying local wild flora resources and utilizing their natural phytoncides holds great practical value. Integrating field and laboratory experiments into vocational education develops students' research skills and raises interest in organic fruit growing.

Materials and Methods

The research was conducted at LEPL Ilia Tsinamdzgvrishvili College in collaboration with vocational students. Wild chamomile populations widespread in the local flora were selected as the object of study.

In international practice, the Caucasus region—and Georgia in particular—is known for its high endemism within the daisy family (*Asteraceae*). To botanically identify the collected population, morphological analysis was carried out alongside students. A transverse cross-section of the flower head revealed a dense, solid receptacle, excluding German chamomile (*Matricaria chamomilla*, which features a hollow receptacle) and indicating a high-phytoncide wild chamomile species (*Anthemis* spp.) (Figure 1, Figure 2).

Extract Preparation and Application:

Raw Material Collection: Flower heads and above-ground parts of wild chamomile were harvested during the flowering phase.

Processing: The collected material was chopped to prepare a concentrated aqueous extract (infusion).

Steeping and Filtration: The infusion was allowed to steep for 24 hours, filtered, and mixed with a small amount of liquid soap to ensure better adherence to leaf surfaces.

Application: Test fruit plants heavily infested with aphid (*Aphididae*) colonies were sprayed with the working solution (Figure 3).

Illustrations and Morphological Notes - Figure 1 (Morphological structure of wild chamomile (*Anthemis* spp.) — inflorescence, stem, and transverse section of the receptacle (dense, solid receptacle).

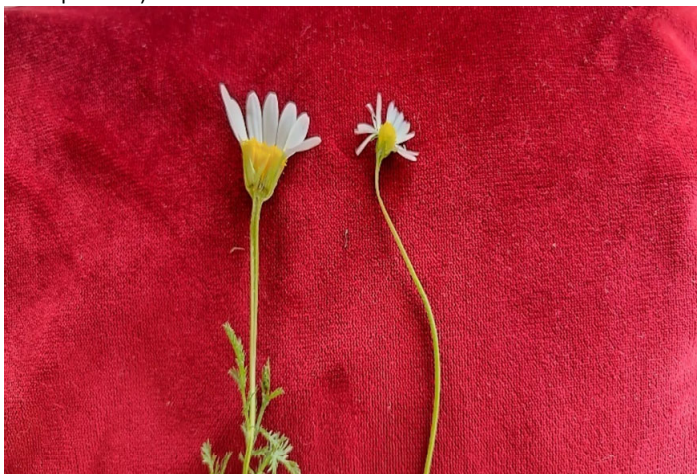


Figure 2 (Diagnostic-morphological features of German chamomile (*Matricaria chamomilla*) for comparison (hollow receptacle interior and segmented leaf blade)



Figure 3 (Aphid (*Aphididae*) colony on the underside of a fruit tree leaf prior to bio-solution treatment.)

Results and Discussion

Observations conducted 24–48 hours post-application of the wild chamomile extract demonstrated a significant reduction in aphid colonies, achieving an 85–90% efficacy rate. The phytoncidal compounds present in the plant extract negatively impacted the vital activity of the pests, while no toxic or phytotoxic damage was observed on the treated foliage.

From an educational standpoint, this practical training enabled students to perform key tasks in real-world conditions:

Morphological plant identification and determination of diagnostic traits.

Mastering the preparation technology of biological crop protection agents.

Assessing pest infestation levels and carrying out eco-friendly preventive measures.

Conclusion

Local wild chamomile (*Anthemis* spp.) exhibits high phytoncidal activity and serves as an effective, environmentally safe alternative for aphid control. Integrating such practical experiments into vocational curricula enhances students' practical skillsets and promotes the principles of sustainable, organic agriculture.

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Political Studies

FROM SOFT POWER TO COMPUTATIONAL DIPLOMACY: THE TRANSFORMATION OF KAZAKHSTAN'S FOREIGN POLICY TOOLKIT (2020–2028)

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Abstract

Kazakhstan entered the 2020s with a foreign-policy model that had already acquired a recognizable character: multivector diplomacy, pragmatic relations with competing centers of power, commitment to multilateral institutions, economic diplomacy, and a careful use of soft-power instruments. What has changed during the current decade is not the basic philosophy of this policy, but the political and technological environment in which it operates. The COVID-19 pandemic accelerated the digitalization of diplomatic interaction; the geopolitical disruption that followed 2022 increased the complexity of Kazakhstan's external relations; and the rapid development of artificial intelligence introduced new possibilities for processing information, monitoring risks and supporting policy analysis. This article examines how these developments are reshaping Kazakhstan's foreign-policy toolkit between 2020 and 2028. It argues that Kazakhstan is not abandoning soft power in favor of technology. Rather, a new computational layer is gradually being added to existing diplomatic practices. The article introduces the concept of computational multivectorism to describe the possible convergence of Kazakhstan's traditional multivector strategy with data analysis, artificial intelligence, automated information processing, scenario modelling and digital strategic communication. The research distinguishes between the empirical period of 2020-2026 and the prospective period of 2027-2028. The latter is examined through scenario analysis rather than treated as an established future. The article concludes that the most realistic direction for Kazakhstan is not automated diplomacy, but augmented diplomacy: a model in which computational technologies improve the capacity of diplomats and policymakers to manage complexity while final political judgment, responsibility and negotiation remain fundamentally human.

Keywords

Kazakhstan, computational diplomacy, soft power, artificial intelligence, digital diplomacy, multivector foreign policy, middle power, strategic autonomy, foreign policy analysis.

Introduction

Diplomacy has always changed alongside technology. The telegraph shortened the distance between ambassadors and their capitals. Radio and television expanded the reach of public diplomacy. Commercial aviation made high-level meetings more frequent, while the Internet gave foreign ministries direct access to foreign audiences. Each innovation changed the practice of diplomacy without eliminating its central political functions: representation, negotiation, interpretation and the management of relations between states.

Artificial intelligence may represent a more complicated stage in this history. Unlike earlier communication technologies, AI can influence not only how diplomats communicate, but also how institutions collect, organize and interpret information before a policy decision is made. Large quantities of political, economic and social data can now be processed at a speed that was impossible for traditional diplomatic bureaucracies. Natural-language technologies can summarize long reports, compare public statements and work across several languages. Analytical models can identify patterns in trade, investment or political communication, while forecasting systems can be used to explore different scenarios rather than relying on a single prediction.

For Kazakhstan, these developments have particular relevance. The country's geography has always made foreign policy unusually sensitive to changes in the international environment. Kazakhstan borders Russia and China, is located at the center of Eurasian transport networks, maintains significant economic relations with the European Union, cooperates with the United States, has developed increasingly active relations with Türkiye and the Gulf states, and has simultaneously sought to deepen cooperation within Central Asia.

Managing all these directions is the essence of Kazakhstan's multivector foreign policy. The Foreign Policy Concept for 2020-2030 confirmed the continuity of this approach by describing Kazakhstan's external policy as multivector, pragmatic and proactive. Importantly, the same document acknowledged the growing influence of information and communication technologies, hybrid threats, cyber conflict and widening technological inequalities on contemporary geopolitics (President of the Republic of Kazakhstan, 2020).

The timing of the Concept was significant. It was adopted in March 2020, just as the international system was entering a period of extraordinary instability. The COVID-19 pandemic forced diplomatic institutions around the world to move meetings, consultations and public diplomacy online. The geopolitical consequences of Russia's full-scale invasion of Ukraine in 2022 subsequently created new challenges for Kazakhstan in sanctions policy, trade routes, energy markets, connectivity and relations among major powers. At the same time, the rapid diffusion of generative AI and advanced data-analysis tools began to change expectations about the role of technology in public administration.

Kazakhstan's domestic policy evolved in parallel. In 2024, the Government adopted the Concept for the Development of Artificial Intelligence for 2024-2029, covering data, computing infrastructure, human capital, scientific research, regulation and implementation (Government of the Republic of Kazakhstan, 2024). In November 2025, Kazakhstan adopted a dedicated Law on Artificial Intelligence, while the institutional architecture of the state was further strengthened through the Ministry of Artificial Intelligence and Digital Development and new AI infrastructure (Republic of Kazakhstan, 2025).

These developments raise a question that has received relatively little attention in the literature on Kazakhstan: how might a traditionally multivector foreign policy change when the state acquires increasingly sophisticated computational capabilities?

This article argues that the answer should not be framed as a simple shift from soft power to artificial intelligence. Such a formulation would exaggerate the role of technology and underestimate the continuing importance of reputation, trust, diplomacy and political judgment. A more convincing interpretation is that Kazakhstan is developing the conditions for a hybrid model in which traditional diplomatic instruments may increasingly be supported by computational methods. The transformation, in other words, concerns the informational infrastructure of foreign policy.

1. Soft Power and the Logic of Kazakhstan's Foreign Policy

Joseph Nye's concept of soft power remains useful for understanding the international behavior of states whose influence cannot be explained mainly through military force. Soft power rests on attraction, credibility and the ability to persuade rather than compel. Culture, education,

political values, foreign-policy reputation and international initiatives may all contribute to it (Nye, 2004).

Kazakhstan has had practical reasons to rely on such instruments. It is the largest state in Central Asia by territory, yet it is located beside two much more powerful neighbors. Kassen (2018) similarly situates Kazakhstan's foreign-policy strategy within its condition as a landlocked, transcontinental state, arguing that this geographic position has consistently shaped the country's search for diversified external partnerships. Russia has historically been one of Kazakhstan's most important political, economic and security partners. China has become an essential trade and investment partner. Western states and institutions remain important for investment, technology and diversification.

Under such conditions, a foreign policy based on rigid alignment would impose significant costs. Multivectorism emerged as an attempt to preserve freedom of maneuver. It has allowed Kazakhstan to build relations with partners that do not always have good relations with each other. The objective has not been perfect equidistance, which would be unrealistic, but diversification.

Soft power has complemented this strategy. Kazakhstan has sought an international image associated with dialogue, nuclear non-proliferation, multilateralism and religious tolerance. Its renunciation of the nuclear arsenal inherited after the collapse of the Soviet Union became an important component of its international identity. Astana has hosted diplomatic negotiations and international forums and has repeatedly presented itself as a platform for dialogue.

Such policies cannot be reduced to public relations. For a state positioned between stronger powers, international reputation can create diplomatic room for maneuver. Yet soft power alone cannot manage the growing complexity of Kazakhstan's external relations. A country may possess a positive international image and still make poor decisions if it fails to process information quickly or recognize emerging risks. The growing importance of data therefore adds another dimension to state capacity.

2. From Digital Diplomacy to Computational Diplomacy

Digital diplomacy and computational diplomacy are related, but they are not the same. Digital diplomacy developed largely around the use of online technologies for communication. Foreign ministries created social-media accounts, embassies began communicating directly with foreign publics, and consular services moved increasingly onto digital platforms.

These developments changed the speed and visibility of diplomacy. A diplomatic statement that once reached the public through a press conference can now circulate internationally within seconds. Embassies can respond directly to misinformation. Citizens can contact consular institutions online. Political leaders can address foreign audiences without relying entirely on traditional media.

Computational diplomacy goes further. Ünver's early work on computational diplomacy drew attention to algorithms, automation and machine learning as forces capable of reshaping foreign-policy communication and the management of uncertainty (Ünver, 2017). Cederman and Girardin (2023) trace a related trajectory in the study of conflict, showing how computational modelling and data-driven methods developed originally for conflict research have gradually extended toward broader applications in diplomatic analysis. More recently, Cafiero defined computational diplomacy as the application of digital and computational methods to the study and practice of international negotiations. His analysis also stresses several features that make diplomacy difficult to datafy: diplomatic information may be secret, crises require rapid response, adversaries can deliberately manipulate information, and relevant datasets may be incomplete or unreliable (Cafiero, 2023).

These limitations are important. Foreign policy cannot be reduced to a technical optimization problem. Diplomats frequently work with incomplete information. Political leaders may deliberately hide their intentions. Governments can change positions suddenly. Historical

memory influences negotiation. Personal trust matters. Symbolism matters. Domestic political pressures matter. An algorithm can recognize statistical patterns without necessarily understanding their political meaning.

For this reason, recent scholarship increasingly favors the idea of augmented diplomacy rather than automated diplomacy. Kacziba and Urbanovics argue that AI can strengthen the analytical and operational capacity of foreign ministries while still being unable to replace contextual, political and normative judgment (Kacziba & Urbanovics, 2026). Manor similarly warns that many predictions about AI diplomacy remain speculative because technological adoption depends on organizational culture, institutional structure and the political conditions in which diplomats work (Manor, 2026).

This article follows that cautious approach. Here, computational diplomacy is understood as the use of data analysis, artificial intelligence, modelling and automated information processing to support diplomatic analysis, communication, negotiation and strategic foresight while preserving human political responsibility for final decisions.

3. Methodology and Periodization

The article employs a qualitative research design that combines document analysis, foreign-policy analysis and scenario-based reasoning. Official Kazakhstani documents are used to examine the state's foreign-policy orientation, digital transformation and emerging AI governance. These include the Foreign Policy Concept for 2020-2030, the Concept for the Development of Artificial Intelligence for 2024-2029, the 2025 Law on Artificial Intelligence and institutional documents relating to Kazakhstan's digital transformation.

The analysis also draws on academic literature concerning soft power, multivectorism, digital diplomacy, computational diplomacy and middle-power behavior.

A distinction is made between two periods. The first, 2020-2026, is empirical. Claims concerning this period refer to developments that have already occurred. The second, 2027-2028, is prospective. Because these years remain in the future at the time of writing, they are approached through alternative scenarios rather than presented as facts.

This distinction is particularly important in research on artificial intelligence. Technological change often generates ambitious predictions, but institutional change is usually slower. The existence of an AI platform does not automatically mean that diplomats use it. Similarly, the existence of a national strategy does not prove that AI has already become part of strategic foreign-policy decision-making.

The analysis therefore focuses on capacity, institutional direction and plausible application, rather than claiming that a fully developed system of computational diplomacy already exists in Kazakhstan.

4. The Foreign-Policy Toolkit at the Beginning of the 2020s

Kazakhstan entered the decade with a diversified diplomatic toolkit. At its center was multivectorism. Relations with Russia remained indispensable, but Kazakhstan simultaneously deepened economic relations with China, preserved substantial ties with the European Union, maintained cooperation with the United States and expanded engagement with other partners.

Multilateral diplomacy was another important component. Kazakhstan participates in institutions with very different memberships and political orientations, including the United Nations, the Shanghai Cooperation Organisation, the Eurasian Economic Union, the Organization for Security and Co-operation in Europe, the Organization of Turkic States and the Conference on Interaction and Confidence Building Measures in Asia.

Such participation serves more than one purpose. It allows Kazakhstan to maintain multiple diplomatic channels, participate in rule-making, increase international visibility and avoid being defined exclusively through one geopolitical relationship.

Economic diplomacy represents another core instrument. Because Kazakhstan's economy remains closely linked to natural resources and external markets, foreign policy and economic policy often overlap. Energy exports, foreign investment, transport infrastructure and access to international markets all have diplomatic implications.

The country's geographic position has also encouraged it to present itself as a connector between regions. Kazakhstan is not simply between Russia and China. It also connects Central Asia with the Caspian region, the Caucasus, Europe, the Middle East and wider Asian markets. This role has become more important as international transportation networks have gained strategic significance.

5. 2020-2022: Digitalization Under Pressure

The pandemic produced an unexpected experiment in digital diplomacy. A profession built around movement, personal meetings and physical diplomatic presence suddenly faced border closures and restrictions on international travel. Virtual consultations became routine. Conferences moved online. Diplomatic missions relied more heavily on digital communication.

This experience demonstrated that international engagement could continue even when traditional diplomatic mobility was severely limited. Yet it also revealed the limits of digital substitution.

Diplomatic negotiations depend partly on relationships that are difficult to quantify. Informal conversations, private meetings and personal impressions often influence outcomes. A videoconference can transmit information effectively, but it does not always reproduce the trust-building function of physical interaction.

This matters for the current debate about AI. The lesson of the pandemic was not that technology can replace diplomacy. It was that diplomacy becomes more resilient when institutions can combine traditional and technological tools. Digitalization initially affected the channel of diplomacy. Artificial intelligence may increasingly affect the analysis behind diplomacy. That difference marks the beginning of the computational turn.

6. The Post-2022 Environment: Multivectorism Becomes More Demanding

The geopolitical environment facing Kazakhstan became substantially more difficult after 2022. Russia remains a major neighbor, economic partner and participant in regional institutions. Kazakhstan cannot treat relations with Russia as optional. At the same time, the war in Ukraine and the international sanctions regime created new economic, financial and political risks.

Kazakhstan consequently had to preserve cooperation with Russia while also protecting its access to Western markets, investment and financial systems. This is multivectorism under greater pressure.

Rather than moving entirely from one geopolitical camp to another, Kazakhstan continued to diversify. China's economic significance remained high. Cooperation with the European Union acquired additional importance. Türkiye's role expanded through bilateral relations and Turkic institutions. Relations with Gulf countries developed further in investment, energy and infrastructure. Regional cooperation within Central Asia became more active.

Recent scholarship on Kazakhstan's foreign policy similarly emphasizes continued diversification rather than abandonment of multivectorism. Nyshanbayev et al. describe contemporary policy as a continuation and adaptation of the country's established multidirectional approach, while other studies increasingly interpret Central Asian multivectorism through the language of hedging and strategic risk management (Nyshanbayev et al., 2025).

This environment creates an important information problem. Consider a single decision involving transport policy. A route that reduces dependence on one partner may increase dependence on another. A decision favorable to European trade may affect relations with China. Sanctions may alter financial arrangements. Changes in Caspian infrastructure can influence the value of a transport project. Energy prices can change the economics of the entire corridor.

No single bilateral relationship can be analyzed in isolation. For Kazakhstan, multivectorism increasingly requires the ability to understand interdependence between vectors. This is precisely where computational methods may become useful.

7. The Middle Corridor: A Practical Illustration

The Trans-Caspian International Transport Route, commonly known as the Middle Corridor, illustrates this new complexity particularly well. The corridor connects China and Central Asia with the Caspian Sea, Azerbaijan, Georgia, Türkiye and European markets.

Its importance increased after 2022 as states and companies sought transport options that could reduce reliance on routes passing through Russia. For Kazakhstan, however, the Middle Corridor is more than a railway and maritime project. It is part of economic diversification, foreign policy and strategic autonomy.

In February 2026, the World Bank approved an \$846 million guarantee designed to mobilize approximately \$1.41 billion for a major railway connectivity project along Kazakhstan's section of the corridor. The project is intended to strengthen Kazakhstan's role as a Eurasian transit hub and improve the efficiency and resilience of its rail network (World Bank, 2026).

The diplomatic implications are substantial. The corridor requires coordination among several states and transport operators. It involves customs policy, ports, railways, investment, financial institutions and geopolitical relationships.

Traditional diplomacy remains indispensable. But computational systems could improve decision-making by combining information on rail capacity, shipping delays, border congestion, commodity flows, weather conditions, infrastructure investments and political risk. A diplomat or policymaker would still determine priorities. The computational system would help reveal how changes in one part of the corridor might affect the rest.

This example shows why computational diplomacy should not be imagined only as AI writing diplomatic messages. Its most valuable applications may take place quietly inside ministries and analytical institutions.

8. Kazakhstan's AI Transformation, 2024-2026

The technological side of the transformation became clearer after 2024. Government Resolution No. 592 of 24 July 2024 approved Kazakhstan's Concept for the Development of Artificial Intelligence for 2024-2029. The document addresses several foundational areas, including data, infrastructure, human capital, research, regulation and acceleration programs (Government of the Republic of Kazakhstan, 2024).

This strategy is not a foreign-policy document. Nevertheless, it matters for diplomacy because computational foreign policy cannot develop independently from national technological capacity. A foreign ministry interested in AI-assisted analysis needs secure computing infrastructure. It needs reliable data. It needs specialists. It needs legal standards. It needs systems capable of handling sensitive government information.

The broader digital transformation of Kazakhstan provides part of this foundation. The country ranked 24th among 193 states in the 2024 UN E-Government Development Index and 10th in online services, reflecting a relatively advanced level of digital public administration (United Nations Department of Economic and Social Affairs, 2024).

The institutional framework expanded further in 2025. Kazakhstan created the Ministry of Artificial Intelligence and Digital Development, giving AI a more explicit position within government structure. The Law On Artificial Intelligence, adopted on 17 November 2025, also introduced a formal national legal framework (Republic of Kazakhstan, 2025). Particularly relevant to the argument of this article is the law's distinction among levels of system autonomy. It recognizes systems that process data and produce recommendations or forecasts while leaving final decisions to humans, alongside more autonomous forms of AI.

This legal distinction is highly compatible with the idea of augmented diplomacy. The most realistic foreign-policy application for a state such as Kazakhstan is not an autonomous system deciding relations with another country. It is an analytical system that produces options, identifies risks or summarizes information while diplomats retain authority.

Kazakhstan also continued investing in AI infrastructure, international technology partnerships and the Alem.ai ecosystem. These developments do not prove that computational diplomacy has already become standard practice inside Kazakhstan's Ministry of Foreign Affairs. They do, however, reduce one of the major barriers to its future development: the absence of national technological infrastructure.

9. Computational Multivectorism: A Proposed Framework

The central conceptual contribution of this article is the idea of computational multivectorism. The term does not describe an officially declared foreign-policy doctrine. It is an analytical concept intended to explain how Kazakhstan's existing multivector strategy might evolve under conditions of increasingly data-intensive diplomacy.

Traditional multivectorism asks: how can Kazakhstan maintain productive relations with several centers of power while avoiding excessive dependence on any one of them? Computational multivectorism adds another question: how can Kazakhstan process enough information to understand how those different relationships affect one another?

This distinction matters because the complexity of multivector diplomacy grows faster than the number of partners. If a country maintains ten important external relationships, policymakers are not managing only ten separate bilateral relationships. They must also consider interactions among them.

Russia's relationship with China matters. China's relationship with the United States matters. EU sanctions policy matters for Kazakhstan's interaction with Russia. Relations between the Gulf states and global energy markets affect investment decisions. Türkiye's role in the Middle Corridor affects connectivity. Developments in Afghanistan affect Central Asian security.

The diplomatic system therefore resembles a network more than a collection of separate bilateral files. Computational methods are particularly suited to examining networks. A future Kazakhstani analytical platform might bring together economic indicators, transport statistics, diplomatic reporting, public statements, energy markets and open-source information. AI could help organize this material into several alternative scenarios.

The objective would not be to produce a single correct answer. It would be to help policymakers ask better questions.

10. Foreign-Policy Applications

The first realistic field for computational methods is information management. Foreign ministries receive enormous quantities of material: embassy reporting, official documents, news, economic information, international-organization publications and public statements. AI-assisted systems could reduce the administrative burden of searching and summarizing this material.

A diplomat preparing for negotiations with several countries could request a structured comparison of recent official statements, trade trends, previous agreements and unresolved issues. The final briefing would still require verification by human specialists.

A second application concerns economic diplomacy. Kazakhstan actively competes for investment while simultaneously seeking to diversify its economy. Data tools can help identify shifts in foreign direct investment, compare sectors, track major investors and monitor projects.

This could be especially useful in rapidly developing partnerships with Gulf states, where sovereign investment funds, renewable-energy companies and infrastructure investors increasingly play significant international roles. A data-based system could assist ministries in identifying patterns across investment announcements, project implementation and sectoral trends.

A third area is crisis monitoring. Foreign ministries already monitor political events, but machine-assisted systems can process large information flows continuously. Such tools could help detect unusual patterns in transportation, commodity prices or public communication that deserve human attention.

A fourth area is multilingual analysis. Kazakhstan's diplomatic environment is unusually multilingual. Kazakh, Russian and English are particularly important, while Chinese, Turkish, Arabic and other languages matter in specific relationships. Improved language models could help diplomats compare large volumes of foreign-language material.

Yet translation is also an area where human review remains essential. Diplomatic language is sensitive. A difference between concern, serious concern, condemnation and warning may have political significance that an automated system fails to appreciate.

11. Public Diplomacy in the Age of Generative AI

Artificial intelligence does not only affect internal analysis. It is also changing the environment in which soft power operates. International reputation is increasingly shaped online. Search engines, social-media algorithms, influencers, automated accounts and generative AI systems all affect what foreign publics see and how quickly information circulates.

This creates new opportunities for Kazakhstan. Digital platforms allow the country to communicate directly about tourism, education, culture, investment and foreign-policy initiatives. But the same environment creates vulnerabilities. False information can spread quickly. Synthetic video and audio can imitate political leaders. Automated networks can amplify narratives that would otherwise remain marginal.

In this environment, public diplomacy becomes partly an analytical task. Diplomatic institutions need to understand not only what they want to communicate, but how information about their country is moving through digital networks. AI can help identify trends in public discourse or detect sudden increases in misleading content.

However, there is an important paradox. The more AI-generated communication fills the information environment, the more valuable credibility becomes. A government that over-automates its communication risks making diplomacy sound impersonal or artificial. Soft power ultimately depends on trust. Computational tools can help protect that trust, but they cannot manufacture it indefinitely.

12. Kazakhstan as a Responsible Middle Power

The emerging middle-power dimension of Kazakhstan's foreign-policy identity also strengthens the relevance of this discussion. Kazakhstan increasingly presents itself as a responsible middle power, a formulation used in recent official discourse.

Middle powers do not possess the global military capabilities of great powers. Their influence usually comes from other sources: diplomatic credibility, coalition-building, institutional engagement, specialized expertise and the ability to act as intermediaries.

This makes analytical capacity particularly valuable. A middle power does not need to compete with the United States or China across the entire technological spectrum. It can concentrate resources on areas where it has strategic interests and diplomatic experience.

For Kazakhstan, these niches could include Eurasian connectivity, energy security, nuclear non-proliferation, critical minerals, climate diplomacy, water cooperation and Central Asian regional affairs. AI and data analysis could strengthen such specialization.

For example, Kazakhstan could develop stronger analytical expertise on Eurasian transport corridors by combining logistical data with geopolitical analysis. It could use advanced modelling in energy diplomacy. It could develop regional early-warning capacity on water stress or climate risks.

The strategic advantage would not come from possessing the largest AI system. It would come from using technology intelligently in areas where the country already has diplomatic relevance.

13. Risks and Limits

The promise of computational diplomacy should not obscure its risks. One of the most serious is automation bias. Once a recommendation appears on a sophisticated digital dashboard, policymakers may give it more authority than it deserves. Numbers often create an impression of objectivity. Yet every model reflects choices about data, assumptions and variables.

A forecast that assigns a 70 percent probability to an outcome may look precise while still being based on incomplete evidence. Algorithmic bias is another problem. A model trained mainly on English-language Western sources could systematically overlook information circulating in Russian, Kazakh, Chinese or other relevant information spaces. This would be especially damaging for a multivector state.

Data sovereignty presents a further concern. Diplomatic information is among the most sensitive data held by governments. Using foreign commercial platforms for confidential diplomatic analysis can create security and dependence risks. The creation of national infrastructure may reduce some of these vulnerabilities, although no modern state is completely technologically autonomous.

Cybersecurity must therefore be treated as part of computational diplomacy rather than as a separate technical problem. A manipulated analytical system could be more dangerous than a system that simply stops working. If an attacker secretly changes the information feeding a forecasting model, decision-makers may act confidently on distorted conclusions.

There is also a professional risk. Diplomatic judgment is partly learned through experience. Younger diplomats need to learn how to read negotiations, understand cultural context, detect ambiguity and form independent assessments. If every analytical task is delegated to software, institutions may gradually weaken the very expertise needed to recognize when the software is wrong.

The appropriate principle is therefore straightforward: automate routine processing where possible, but do not automate political responsibility.

14. Three Scenarios for 2027-2028

Scenario One: Limited Digital Enhancement

In the first scenario, Kazakhstan continues its broad digital transformation, but the Ministry of Foreign Affairs adopts AI cautiously. The main applications remain translation, document search, administrative automation, public communication and routine information monitoring. Foreign-policy assessments continue to be produced largely through established institutional practices. This scenario would still improve diplomatic efficiency, but it would not amount to mature computational diplomacy.

Scenario Two: Augmented Multivector Diplomacy

The second scenario represents a deeper but still controlled transformation. Foreign-policy institutions begin integrating selected AI tools into strategic analysis. A secure system could bring together economic data, regional reporting, transport statistics, open-source material and international political developments.

It might support scenario analysis concerning sanctions, energy markets, transport corridors, investment risks or regional crises. Human analysts would review outputs. Senior diplomats and political leaders would remain responsible for decisions.

This scenario most closely corresponds to the concept of computational multivectorism proposed in this article. It would combine multivector diplomacy, soft power, middle-power activism and computational analysis. Given Kazakhstan's existing trajectory in digital government

and AI policy, this is arguably the most plausible pathway if institutional capacity continues to develop.

Scenario Three: Technological Overreach

The third scenario is less positive. Government institutions adopt AI faster than they develop procedures for verification, cybersecurity and professional oversight. Reliance on external technology providers creates vulnerabilities. Poor-quality datasets produce misleading recommendations. Officials begin trusting apparently precise forecasts without adequately examining their assumptions.

A serious analytical failure during a diplomatic or economic crisis could then reduce confidence in the entire process. This scenario demonstrates that the success of computational diplomacy depends less on acquiring fashionable technology than on building strong institutions around it.

15. Discussion

Kazakhstan's experience points to a broader change in international relations. The traditional boundary between domestic digital policy and foreign policy is becoming increasingly difficult to maintain.

AI infrastructure affects national competitiveness. Cybersecurity affects sovereignty. Data regulation affects international business. Semiconductor supply chains affect strategic autonomy. Online information affects national reputation. Technology policy therefore becomes part of foreign policy even before foreign ministries begin using AI directly.

For Kazakhstan, this convergence is particularly important because strategic autonomy already lies at the heart of multivectorism. The country has long attempted to avoid excessive dependence on any single external power. In the twenty-first century, however, dependency is no longer only military, political or economic. It can also be technological.

A state that depends completely on external platforms to process its most important data may discover that technological dependence has foreign-policy consequences. This means that digital capacity increasingly becomes one dimension of sovereignty.

At the same time, technological sovereignty should not be confused with technological isolation. Kazakhstan benefits from international partnerships, investment, knowledge exchange and access to global innovation. The challenge resembles the broader challenge of multivectorism itself: cooperation without excessive dependence.

In this sense, Kazakhstan's traditional diplomatic philosophy may be surprisingly relevant to the AI era. Multivectorism has always involved diversification. Computational diplomacy adds a new object of diversification: technology.

Conclusion

Between 2020 and 2026, Kazakhstan's diplomatic environment changed considerably. The decade began with the adoption of the Foreign Policy Concept for 2020-2030, which reaffirmed multivectorism, pragmatism and proactive engagement. The pandemic accelerated digital diplomatic practices. The geopolitical disruption after 2022 made diversification and strategic autonomy more urgent. The growing importance of the Middle Corridor strengthened Kazakhstan's position as a connective state while simultaneously increasing the complexity of its external partnerships.

Domestic technological developments added another element to this transformation. The adoption of the Artificial Intelligence Development Concept for 2024-2029, the 2025 AI law, the creation of specialized institutions and the expansion of national AI infrastructure indicate that Kazakhstan is building capabilities that may eventually be used in increasingly sophisticated forms of foreign-policy analysis.

These developments do not mean that algorithms are replacing diplomacy. There is little reason to expect such an outcome, and little evidence that it would be desirable. Diplomacy

remains a political and profoundly human activity. Trust, judgment, personal relationships and historical understanding cannot simply be converted into data points.

What is changing is the amount of information surrounding diplomatic decisions and the speed at which governments are expected to respond. For this reason, Kazakhstan's most realistic trajectory is not toward automated diplomacy but toward augmented diplomacy.

Within such a model, traditional soft power continues to matter. Multivectorism continues to provide the basic strategic logic. Middle-power diplomacy provides an international role. Computational tools provide additional analytical capacity.

The article has described the convergence of these elements as computational multivectorism. The value of this concept lies in its recognition that artificial intelligence does not necessarily replace established foreign-policy traditions. It can instead become embedded within them.

For Kazakhstan, this distinction is particularly important. The success of its foreign policy has historically depended on its ability to navigate complexity without surrendering strategic autonomy. In the coming years, the same principle may apply to technology.

The central challenge will not be whether Kazakhstan can become a fully algorithmic diplomatic actor. It will be whether the country can use new computational tools without losing the human judgment, flexibility and balance that have long defined its diplomacy.

In this sense, the transformation from soft power to computational diplomacy should not be understood as a break with Kazakhstan's diplomatic past. It is more accurately seen as the next stage in the evolution of the instruments used to pursue the same enduring goal: preserving sovereignty and strategic room for maneuver in a complex international environment.

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Medical Sciences

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Clinical Features of Bronchial Asthma in Children with Different Frequencies of Exacerbations in Almaty, Kazakhstan

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Abstract

Background. Bronchial asthma is one of the most common chronic respiratory diseases in children. Despite advances in modern diagnosis and treatment, frequent exacerbations remain one of the main causes of poor disease control, medical consultations, and hospitalization. In children, it is particularly important to identify the clinical features of the disease in patients who are prone to recurrent exacerbations.

Objective. To study the clinical features of bronchial asthma in children aged 5–15 years depending on the frequency of exacerbations based on a retrospective analysis of medical records from 2020 to 2025.

Materials and Methods. A retrospective comparative study of clinical data from 120 children with bronchial asthma aged 5–15 years was conducted. The main group included 50 children with frequent exacerbations, while the comparison group consisted of 70 children with infrequent exacerbations.

Results. Boys predominated among the study participants: 64.0% in the main group and 55.7% in the comparison group. Early disease onset before the age of 5 years was more common among children with frequent exacerbations—36.0% compared with 28.6%. Poor asthma control was identified in 62.0% of children in the main group and 22.9% of children in the comparison group. A positive allergic history was reported in 78.0% and 62.9% of patients, respectively. Allergic rhinitis and recurrent respiratory infections were also more common among children with frequent exacerbations. Regular controller therapy was received by 58.0% of children in the main group and 72.9% of those in the comparison group. Poor treatment adherence was observed in 52.0% and 32.9% of patients, respectively. The most pronounced differences were observed in hospitalization rates: hospitalization due to bronchial asthma exacerbation occurred in 62.0% of children in the main group compared with 20.0% in the comparison group.

Conclusion. Children with frequent bronchial asthma exacerbations more often had poor disease control, a more severe course of the disease, a positive allergic history, concomitant allergic rhinitis, and recurrent respiratory infections. In addition, irregular use of controller therapy and poor treatment adherence were more common in this group. Frequent exacerbations were associated with a higher rate of hospitalization. The findings highlight the need for closer monitoring of children with recurrent exacerbations, including assessment of asthma control, adherence to prescribed treatment, and concomitant conditions.

Keywords: bronchial asthma, children, exacerbation, frequent exacerbations, asthma control, controller therapy, treatment adherence, hospitalization.

Introduction

Bronchial asthma (BA) is one of the most common chronic respiratory diseases in children. The disease can significantly affect a child's daily activities, school attendance, and quality of life, particularly when symptoms are poorly controlled and exacerbations occur frequently. According to the World Health Organization, asthma is one of the most common chronic diseases in childhood and remains an important public health problem [1].

The problem of bronchial asthma is also highly relevant in Kazakhstan. According to the Ministry of Health of the Republic of Kazakhstan, the overall incidence of bronchial asthma in the country increased from 93.4 cases per 100,000 population in 2017 to 126.1 cases per 100,000 population in 2020. Children under 14 years of age represented one of the most vulnerable groups; in 2020, the incidence rate in this age group was 132.2 per 100,000 population [2]. Differences between urban and rural areas were also reported: in 2020, the incidence rate in urban areas was 156.3 per 100,000 population, compared with 82.8 per 100,000 in rural districts [2].

Data obtained from the electronic healthcare system of Kazakhstan are also of interest. A large retrospective study analyzed data from 53,463 children with bronchial asthma aged 0–17 years between 2014 and 2021. Boys accounted for 63.7% of the patients, while almost half of the children (47.9%) were aged 5–11 years. The highest incidence was recorded among children aged 5–11 years. The authors also reported higher incidence rates among boys than among girls [3].

The dynamics of asthma incidence among children also deserve attention. According to a study based on regional data from Kazakhstan, between 2010 and 2019, the incidence of asthma among children aged 0–14 years increased from 46.5 to 194.2 cases per 100,000 children, representing an increase of more than fourfold [4]. At the same time, considerable regional differences were observed, suggesting that environmental conditions, access to medical care, and other factors may influence the detection and course of the disease.

There is also evidence of underdiagnosis of bronchial asthma. In the CORE study, which included participants from Almaty, the prevalence of physician-diagnosed asthma among the adult population of Kazakhstan was 19 cases per 1,000 people, whereas the prevalence of wheezing was considerably higher at 254.8 per 1,000 people. This may indicate that some cases of the disease remain undiagnosed or are not reflected in official statistics [5].

The problem is particularly important in children because of the impact of exacerbations on the course of the disease. A study of children with bronchial asthma in Almaty, which included 518 medical records from 2015–2019, found that boys accounted for the majority of hospitalized patients (62.5%). An increase in the number of hospitalizations was also observed during the study period [6]. These findings indicate that frequent exacerbations remain an important marker of disease severity and poor asthma control in children.

Recent data also make it possible to assess factors associated with hospitalization among children with bronchial asthma. In a 2025 study of children receiving outpatient care, 915 hospitalizations were recorded among 31,525 patients (2.8%). The risk of hospitalization was higher among children aged 5–11 years, while respiratory infections, allergic rhinitis, and acute rhinosinusitis were among the factors associated with hospitalization [3,7].

Thus, bronchial asthma remains a relevant problem in pediatric care in Kazakhstan. Despite improvements in diagnosis and patient monitoring, the incidence of the disease and its exacerbations remains an important area of clinical interest. It is particularly important to identify the characteristics of children who experience exacerbations more frequently, as this may help to identify patients with a more severe or poorly controlled course of the disease at an earlier stage. Therefore, studying the clinical characteristics of children with frequent and infrequent bronchial asthma exacerbations is a relevant area of retrospective research.

Objective

To study the clinical features of bronchial asthma in children aged 5–15 years in Almaty, Kazakhstan, depending on the frequency of exacerbations based on a retrospective analysis of medical records from 2020 to 2025.

Materials and Methods

A retrospective comparative study of clinical data from children with bronchial asthma aged 5–15 years was conducted. The study included data from 120 patients who were followed up during the period from 2020 to 2025.

Depending on the frequency of bronchial asthma exacerbations, the patients were divided into two groups. The main group consisted of 50 children who experienced frequent exacerbations. The comparison group consisted of 70 children with infrequent exacerbations of bronchial asthma. This division made it possible to compare the clinical features of the disease in children with different frequencies of exacerbations.

During the retrospective analysis, information recorded in the patients' medical records throughout the observation period was assessed. The main clinical characteristics and course of the disease, as well as the frequency of medical consultations and hospitalizations due to bronchial asthma exacerbations, were analyzed.

The inclusion criteria were an age of 5–15 years, an established diagnosis of bronchial asthma, and sufficient medical documentation to assess the course of the disease during the study period. Patients whose medical records did not contain sufficient information to determine the frequency of exacerbations were excluded from the analysis.

To assess differences between the main and comparison groups, the clinical parameters under study were compared. The collected data were systematized and subjected to statistical analysis. Differences were considered statistically significant at $p < 0.05$.

Table 1. Criteria for patient group allocation according to the frequency of bronchial asthma exacerbations

Group	Criterion
Main group	Children with BA and ≥ 2 exacerbations/year
Comparison group	Children with BA and 0–1 exacerbation/year

Results

The retrospective analysis included 120 children with bronchial asthma aged 5–15 years. Depending on the frequency of exacerbations, the patients were divided into two groups: the main group included 50 children with frequent exacerbations, while the comparison group included 70 children with infrequent exacerbations.

Age and Sex of the Patients

The mean age of the children was approximately 9.6 years in the main group and 9.3 years in the comparison group. No substantial difference in age was observed between the groups.

The general characteristics of the participants are presented in Table 2. Boys predominated in both groups. In the main group, there were 32 boys (64.0%) and 18 girls (36.0%). In the comparison group, boys accounted for 39 patients (55.7%) and girls for 31 patients (44.3%).

Table 2. General characteristics of the selected patients

Parameter	Main group (n=50)	Comparison group (n=70)
Mean age, years	9.6	9.3
Boys	32 (64.0%)	39 (55.7%)
Girls	18 (36.0%)	31 (44.3%)

Thus, the differences in sex distribution were relatively small, although the proportion of boys was somewhat higher among children with frequent exacerbations.

Age at Disease Onset

Analysis of the age at onset of bronchial asthma showed that the disease began at an early age in some children. In the main group, disease onset before the age of 5 years was recorded in 18 children (36.0%), compared with 20 children (28.6%) in the comparison group. These data are presented in Table 3.

The disease was first diagnosed at 5–9 years of age in 21 children (42.0%) in the main group and in 30 children (42.9%) in the comparison group. Asthma onset after the age of 9 years was recorded in 11 (22.0%) and 20 (28.6%) children, respectively.

Table 3. Age at onset of BA among the selected patients

Age at BA onset	Main group (n=50)	Comparison group (n=70)
Under 5 years	18 (36.0%)	20 (28.6%)
5–9 years	21 (42.0%)	30 (42.9%)
Over 9 years	11 (22.0%)	20 (28.6%)

Thus, early disease onset was somewhat more common in the main group. However, early onset of asthma alone was not necessarily associated with frequent exacerbations, and this parameter should therefore be considered together with other characteristics of the disease course.

Severity and Control of Bronchial Asthma

The severity and control of bronchial asthma among the selected patients are presented in Table 4. One of the most noticeable differences between the groups was the degree of disease control. Signs of poor asthma control were observed in 31 children (62.0%) with frequent exacerbations. In the comparison group, poorly controlled disease was observed in 16 children (22.9%).

Controlled disease was observed in 19 children (38.0%) in the main group and in 54 children (77.1%) in the comparison group.

Table 4. Severity and control of bronchial asthma among the selected patients

Asthma control	Main group (n=50)	Comparison group (n=70)
Controlled	19 (38.0%)	54 (77.1%)
Uncontrolled	31 (62.0%)	16 (22.9%)

Thus, poor asthma control was considerably more common among children with frequent exacerbations. This is an expected finding, as frequent exacerbations may themselves reflect inadequate disease control.

When disease severity was assessed, as shown in Table 5, a tendency toward a more severe course was observed in the main group. Mild asthma was diagnosed in 13 children (26.0%) in the main group and in 29 (41.4%) in the comparison group. Moderate asthma was observed in 27 (54.0%) and 32 (45.7%) children, respectively, while severe asthma was recorded in 10 (20.0%) and 9 (12.9%) children.

Table 5. Assessment of BA severity among the selected patients

BA severity	Main group	Comparison group
Mild	13 (26.0%)	29 (41.4%)
Moderate	27 (54.0%)	32 (45.7%)
Severe	10 (20.0%)	9 (12.9%)

The findings indicate that moderate and severe forms of the disease were more common among children with frequent exacerbations.

Allergic History

A positive allergic history was reported in 39 children (78.0%) in the main group and in 44 children (62.9%) in the comparison group.

The most common conditions reported in the medical history were allergic rhinitis, atopic dermatitis, and allergic reactions to food or household allergens.

Thus, signs of atopic predisposition were more common among children with frequent exacerbations. However, the differences between individual allergic conditions should be assessed separately, as the presence of an allergic history alone does not indicate the extent of its influence on the course of asthma.

Concomitant Diseases

Analysis of concomitant conditions showed that allergic rhinitis and recurrent respiratory infections were the most common. The data are presented in Table 6.

Allergic rhinitis was diagnosed in 26 children (52.0%) in the main group and in 23 children (32.9%) in the comparison group. Recurrent respiratory infections were reported in 22 (44.0%) and 19 (27.1%) children, respectively.

Atopic dermatitis was less common and was observed in 9 (18.0%) children in the main group and 8 (11.4%) in the comparison group.

Table 6. Concomitant diseases among the selected patients

Concomitant condition	Main group	Comparison group
Allergic rhinitis	26 (52.0%)	23 (32.9%)
Recurrent respiratory infections	22 (44.0%)	19 (27.1%)
Atopic dermatitis	9 (18.0%)	8 (11.4%)

Thus, allergic rhinitis and recurrent respiratory infections were more common among children with frequent exacerbations. This is consistent with data from large studies of childhood asthma, in which respiratory infections and allergic rhinitis were also associated with a higher likelihood of hospitalization.

Controller Therapy

Assessment of prescribed treatment showed that most children in both groups received anti-inflammatory controller therapy. However, regular use of medication was more common in the comparison group.

In the main group, 29 children (58.0%) received regular controller therapy, compared with 51 children (72.9%) in the comparison group. Irregular treatment or self-discontinuation of therapy was reported in 21 (42.0%) and 19 (27.1%) children, respectively.

Thus, irregular use of controller therapy was more common among children with frequent exacerbations. However, based on retrospective data, it cannot be stated conclusively that irregular treatment was the cause of frequent exacerbations, as other factors could also have influenced the course of the disease.

Treatment Adherence

A similar trend was observed when treatment adherence was assessed. Good adherence to prescribed therapy was reported in 24 children (48.0%) in the main group and in 47 (67.1%) children in the comparison group.

Poor adherence was observed in 26 (52.0%) and 23 (32.9%) children, respectively.

Thus, poor treatment adherence was more common among children with frequent exacerbations. The medical records most commonly documented missed doses and self-discontinuation of controller therapy after clinical improvement.

Hospitalizations

The most pronounced differences between the groups were observed in the analysis of hospitalizations. In the main group, hospitalization due to bronchial asthma exacerbation during the study period was recorded in 31 children (62.0%). In the comparison group, 14 children (20.0%) were hospitalized.

Repeated hospitalizations were mainly observed among children in the main group: 14 patients (28.0%) had two or more hospitalizations during the observation period. In the comparison group, repeated hospitalization was recorded in 5 children (7.1%).

Thus, children with frequent exacerbations required inpatient treatment considerably more often. The difference was particularly noticeable in the frequency of repeated hospitalizations.

Discussion

Comparison of the two groups showed the most pronounced differences in asthma control, regularity of controller therapy, treatment adherence, the presence of allergic rhinitis and recurrent respiratory infections, and hospitalization rates.

Overall, children with frequent exacerbations more often had poor disease control, a more severe course of asthma, a positive allergic history, concomitant allergic rhinitis, recurrent respiratory infections, and irregular use of controller therapy. The most substantial difference between the groups was observed in the frequency of hospitalizations.

The findings suggest that frequent bronchial asthma exacerbations in children are associated not with a single factor but with a combination of disease-related characteristics, concomitant allergic and respiratory conditions, and adherence to prescribed treatment.

Conclusion

The retrospective analysis examined the clinical features of bronchial asthma in 120 children aged 5–15 years during the period from 2020 to 2025. According to the frequency of exacerbations, the patients were divided into two groups: 50 children with frequent exacerbations and 70 children with infrequent exacerbations.

Children with frequent exacerbations more often had poorly controlled bronchial asthma. This group also more frequently included patients with moderate and severe forms of the disease, a positive allergic history, allergic rhinitis, and recurrent respiratory infections.

Treatment adherence was another important finding. Irregular use of controller therapy and self-discontinuation of medication after clinical improvement were more common among children with frequent exacerbations. The most noticeable difference between the groups was observed in hospitalization rates: children with frequent exacerbations required inpatient treatment considerably more often, including repeated hospitalization.

Thus, frequent bronchial asthma exacerbations in children were more often observed in association with poor disease control, concomitant allergic and respiratory conditions, and less regular use of controller therapy. The findings highlight the need for closer monitoring of children who experience recurrent exacerbations, with particular attention to asthma control, adherence to prescribed treatment, and concomitant conditions.

The analysis suggests that early identification of children with more frequent exacerbations may help to focus clinical attention on these patients and allow treatment to be adjusted in a timely manner.

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METHODOLOGY, EFFECTIVENESS AND RESULTS OF SCREENING FOR THREE PRIORITY CANCERS IN KAZAKHSTAN: A COMPREHENSIVE ANALYTICAL REVIEW

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Annotation: This scientific and analytical study examines the epidemiological patterns of cervical, breast, and colorectal cancer in the regions of the country, with particular emphasis on incidence and mortality rates and their regional variation. The study provides a comprehensive assessment of the current state of cancer screening and prevention, including the screening approaches used for the early detection of these malignancies in clinically asymptomatic

populations. Particular attention is given to the organization and implementation of population-based screening programs, the target populations, screening intervals, diagnostic methods, and the subsequent management of individuals with abnormal screening results. The analysis also considers the role of screening in reducing the burden of malignant neoplasms through early detection and timely referral for further diagnostic evaluation and treatment. The study presents detailed, step-by-step algorithms for the organization and implementation of screening for cervical, breast, and colorectal cancer, outlining the principal stages from identification and invitation of eligible individuals to primary screening, additional diagnostic procedures, confirmation of the diagnosis, and appropriate follow-up. The diagnostic capabilities and practical significance of the screening methods currently applied are described, with particular emphasis on their potential for detecting precancerous conditions and early-stage malignancies before the onset of clinical symptoms. The findings highlight the importance of a systematic, evidence-based approach to cancer screening and demonstrate the potential of well-organized preventive programs to improve early detection, facilitate timely treatment, and ultimately contribute to reductions in cancer-related incidence and mortality.

Key words: oncology, primary care, early diagnosis, cancer screening, cervical cancer, breast cancer, colorectal cancer, epidemiology, incidence, mortality, HPV, Pap test, smear for oncocytology, ultrasound examination, mammography, hemocult test, fecal occult blood test - FOBT, total colonoscopy.

Early detection of malignant neoplasms remains one of the fundamental priorities of modern oncology and an essential component of effective cancer control. The clinical outcomes of many malignant diseases are strongly influenced by the stage at which the tumor is diagnosed, with earlier-stage detection generally associated with a greater range of therapeutic options, improved treatment outcomes, and more favorable long-term prognosis. Consequently, the development and implementation of effective strategies for identifying malignant and premalignant conditions before the appearance of clinical manifestations represent an important direction in contemporary preventive medicine. Cancer screening is an established approach to secondary prevention aimed at detecting disease in individuals who do not yet exhibit symptoms or clinical signs suggestive of malignancy. Unlike diagnostic procedures performed in patients with suspected disease, screening is conducted among predefined target populations according to established age, sex, and risk-based criteria. Its primary objective is to identify cancer at a preclinical or early stage, when the pathological process may be more amenable to curative treatment. In addition, screening may facilitate the detection of premalignant lesions and other pathological changes that have the potential to progress to invasive cancer, thereby creating an opportunity for timely intervention and prevention of malignant transformation [1].

The effectiveness of a screening program depends not only on the diagnostic performance of individual screening methods but also on the quality of its overall organization and implementation. A well-functioning screening system requires clearly defined target populations, standardized procedures for participant recruitment and examination, appropriately trained healthcare professionals, and consistent criteria for interpreting and managing screening results. Equally important is the availability of an established pathway for the subsequent evaluation of individuals with abnormal findings, including confirmatory diagnostic procedures, specialist referral, treatment, and follow-up. Without adequate coordination between these stages, the potential benefits of screening may be substantially reduced [1,2].

Screening technologies and diagnostic approaches should meet several fundamental requirements to ensure their applicability at the population level. Ideally, screening procedures should be sufficiently simple, safe, accessible, reproducible, and acceptable to the target

population, while demonstrating adequate sensitivity and specificity. High sensitivity is essential for minimizing the number of clinically significant cases that remain undetected, whereas adequate specificity helps to reduce false-positive results and unnecessary diagnostic interventions. Therefore, the development of standardized, evidence-based screening algorithms and their systematic implementation are critical for improving the early detection of cancer and precancerous conditions and, ultimately, for reducing cancer-related incidence and mortality [3].

Screening plays an important role in improving early diagnosis and treatment outcomes. According to the Guide to Cancer Early Diagnosis by Ilbawi A. et al. [4], screening aims to detect unrecognized cancer or its prior lesions in a typically healthy, asymptomatic population through tests or other procedures that can be applied quickly and are widely available to the target population. In screening, the target population is assessed for unrecognized cancer or precancer, and most people tested will not be diagnosed with the disease. Screening should be seen as a process and not as the performance of a specific test, examination, or procedure. The screening process includes a system of informing and inviting the target population to participate; administering the screening test; following-up with test results and referral for further testing among those with abnormal test results; ensuring timely pathologic diagnosis, staging and access to effective treatment with routine evaluation to improve the process. A screening program encompasses the process from invitation to treatment and requires planning, coordination and monitoring and evaluation.

To date, the republican cancer screening program includes three nosological forms of malignant neoplasms - cervical cancer (CC), breast cancer (BC), colorectal cancer (CRC). Let's consider the current epidemiological indicators, methodology and results of cancer screening in our country.

CC in the structure of all malignant tumors of both sexes of the population in 2022 took 6th place with a share of 5.51% (2021 - 4th place, 5.54%), in women - stable 2nd place - 9.7% (9.7%) [5].

The incidence rate per 100 thousand population increased from 9.4 to 9.92. In 10 regions of the republic, the incidence rate is higher than the national average: Pavlodar - 17.2 per 100 thousand people (2021 - 16.7) - the highest level, East Kazakhstan - 14.3 (10.8), North Kazakhstan - 14.3 (10.2), Atyrau - 13.2 (13.8), Zhetysay - 11.7, Karaganda - 11.7 (12.0), Abay - 11.1, Akmola - 11.1 (11.9), Mangistau - 11.1 (9.7), Kostanay - 10.8 (10.6) regions.

Low incidence rates in Zhambyl region - 5.8 per 100 thousand population (5.7), Turkestan region - 6.1 (5.2), Aktobe region - 8.3 (11.6), Kyzylorda region - 8.5 (8.2) areas.

CC in the structure of causes of death from malignant tumors of the population of both sexes in 2022 rose from 9th to 8th position, with a share of 4.6% (2021 - 4.3%), mortality from CC is stable at 3.1 per 100 thousand population (3.1).

The mortality rate from CC in 10 regions is higher than the national average: Akmola - 4.2 per 100 thousand population (2021 - 3.1) - maximum level, West Kazakhstan - 4.1 (4.8), Pavlodar - 3.8 (5.6), Almaty - 3.7 (2.5), Zhetysay - 3.7, Atyrau - 3.4 (4.0), East Kazakhstan - 3.3 (3.8), Karaganda - 3.2 (4.7), Kostanay - 3.2 (2.4) regions and Almaty city - 3.4 (2.9).

Below the national average, mortality was recorded in Abay region, cities Astana, Shymkent - 2.9 per 100 thousand population, Mangistau - 2.8 (3.0), Turkestan - 2.3 (2.2), Aktobe - 2.2 (3.0), North - Kazakhstan - 2.0 (2.6), Kyzylorda regions - 1.7 (3.5) - the best result [5].

In 12 regions, a 100% level of morphological verification of the diagnosis was ensured, the lowest or worst indicator for the third year was in the Kyzylorda region - 94.3%, below the national average indicators in Akmola - 98.8%, Atyrau - 98.9%, Kostanay - 98, 9%, Mangistau - 97.6%, Pavlodar - 96.6%, regions and Almaty city - 98.5%;

In a number of regions, the frequency of diagnosis of stage I-II CC was below the national average (88.1%) - in Akmola - 76.2% (2021 - 73.6%) - the worst result in the country, in Karaganda

- 77, 2%, Zhetysay - 82.9%, Abay - 83.8%, Kostanay - 84.3%, Aktope - 85.5%, West Kazakhstan - 85.7%, Pavlodar - 81.3%, while that in the Atyrau region - 100.0% result.

The proportion of stage IV CC is higher than the national average (2.7%) in the following regions: the worst result is in Zhetysay (6.1%), above the national average in Karaganda - 5.1% (2021 - 5.6%), Akmola - 4.8% (2.3%), Kostanay - 4.5% (4.4%), North Kazakhstan - 3.9% (7.4%), Almaty - 3.7 % (5.1%), Zhambyl - 2.9% (0.0) regions, cities Almaty – 3.6% (1.8%) and Shymkent – 3.8% (5.9%). The lowest neglect is in the East Kazakhstan region - 1.0% (0.7%).

Late diagnosis rates (III-IV stages) for CC are above the national average - 11.9% (15.4% in 2021) were noted in Akmola - 23.8% (2021 - 26.4%) - worst result, Karaganda - 22.8% (35.2%), Pavlodar - 18.8% (20.8%), Zhetysay - 17.1% (24.2%), Abay - 16.2% (12.8%), Kostanay - 14.6% (15.6%), Aktope - 14.5% (9.6%), West Kazakhstan - 14.3% (32.4%) regions. The lowest neglect is in the Mangistau region - 6.0% (20.8%).

Across the country, the five-year survival rate of patients with CC registered in 2018 was 59.9% in 2022, with a decrease from the level of 2021 (67.5% for those registered in 2017), and with a significant range in by region, from the maximum – 72.9% (2021 – 70.7%) in the North Kazakhstan region, to the minimum – 34.9% (64.4%) in the Atyrau region [5].

CC screening is a periodic, comprehensive examination of women of a certain age group as part of a special medical program to prevent and reduce incidence and mortality from CC [6].

CC screening is a population-based preventive intervention aimed at detecting cervical precancerous lesions and CC at an early stage, when timely diagnostic assessment and treatment can prevent progression to invasive disease. In Kazakhstan, CC screening is organized within the national population screening program and is conducted among predefined target groups according to age and clinical eligibility criteria [7,8,9].

According to the current national screening framework, women who reach the ages of 30, 34, 38, 42, 46, 50, 54, 58, 62, 66, 70 and 74 years and who are not under dynamic follow-up for cervical malignancy constitute the target population for CC screening. Screening is performed once every four years, with the screening episode expected to be completed within 60 days.

The age-specific schedule represents a population-based strategy in which eligible women are identified through the primary healthcare system. Recent data from Kazakhstan confirm the use of a four-year screening interval and cytological examination for CC screening within the national program.

The preparatory stage is performed within the primary healthcare organization. It includes:

- identification and annual formation of the target population;
- verification and monthly updating of the list of eligible women;
- informing women about the purpose and benefits of CC screening;
- invitation to participate in screening;
- registration of screening attendance and organization of timely completion of the screening pathway.

The national regulations require primary healthcare organizations to form target groups from the population attached to the healthcare organization and to establish a sequential pathway for the provision of screening services. The target population is initially compiled annually, with subsequent monthly correction.

The primary screening examination is performed in the primary healthcare setting by an appropriately trained healthcare professional. The screening procedure includes collection of a cervical specimen for cytological examination.

Under the current Kazakhstan program, cervical screening is based on cytological examination of a cervical smear using the Papanicolaou (Pap) test, with liquid-based cytology used within the national screening program. The collected specimen is submitted to a cytology

laboratory for standardized evaluation.

Before specimen collection, the woman should receive appropriate instructions concerning factors that may interfere with specimen quality. The collected material must be properly identified, documented and transported according to laboratory requirements.

Cytological examination should be reported using standardized terminology, preferably the Bethesda System, which provides a reproducible framework for classifying cervical cytological findings [10].

The cytological result may be classified as:

- NILM (Negative for Intraepithelial Lesion or Malignancy) – no evidence of intraepithelial lesion or malignancy;
- ASC-US (Atypical Squamous Cells of Undetermined Significance);
- ASC-H (Atypical Squamous Cells, cannot exclude HSIL);
- LSIL (Low-Grade Squamous Intraepithelial Lesion);
- HSIL (High-Grade Squamous Intraepithelial Lesion);
- AGC (Atypical Glandular Cells) and other glandular abnormalities;
- cytological findings suspicious for or diagnostic of invasive carcinoma.

The Bethesda terminology is widely used in contemporary cervical screening and abnormal-result management. Current evidence-based guidelines emphasize that management should depend not only on the cytological category but also, where available, on Human papillomavirus (HPV) status, previous screening history and the estimated risk of clinically significant cervical intraepithelial neoplasia.

A woman with an abnormal cytological result should not simply return to routine screening. She should enter a diagnostic pathway according to the severity of the abnormality and the applicable national clinical recommendations.

The diagnostic pathway may include: abnormal cytology → clinical assessment → HPV testing where indicated → colposcopy → directed cervical biopsy when indicated → histological examination → definitive diagnosis → treatment or surveillance.

Risk-based management is preferable to management based exclusively on a single cytological result. The 2019 American Society for Colposcopy and Cervical Pathology consensus guidelines, published in 2020 and subsequently updated, incorporate current screening results together with previous results and clinical history when determining the need for surveillance, colposcopy or treatment.

For example, high-grade cytological abnormalities generally require prompt diagnostic evaluation, while selected low-grade abnormalities may be managed with HPV-based triage and/or surveillance depending on the patient's estimated risk. Unsatisfactory cytology requires repeat testing or further evaluation according to the applicable guideline.

The second stage of the national screening pathway is intended to determine the cause of an abnormal screening result and establish a definitive diagnosis. Under the Kazakhstan regulations, women with abnormal screening findings are referred by the primary healthcare physician for further examination. Depending on the screening result, this may include consultation with an obstetrician-gynecologist, colposcopy or videocolposcopy, cervical biopsy when indicated, histological examination and consultation with an oncologist or gynecologic oncologist.

Thus, the screening process should be regarded as a continuum extending from population identification and primary testing to diagnostic confirmation and subsequent treatment or surveillance, rather than as an isolated cytological examination.

At the final stage, the screening results and the established clinical diagnosis are documented in the healthcare information system. The woman is informed of the results and receives recommendations regarding further diagnostic evaluation, treatment, surveillance or

return to routine screening.

The national regulations specifically require screening organizations to record screening results, final diagnoses and recommendations for further examination and follow-up. The screening episode is considered complete when the appropriate endpoint of the clinical pathway has been documented.

The contemporary population-based cervical cancer screening algorithm can therefore be summarized as follows:

Identification of the target population → invitation and information → cervical specimen collection → primary cytological screening → cytological classification → assessment of abnormal results → HPV testing/triage where indicated → colposcopy and biopsy when indicated → histological confirmation → treatment or surveillance → documentation and return to routine screening.

This approach combines the organizational framework of the national screening program in Kazakhstan with contemporary principles of risk-based management of abnormal cervical cancer screening results.

Now, regarding the results of CC screening. In 2022, 771,282 women of the target group aged 30 to 70 years were examined during cytological screening (in 2021 - 757,454).

During cytological screening in 2022, 392 cases of cervical cancer were identified (319 in 2021). The detection rate increased from 0.42 to 0.51 per 1000 women examined

High detection of CC during screening is ensured in Aktobe, Almaty, Atyrau, East Kazakhstan, Kyzylorda, Pavlodar, North Kazakhstan, Turkestan regions and Shymkent city. The detection rate in these regions ranges from 0.55 to 1.59 per 1000 women examined. The best indicator is in Atyrau region - 1.59. Compared to 2021, there is an increase in detection in 10 regions, with the exception of Akmola, Aktobe, Zhambyl, Kostanay, Mangistau, North Kazakhstan regions and Shymkent city. The worst result in Astana is 0.15 per 1000 women examined [5].

Cytologically, cervical precancer was detected in 1.16% of those examined (2021 – 0.99%). The detection rate of precancer below 0.6% (the planned indicator for 2022, according to the Comprehensive Plan) was noted in Aktobe, Karaganda and Kostanay regions.

A high proportion of stage I CC (70% or more) was detected in 6 regions of the country (in 8 in 2021): Kostanay, Mangistau (94.7% - best result), North Kazakhstan, Turkestan regions, cities Almaty and Astana. Low levels of early detection of CC (below 50%) were not observed in any region.

Localized processes (stages I-II) were identified in 99.2% of all cases of detected cancer (96.5%). In the Akmola and Karaganda regions, cases of CC were identified not only in localized, but also in widespread stages of the process. A total of 3 cases of CC in stage III and no cases in stage IV were identified (11 and 0, respectively) [5].

BC ranks first in the structure of the frequency of malignant tumors of both sexes in the population with a share of 14.7% (2021 - 15.4%). This situation has been stable since 2004; in addition, BC ranks first and remains consistently in this position in the structure of female oncopathology. The incidence of BC in 2022 in the country as a whole increased to 26.5 per 100 thousand (2021 – 26.3). In the structure of cases, BC occupies the 1st ranking place in the vast majority of regions and cities of the country, except for three: Akmola, Kyzylorda and North Kazakhstan regions, where lung cancer takes the 1st ranking place [4].

Above the national average - 26.5 per 100 thousand of us. – incidence of BC in 10 regions of the country: Abay – 33.3, Akmola – 32.7 (2021 – 29.8), East Kazakhstan – 44.7 (39.9) – the highest level, West Kazakhstan – 31.2 (28.4), Karaganda – 40.2 (40.1), Kostanay – 37.5 (35.8), Pavlodar – 43.2 (47.4), North Kazakhstan – 34.7 (38.2) regions and Almaty city – 35.4 (34.5), Astana city – 31.5 (28.4). Below average indicators per 100 thousand of us. in Aktobe - 21.6 (24.3), Almaty - 21.9 (17.7), Atyrau - 22.8 (15.7), Zhambyl - 14.2 (15.1), Zhetysay - 22.8, Kyzylorda - 14.6 (14.4),

Mangistau - 14.7 (17.3), Turkestan - 11.3 (11.7) regions and Shymkent city - 14.9 (21.9) [5].

BC ranks third in the structure of causes of death from malignant tumors in the population of both sexes for the thirteenth year in a row, amounting to 8.1% in 2022 (2021 – 8.7%). In the republic as a whole, mortality from BC decreased by 13.0%, from 6.2 to 5.4 per 100 thousand people.

The regions where mortality from BC is higher than the national average include: Abay - 10.1 per 100 thousand people (maximum level), East Kazakhstan - 8.0 (2021 - 8.5), Pavlodar - 7.1 (10.0), North Kazakhstan - 7.0 (11.4), Kostanay - 6.9 (7.5), Akmola - 6.5 (8.2), West Kazakhstan - 5.7 (6.9), Zhambyl - 5.5 (4.8) and Astana city – 6.3 (6.6), Almaty city – 6.6 (9.5). The indicators are significantly lower in Aktobe - 4.5 (3.5), Almaty - 4.5 (5.8), Zhetysu - 4.0, Atyrau - 3.7 (3.0), Kyzylorda - 4.4 (4.1), Turkestan - 3.6 (3.6), Mangystau regions - 2.7 (3.6) - the lowest level [5].

Mass screening to identify BC patients should mainly involve healthy women without any signs of the disease or symptoms. Screening not only helps to detect hidden forms of cancer that can be treated, but also has psychological value for women. As a result of screening, women are convinced that they do not have BC, and this is the most important potential success of such programs. While the ultimate goal of screening is to reduce BC mortality, its immediate goal is to detect cancer before clinical manifestation. However, BC is a heterogeneous disease, which can significantly affect the effectiveness of screening. Screening models for BC are usually based on the fact that the majority of detected tumors are invasive cancers in the early stage of progression. In addition, it must be taken into account that the detection of cancer (or its precursors) before clinical manifestation increases the risk of false positive diagnosis [11,12].

Mammography has a sensitivity of 95% and a specificity of 97%. These indicators decrease when examining women with denser mammary glands (young age, use of hormone therapy), with low quality mammography, and also with insufficient qualifications of the radiologist. Detection of high-grade invasive cancer by screening, when the tumor is not yet detected by clinical examination (palpation), means the possibility of reducing mortality from BC [13].

Preventive screening for early detection of BC in the Republic of Kazakhstan includes [7]:

1) mammography of both mammary glands in two projections - direct and oblique in the mammography room of the city, district polyclinic (mobile medical complex). All digital mammograms in the presence of a system for archiving and transferring medical images are copied to CDs and other electronic media and transferred to the server of the mammography room of the Cancer Center using specialized licensed software integrated between medical organizations; in case of impossibility of digital transmission - they are printed on X-ray film at a scale of 1:1 - 100% (1 patient - 1 set - 2 or 4 mammograms) with subsequent transfer to the mammography room of the Cancer Center;

2) interpretation of mammograms according to the BI-RADS classification (M0t, M0d, M1, M2, M3, M4, M5) by two or more independent radiologists of the same medical organization - double reading or different medical organizations: a radiologist of the mammography room city, district polyclinic (mobile medical complex) - the first reading, and the radiologist of the mammography room of the Cancer Center - the second reading;

3) in-depth diagnostics - targeted mammography, ultrasound examination (hereinafter - ultrasound) of the mammary glands, trepanobiopsy, including under ultrasound or stereotaxic control for histological examination, which is carried out in case of detection of pathological changes on mammograms (M0d) in the mammography room of the Cancer Center.

✓ An average medical worker or a responsible person of the organization of outpatient care sends the patient for mammography to the district, city polyclinic.

✓ The X-ray laboratory assistant of the mammography room of the city, district polyclinic (mobile medical complex) performs mammography, fills out a referral for double reading of mammograms and transmits the referral through information interaction.

Radiologist of the mammography office of the city, district polyclinic (mobile medical complex): fulfills the requirements for the safety and quality of mammographic examinations; evaluates the quality of the images provided and the correctness of the installation; performs repeated mammography in the M0t category (technical errors of mammography); determines the radiological density of the mammary glands on the ACR scale (A, B, C, D) indicating this parameter in the study protocol; conducts the first reading of mammograms with interpretation of the BI-RADS classification results. In the M0d category (undetermined or suspicious radiological changes requiring additional examination), the study protocol indicates the predominant pathology: education, asymmetry, violation of architectonics, microcalcifications; sends mammograms, electronic copies of mammograms through the archiving system and transfer of medical images to the workplace of the mammography office of the Cancer Center together with directions for double reading of mammograms; directs low-dose computed tomographic images through the system of archiving and transferring medical images to the workplace of the computer tomography office of the Cancer Center together with copies of images recorded on CD-ROMs or other electronic media and directions for double reading.

♦ The radiologist of the mammography room of the Cancer Center: evaluates the quality of the provided images and the correctness of the styling. Viewing digital x-ray images transferred to the server or on digital media (CD, DVD) is carried out on a monitor for interpreting digital x-ray images with a resolution of at least 5 megapixels, which has a certified grayscale transmission in accordance with the DICOM standard; conducts a double (second) reading of mammograms with the interpretation of the results according to the BI-RADS classification, using, if necessary, archival images. Organizes the third reading according to indications. With double reading, an independent interpretation of the images is carried out (blinding method - the second radiologist does not know the results of the first reading); in the M0m category (technical errors in mammography), recommends repeat mammography; in the M0d category (uncertain or suspicious radiographic changes requiring additional examination), the study protocol indicates the predominant pathology: education; asymmetry, violation of architectonics, microcalcifications; recommends that the outpatient care organization, according to indications, invite the patient for in-depth diagnostics (targeted mammography, ultrasound of the mammary glands, trephine biopsy, including under ultrasound or stereotaxic control, followed by histological examination of the material); collects and archives all mammograms (films and electronic media) made as part of the examination. The shelf life of mammograms is at least 3 years after leaving the age subject to a screening study; the results of the double (second) reading are transferred to the outpatient care organizations through information exchange.

♦ Indications for in-depth diagnostics are the conclusions of double reading mammograms M0d (uncertain or suspicious X-ray changes requiring additional examination).

♦ In-depth diagnostics is carried out in two stages. At the first stage, ultrasound is performed, according to indications, targeted mammography, possibly with an increase (with asymmetry, violation of architectonics and the presence of microcalcifications). When visualizing a suspicious pathology (M4 and M5), the second stage is performed - trepanbiopsy, including under ultrasound control and stereotaxic control for histological examination.

♦ Histological examination is carried out in the laboratory of pathomorphology or pathological bureau. Morphological interpretation of the biopsy is carried out in accordance with the recommendations of the World Health Organization.

♦ Physician or responsible person of the outpatient care organization:

- 1) upon receipt of a mammography result according to the BI-RADS classification:
 - in case of M0t (technical errors in mammography) - sends the patient for a second X-ray examination to the mammography room of the city, district polyclinic (mobile medical complex);
 - with M0d (undefined or suspicious X-ray changes requiring additional examination) -

sends the patient for in-depth diagnostics to the mammography room of the Cancer Center;

- with M1 (no changes detected) - recommends that the patient undergo a follow-up mammography examination after 2 years. With radiological density of the mammary glands, C and D are sent for ultrasound of the mammary glands to exclude a false-negative result of mammography;

- with M2 (benign changes), refer the patient for a consultation with an oncologist (mammologist) of the clinical diagnostic department, followed by a screening mammography examination after 2 years;

- with M3 (probable benign changes) - sends the patient for short-term dynamic radiation observation to the local doctor with the recommendation of control mammography or ultrasound in 6 months;

- with M4 (signs that cause suspicion of malignancy), M5 (practically reliable signs of malignancy) and if it is technically impossible to perform a trepanbiopsy or a biopsy is refused, a referral to an oncologist (mammologist) of the clinical diagnostic department for dynamic observation and decision on the verification of the identified pathology;

2) upon receipt of the result of a histological examination:

- benign education - refers the patient to an oncologist (mammologist) of the clinical diagnostic department for dynamic monitoring, followed by a screening mammography examination after 2 years;

- formation with an indeterminate malignant potential or carcinoma in situ - refers the patient to the Cancer Center for consultation and treatment, followed by dynamic observation by an oncologist (mammologist) of the clinical diagnostic department at the place of her attachment;

- malignant neoplasm - refers the patient to the Cancer Center for treatment and follow-up;

3) communicates the results of the screening examination to the patient in any available way (by telephone, in writing, through electronic means of communication);

4) enters the results of double reading, in-depth diagnostics, histological examination, recommendations of the radiologist of the Cancer Center mammography room into the information system.

Establishing the size of the primary tumor is especially important in screening. Tumor size is an important criterion for evaluating the quality of screening and determining the ability of X-ray mammography to detect non-palpable tumors. Therefore, it is extremely important that pathologists measure tumor diameter as accurately as possible. The smaller the size of the primary tumor, the greater the likelihood of error in determining its size.

Let's analyze the results of BC screening. Mammography screening identified 1,570 cases of BC in 2022 (1,402 in 2021). The cancer detection rate increased from 1.78 to 1.94 per 1000 examined. The best result is in the Karaganda region – 2.63 per 1000 women examined. Low detection rate per 1000 examined, compared to the republican average, in Atyrau (1.72), Zhambyl (0.58), Kyzylorda (1.68), Mangistau (0.42 - worst result), Turkestan (1.22) regions and cities Astana (1.5) and Shymkent (1.58). Compared to 2021, there was an increase in the detection of BC in 9 regions, with the exception of Aktobe (decrease from 2.87 to 2.19 per 1000 women examined), Karaganda (from 2.73 to 2.63), Mangistau (from 1.10 to 0.42), North Kazakhstan (from 3.27 to 2.31), Turkestan (from 1.36 to 1.22) regions and cities Astana (from 1.54 to 1.50), Almaty (from 2.24 to 2.18) and Shymkent (from 2.35 to 1.58) [5].

In 2022, the proportion of patients identified during screening studies with early stages of BC (stage 0-I) was 50.2% during screening (in 2021 - 47.9%). A high proportion of stages 0-I BC (over 50%) was recorded in 8 regions (in 8 in 2021): Akmola, West Kazakhstan, Karaganda (70.8% - best result), Pavlodar, North Kazakhstan, Turkestan regions, cities Astana and Shymkent. Low levels of early detection of BC (below 40%) were noted in Aktobe (19.3% - worst result), Zhambyl

(34.8%), Kostanay (39.5%), Mangistau (27.3%) regions and Almaty city (37.3%). Localized cancer (0-I and II stages) amounted to 96.2% (2021 - 95.5%), while not a single case was detected in stages III-IV in Atyrau, West Kazakhstan, Zhambyl, Kyzylorda, Mangistau, Pavlodar regions, cities Astana and Shymkent. A total of 46 cases of breast cancer in stage III and 14 in stage IV were identified (52 and 11, respectively) [5].

Epidemiological indicators of CRC in the form of colon cancer and colorectal cancer are considered separately for objective reasons.

Colon cancer with a specific gravity of 5.53% (2021 - 5.2%) in the structure of oncopathology of both sexes of the population has risen to 5th place, in men it remains in 6th place - 5.8% (5.5 %), for women - in the 5th - 5.3% (4.91%) The incidence rate of cancer of this localization in the country in the reporting year increased from 8.8 to 9.95 per 100 thousand population.

The incidence of colon cancer in 10 regions is higher than the national average - 9.95 per 100 thousand population: Kostanay - 20.7 (2021 - 15.9), Pavlodar - 18.8 (15.3), North Kazakhstan - 18, 0 (12.7), East Kazakhstan - 16.9 (13.4), Karaganda - 15.4 (15.0), Akmola - 14.6 (10.2), West Kazakhstan - 11.0 (10.1), Abay - 10.0 (9.0) regions and cities Almaty - 12.8 (12.1) and Astana - 10.5 (9.0). As in 2021, colon cancer was detected much less frequently in Turkestan - 3.1 per 100 thousand population (2.7), Kyzylorda - 4.1 (4.6), Zhambyl - 5.5 (5.8), Almaty - 6.3 (4.7), Zhetysu - 6.4, Mangistau - 6.8 (4.9) regions and Shymkent city - 5.0 (4.0) [5].

Rectal cancer in the structure of malignant neoplasms of both sexes retains 7th place in rank with a specific gravity of 4.9% (2021 - 4.92%), but in men it dropped from 4th to 5th place - 6.1%, for women - from 9th to 10th - 4.0%. The incidence rate per 100 thousand population increased from 8.4 to 8.8.

A high incidence rate was recorded in Kostanay - 17.8 per 100 thousand population (2021 - 16.2), East Kazakhstan - 17.7 (13.9), North Kazakhstan - 15.6 (15.1), Pavlodar - 14.9 (18.1), Karaganda - 13.3 (11.7), Abay - 12.9, West Kazakhstan - 12.9 (9.8), Akmola - 10.3 (13.1) regions and Astana city - 10.3 (9.0). Traditionally, a low incidence of rectal cancer is observed in Mangistau - 3.1 (2.8), Turkestan - 3.3 per 100 thousand population (2.7), Zhambyl - 3.7 (5.1), Kyzylorda - 4, 1 (5.3), Almaty - 5.3 (5.6) regions and in Shymkent city - 5.5 (5.0) [5].

Rectal cancer in the structure of causes of death from malignant neoplasms of the population of both sexes in 2022 remained in 5th place with a share of 5.41% (2021 - 5.41%). In the republic as a whole, the mortality rate from this form of cancer was 3.6 per 100 thousand population (3.87).

The mortality rate per 100 thousand population was higher than the national average in East Kazakhstan - 7.8 (2021 - 8.6) - the maximum level, Pavlodar - 7.5 (7.6), Abay - 5.9, North Kazakhstan - 5.8 (4.3), Kostanay - 4.9 (4.9), West Kazakhstan - 4.8 (4.2), Karaganda - 3.8 (5.2) regions. Below the national average - 3.8 per 100 thousand population, mortality in Aktobe - 3.2 (4.1), Almaty - 2.6 (2.6), Atyrau - 2.5 (3.4), Zhetysu - 2, 6, Zhambyl - 3.3 (2.7), Turkestan - 2.1 (1.6), Mangistau - 1.9 (1.2), Kyzylorda regions - 1.8 (2.1) - the lowest figure, and cities Almaty - 3.7 (4.3), Shymkent - 2.6 (2.1).

Colon cancer in the structure of causes of death from malignant neoplasms of the population of both sexes in 2022, as in 2021, ranks 6th, with a share of 5.2% (2021 - 5.0%). At the same time, the mortality rate in the country decreased by 5.6%, from 3.6 to 3.4 per 100 thousand population.

Mortality rates in 10 regions are higher than the national average: East Kazakhstan - 7.1 per 100 thousand population (2021 - 5.1) - maximum level, Pavlodar - 5.6 (6.0), Kostanay - 5.3 (5.6), Akmola - 5.2 (3.8), Abay - 5.1, Karaganda - 5.1 (5.6), West Kazakhstan - 4.8 (4.4), North Kazakhstan - 4.8 (5.0) regions and cities Astana - 3.6 (2.7), Almaty - 4.5 (5.3). Low mortality rates from colon cancer were noted in Kyzylorda - 1.2 per 100 thousand population (2.7) - the best

result, Turkestan - 1.3 (1.7), Mangistau - 1.6 (2.6), Aktoobe – 2.0 (2.5), Zhetysu – 2.4, Zhambyl – 2.5 (3.7), Atyrau – 2.5 (1.8), Almaty – 2.6 (1.8) regions and cities Astana – (2.7), Shymkent – (2.4).

For colon cancer (94.0%) - 100% verification level was achieved in 3 regions (Abay, Almaty and Turkestan regions), high rates in the Astana city (98.5%), Shymkent city (98.0%), Zhambyl (98.4%), Atyrau (98.2%) regions, low – in Akmola region (86.7%), Almaty city (84.3%), in the Kyzylorda region (61.8%) – the worst result since 2017.

For rectal cancer (97.4%) - in 6 regions there is a 100% verification level, the worst level is still in the Kyzylorda region - 85.3%, lower than the republican average in the Akmola region - 92.6%, Aktoobe region - 96.8%, Mangystau region - 87.0%, Pavlodar region - 95.3%, Almaty city - 93.2% [5].

The frequency of diagnosis of stage I-II rectal cancer, as a visually accessible localization (68.9% - national average) in the regions, was: in Akmola - 34.6% - the worst result, as in 2021, in the country (2021 - 44.1%), Mangistau - 47.8%, Abay - 53.9%, West Kazakhstan - 59.1%, Almaty - 66.2%, Zhetysu - 68.6%, Karaganda - 65.7% regions and Shymkent city - 62.9%.

For colon cancer (52.4%), early diagnosis rates are higher in Pavlodar (65.9% - best result), Abay, Aktoobe, Atyrau, East Kazakhstan, Zhambyl, Zhetysu, Karaganda, Kostanay, Pavlodar, North Kazakhstan, Turkestan regions and Shymkent. The lowest figure (23.5%) is in the Kyzylorda region.

For colon cancer (17.3%), the rates of neglect at stage IV are higher - in Akmola - 31.0% - the worst result (2021 - 20.3%), Zhetysu - 27.3%, Abay - 23.1%, Turkestan - 22.2% (29.1%), Karaganda - 28.1% (28.6%), West Kazakhstan - 18.8% (8.2%), Mangistau - 17.6% (19.4%) regions and cities Astana - 18.0% (22.9%), Shymkent - 20.0% (22.7%). The lowest level of neglect is 2.9% in the Kyzylorda region (7.9%).

The proportion of stage IV in rectal cancer (13.1%) is higher in Akmola - 29.6% - the worst result (2021 - 19.4%), Abay - 19.7%, Kyzylorda - 17.6% (9.1%), Karaganda - 16.9% (28.4%), Almaty - 15.6% (17.0%), Kostanay - 14.8% (11.1%), Zhambyl - 13.3% (13.6%) regions and Shymkent city - 14.5% (12.5%). The lowest level of neglect - 6.0% - is in the Atyrau region (12.5%).

Late diagnosis of rectal cancer as a visually accessible localization (stages III-IV) in 2022 amounted to 31.1% (in 2021 - 33.5%).

For rectal cancer, the level of neglect is higher than the national average - 31.1%, the indicators in Akmola - 65.4% (2021 - 55.9%) - the worst result in the country, Mangistau - 52.2% (38.1%), Abay – 46.1% (30.6%), West Kazakhstan – 40.9% (25.4%), Karaganda – 34.3% (46.5%), Almaty – 33.8% (35.7%), Zhetysu - 31.4% (34.1%) regions and Shymkent city - 37.1% (42.9%). The lowest neglect is in the Atyrau region - 12.0% (17.5%).

In the country as a whole in 2022, the five-year survival rate of patients with CRC registered in 2018 decreased to 40.4% (2021 - 52.9% for those registered in 2017); there is a significant dispersion of indicators by region, from maximum – 56.1% (47.5%) in the Kyzylorda region, to minimum – 24.3% (51.5%) in the Aktoobe region [5].

Screening of CRC screening is the systematic use of screening studies in an asymptomatic population. The purpose of screening is to identify people with abnormalities suggestive of CRC. These persons in the future need additional examination to clarify the diagnosis. Opportunistic screening is the non-systematic use of screening tests in routine medical practice. A screening program is much more challenging than an early detection program. At the same time, the success of the screening program is largely determined by the awareness of the population and medical workers about the possibilities of early diagnosis of CRC. The feasibility of a screening program is determined by several factors that relate to the disease being screened, the screening test, the characteristics of the population, and the characteristics of the healthcare system.

The first factor is that the disease must be well understood, common enough in the target population to justify screening, have a recognizable early stage; treatment of the disease at an early stage should be more effective than at a later stage.

The second is that the test should be characterized by sufficient sensitivity, i.e. the ability to detect cancer among people with the disease; sufficient specificity - the probability that among people who do not have a disease, the test result will be negative; have a high positive predictive value (positive predictive value) or, in other words, the likelihood that people with a positive test result have the disease; have a high predictive value of a negative result (negative predictive value), i.e. the likelihood that people with a negative test result do not have the disease; security; low cost; and acceptability - the likelihood that people for whom this test is intended will agree to the examination (which to some extent depends on the awareness of the population about the possibilities and importance of early diagnosis).

The third factor is that the healthcare system should be ready for maximum screening test coverage of the target group, have the resources to confirm the diagnosis, appropriate treatment and follow-up of people with positive test results, and regularly conduct screening tests at regular intervals. At the same time, the benefits of screening must outweigh the potential physical and psychological harm and justify the financial costs of its implementation [14].

The factors most significant for the development of CRC are:

- the presence of chronic inflammatory bowel diseases, adenomatous polyps, cancer of other localization, etc.;
- family history (presence of one or two first-degree relatives with CRC or familial diffuse intestinal polyposis);
- the age of men and women over 50 years old, taking into account the fact that more than 90% of patients with colorectal cancer are people of this age (medium risk).

Age, regardless of gender, is an important risk factor for CRC. After the age of 50, the incidence of CRC increases from 8 to 160 per 100,000 population. Thus, people who have reached the age of 50, even in the absence of symptoms, constitute a moderate risk group for CRC.

The second category of increased risk of CRC (20%) is made up of persons with a genetic and family predisposition, suffering from chronic inflammatory bowel diseases, diffuse familial polyposis.

The high-risk CRC group is determined by the so-called Amsterdam criteria (the presence of malignant tumors in two generations, the presence of cancer in a first-line relative under the age of 50 years), in this case, CRC screening should be carried out after the age of 30 years [15].

The degree of individual risk of developing CRC is determined before screening to select the scope of studies and the frequency of their conduct.

The interval for oncological colorectal screening is 1 time in 2 years, target group: men and women aged 50-70 years, with the exception of persons registered at the dispensary for CRC and colon polyposis. At the same time, when forming the target group, one should take into account the absence of severe concomitant diseases, such as the presence of a common malignant neoplasm, cerebrovascular diseases in the stage of decompensation, chronic obstructive pulmonary disease with respiratory failure, cirrhosis of the liver, myocardial infarction with congestive heart failure, diabetes mellitus with vascular complications. and others, which are highly likely to lead to death in the next 10 years.

The first step in screening for CRC is the fecal occult blood test (FOBT). Traditionally, such methods include a benzidine test for occult blood in the feces. This is a biochemical method based on the assessment of pseudoperoxidase activity of hemoglobin. There is ample evidence that invitation to guaiac FOBT screening (gFOBT) reduces CRC mortality by approximately 15% in age-matched average-risk populations.

To ensure the effectiveness of screening with gFOBT, the interval for screening under the national screening program should not exceed two years. To date, there is an immunochemical FOBT method - iFOBT, which is superior in efficiency to gFOBT in terms of the probability of detecting adenoma and cancer. iFOBT has improved analysis performance compared to gFOBT.

Immunochemical (immunochromatographic) examination of feces for occult blood - iFOBT or hemocult test is carried out for all men and women of the target group using an express method, which allows you to get a result within 3-5 minutes, without the participation of a medical worker. However, the evaluation of the test is carried out only by a medical worker in the PHC preventive department.

With a positive analysis of feces for occult blood, the second stage of colorectal screening is performed, which consists in endoscopic examination of the colon - total colonoscopy [7]. At the same time, in this case, this medical manipulation is of a therapeutic and diagnostic nature, since it allows one-stage removal of adenomatous polyps, which, according to various authors, occur in every third subject after 50 years of age. At the same time, women have 20% fewer polyps than men, but they have more right-sided lesions, which are more difficult to detect using fecal blood tests, because they are less traumatic [16].

What results were obtained from screening for CRC? In 2022, 937,859 men and women of the target group aged 50 to 70 years were examined during colorectal screening (in 2021 - 920,640) [5].

Colorectal screening revealed 325 cases of colorectal cancer in the reporting year, which is 114 cases more than in the previous year (211 cases). The detection rate increased from 0.23 to 0.35 per 1000 patients examined. Low detection of colorectal cancer was noted in Zhambyl, Karaganda, Kostanay, Kyzylorda, Mangistau, Turkestan - the worst result, East Kazakhstan regions, Astana city - from 0.07 to 0.30 per 1000 examined. The best result is in the North Kazakhstan region – 0.81 per 1000 examined. Compared to 2021, there was a decrease in the detection of colorectal cancer per 1000 people examined during screening in Karaganda (from 0.22 to 0.21), Kostanay (from 0.29 to 0.28), Mangistau (from 0.20 to 0.12) regions and Astana city (from 0.20 to 0.19).

Colon precancer (adenoma detection rate) was detected in 27.5% of patients who underwent colonoscopy (2021 – 22.8%). The detection rate of precancer in Akmola, Aktobe, Almaty (8.5% is the worst result), West Kazakhstan, Zhambyl, Kostanay, Kyzylorda, Mangistau, Pavlodar, North Kazakhstan, Turkestan regions and cities is lower than the national average Astana and Shymkent. The best result is 36.2% in Almaty city. It should be noted that the planned indicator for the detection of precancer of the colon and rectum in the country for 2022, according to the Comprehensive Plan, was 23.0% and was achieved.

In 2022, the proportion of patients identified during screening studies with early stages of malignant neoplasms (stages 0-I) was 26.2% during colorectal screening (in 2021 - 27.5%).

High early detection of colorectal cancer (above 30%) was noted in Akmola, West Kazakhstan, Karaganda, Kostanay, Kyzylorda, Turkestan regions and Astana city (57.1% - the best result). Not a single case of early cancer has been identified in the Mangistau region. Cases of cancer in stages III-IV detected during screening were registered in Akmola, Aktobe, Almaty, West Kazakhstan, Zhambyl, Karaganda, Kostanay, Mangistau regions and Almaty city. A total of 21 cases of colorectal cancer in stage III and 3 in stage IV were identified (in 2021 - 18 and 5, respectively) [5].

The complex analysis carried out allows us to conclude that satisfactory results of cancer screening can be achieved only with its proper organization, high quality of implementation, active participation in population screening, the use of highly sensitive tests and instrumental methods of preventive examination, as well as subsequent accurate diagnosis of identified tumors and timely treatment. High-quality screening leads to early diagnosis of pedological diseases and malignant pathology in the early stages, which, in turn, increases the effectiveness of treatment and improves the prognosis of the disease. Target groups that, for one reason or another, do not participate in screening should be informed that there are no other methods other than screening that would reduce mortality from malignant neoplasms. Incidence and mortality rates from CC,

BC and CRC clearly reflect the epidemiological situation with this pathology in the regions of our country.

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THEORETICAL AND METHODOLOGICAL FOUNDATIONS OF EDUCATIONAL INNOVATION IN THE SYSTEM OF HIGHER MEDICAL EDUCATION IN KAZAKHSTAN

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Abstract. The article explores the theoretical and methodological foundations of educational innovation within the structure of higher medical education in the Republic of Kazakhstan. Based on a comprehensive analysis of scientific and pedagogical data covering the period from 2014 to 2022, the dynamics of innovation processes development in medical universities are explicated. The study examines the regularities of the transition from the stage of forming primary innovative responsiveness within the academic environment to the stage of diversification of interactive and simulation-based learning technologies. The dialectics of internal and external barriers arising during the modernization of higher medical schools are analyzed.

Keywords: educational innovation, medical didactics, innovation process, educational environment, interactive learning.

Introduction

Pedagogical innovation in the higher medical education system constitutes an independent branch of general pedagogical science that studies the regularities of updating didactic systems, as well as the processes of creation, introduction, mastering, and institutionalization of pedagogical novelties. The specificity of a medical university imposes strict determinants on the character of innovation processes: any introduced novelties must be tightly aligned with requirements of clinical safety, evidence, and efficiency in shaping the professional competencies of future healthcare specialists.

A theoretical analysis of the evolution of educational innovation in Kazakhstan allows for identifying the inner logic and regularities of educational space transformation. The process of transition from the traditional (explanatory-illustrative) paradigm of teaching to a subject-subject (constructivist) model over the last decade has been heterogeneous, undergoing stages from initial psychological resistance to deep technological diversification.

The purpose of this study is a theoretical interpretation, systematization, and substantial analysis of the developmental stages of educational innovation in the medical universities of Kazakhstan based on the generalization of empirical data from recent years.

Theoretical Analysis of Innovation Process Stages

1. The Phenomenon of Innovation Resistance and Readiness of the Educational Environment

During the initial stages of systemic modernization in higher medical schools, the psychological and organizational readiness of the faculty members served as the primary object of study in pedagogical innovation. Innovation theory postulates that the introduction of any novelty inevitably triggers the phenomenon of resistance from the social environment.

In the context of Kazakhstani medical education (drawing upon empirical cross-sections from 2014), it was established that 50% of educators experienced a pronounced need for defining special conditions to implement innovative methods. The main structural barriers included:

- Time deficit: 51% of respondents claimed a lack of time and psychophysiological resources to master innovations;
- Competence barrier: 30% of teachers noted a lack of sustainable didactic skills required for designing interactive lessons;
- Psychological barrier: 10% of participants in the educational process experienced a direct "fear of failure" before changing established patterns of pedagogical activity.

Only 43% of the faculty members possessed a high level of innovative responsiveness and inner conviction regarding the expedience of the ongoing reforms. This stage proved that the primary basis of pedagogical innovation is not technological equipment, but rather the cultivation of an innovative culture and the provision of psychological support for educational subjects.

2. Methodological Diversification and Didactic Integration of Novelties

The development period of innovation processes at the beginning of the 2020s was marked by overcoming psychological barriers and moving pedagogical innovation into a stage of large-scale diversification of didactic approaches. A systematic classification of innovative teaching methods took place, which were distributed across four fundamental macro-groups:

- Problem-oriented methods: Problem-Based Learning (PBL, D-PBL), Team-Based Learning (TBL), Case-Based Learning (CBL), Situation-Based Learning (SBL), Research-Based Learning (RBL), and project-based learning technologies. The didactic value of these methods lies in shifting the teacher's role from a transmitter of information to a facilitator and moderator of the cognitive process.
- Simulation technologies: Objective Structured Clinical Examination (OSCE), high-fidelity modeling of clinical scenarios using hi-fi manikins, and the Clinical Evaluation Exercise (CEX) method. This block provided standardization for checking practical skills.
- Active forms of learning intensification: case studies, brainstorming, mind maps, role-playing, and flipped classroom models.
- E-learning technologies: interactive virtual simulators, educational video games, and specialized software complexes based on LMS systems.

Studies on the effectiveness of implementing these complexes recorded a high level of student satisfaction (86%). The didactic effect of innovations correlated with the stage of study: peak satisfaction rates (91–92%) were recorded among senior students, where the integration of innovative methods directly facilitated successful mastery of clinical protocols and algorithms.

3. Modification of Barriers Under Macro-Social Challenges

At the current stage of pedagogical innovation development (the 2021–2022 period), a radical modification in the nature of innovation process barriers occurred. Influenced by a forced transition to hybrid and distance learning technologies, the internal (psychological) barriers of teachers transformed into external (infrastructure and systemic) challenges.

A theoretical analysis of medical university experiences during this period highlights three key destructive factors:

1. Infrastructure gap: material and technical inequality among students (deficit of subscriber devices, unstable communication channels), hindering the continuity of the innovation process.
2. Competence dissonance: the urgent need for the faculty to master information and communication technologies (ICT) while maintaining a high level of clinical expertise.
3. Deformation of the upbringing space: reduced efficiency of traditional methods for transmitting medical deontological principles under conditions of mediated (screen) communication.

Conclusions

1. The historical and pedagogical evolution of higher medical schools in Kazakhstan during the analyzed period demonstrates a regular transition from local, administrative-directive implementation of separate interactive techniques to the formation of systemic, simulation-technological educational environments.
2. The development process of pedagogical innovation is characterized by a dialectical change in the nature of restraining factors: psychological resistance and deficit of didactic skills among teachers at early stages were replaced by infrastructural challenges and technological gaps at the modern stage of hybrid learning.
3. The high didactic efficacy of constructivist learning methods (PBL, TBL, CBL, simulation scenarios) has been proven, providing a qualitative increase in clinical thinking skills, systematization of knowledge, and readiness of graduates for independent professional activity.

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THE SCIENTIFIC DISCOURSE ON RECONFIGURING THE PHARMACOLOGICAL FRONTIER OF GENERAL ANESTHESIA: CONTEMPORARY ADVANCES IN ANESTHETIC PHARMACOLOGY, MECHANISTIC INSIGHTS, PRECISION PERIOPERATIVE PHARMACOTHERAPY, PHARMACOSAFETY, INTRAVENOUS AND INHALATIONAL ANESTHETIC AGENTS, PHARMACOKINETIC–PHARMACODYNAMIC INTERACTIONS, MULTIMODAL THERAPEUTIC STRATEGIES, ADVERSE- EFFECT MITIGATION, AND PATIENT- CENTERED CLINICAL OPTIMIZATION

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ABSTRACT

General anesthesia represents a complex pharmacological state produced through the coordinated modulation of consciousness, nociception, amnesia, immobility, autonomic responsiveness, and physiological homeostasis. Contemporary anesthetic practice has progressively moved beyond the conventional selection of individual hypnotic, analgesic, and neuromuscular agents toward an integrated pharmacological paradigm emphasizing mechanism-based drug selection, individualized dosing, multimodal pharmacotherapy, pharmacokinetic–pharmacodynamic optimization, and systematic mitigation of medication-related harm. This scientific discourse critically examines the reconfiguration of the pharmacological landscape of general anesthesia through contemporary advances in anesthetic pharmacology, mechanistic pharmacology, precision perioperative pharmacotherapy, evidence-based medicine, and pharmacosafety. Particular attention is directed toward the complementary and contrasting pharmacological characteristics of intravenous and inhalational anesthetic agents, including their molecular targets, dose–response relationships, onset and recovery profiles, organ-dependent disposition, context-sensitive effects, and interactions with concomitantly administered perioperative medications. The analysis further considers pharmacokinetic–pharmacodynamic interactions as major determinants of anesthetic efficacy, therapeutic precision, emergence characteristics, hemodynamic stability, respiratory function, and postoperative recovery. An evidence-based perspective is applied to the contemporary use of hypnotic, analgesic, sedative, and adjunctive pharmacological strategies, recognizing that anesthetic drug selection must account for both population-level evidence and clinically relevant patient heterogeneity. Particular emphasis is placed on precision-oriented approaches incorporating age, body composition, comorbidity, organ function, pharmacogenomic variability, concurrent medications, surgical complexity, and anticipated physiological perturbations into individualized anesthetic planning. Multimodal therapeutic strategies are examined as an important component of modern perioperative pharmacology, particularly through rational combinations of agents that may provide synergistic analgesic, hypnotic, antiemetic, and autonomic effects while reducing unnecessary exposure to individual drugs and potentially limiting dose-dependent adverse reactions. Within this framework, pharmacological optimization is conceptualized not merely as achieving adequate anesthesia but as balancing efficacy, safety, recovery quality, and preservation of physiological function across the entire perioperative trajectory. Pharmacosafety constitutes a central dimension of contemporary anesthetic pharmacology because general anesthesia frequently involves simultaneous administration of multiple pharmacologically active agents with overlapping cardiovascular, respiratory, neurological, and metabolic effects. Accordingly, the assessment of drug–drug interactions, cumulative pharmacodynamic burden, dosing errors, adverse drug reactions, medication-related complications, and delayed recovery is essential for rational clinical decision-making. The discourse additionally addresses the pharmacological mechanisms underlying hypotension, respiratory depression, and postoperative nausea and vomiting, emergence disturbances, delirium, residual neuromuscular blockade, cardiovascular instability, and other clinically consequential adverse effects, while emphasizing evidence-informed strategies for their prevention and mitigation. Special consideration is given to the importance of appropriate agent selection, titration, monitoring, reversal strategies, and structured perioperative medication management. The synthesis further conceptualizes anesthetic pharmacology as an interdisciplinary field connecting molecular pharmacology, clinical

pharmacology, pharmacokinetics, pharmacodynamics, pharmacogenomics, perioperative medicine, patient safety, and evidence-based clinical practice. Emerging technologies, quantitative pharmacological modeling, depth-of-anesthesia monitoring, precision dosing approaches, artificial intelligence-assisted decision support, and increasingly individualized perioperative pathways may further transform anesthetic drug management. Nevertheless, technological sophistication does not eliminate the necessity for pharmacological judgment, critical appraisal of evidence, continuous physiological assessment, and individualized risk–benefit evaluation. The contemporary general anesthesia is best understood as a dynamic pharmacological system in which drug mechanisms, exposure, interactions, patient characteristics, monitoring, and clinical context collectively determine therapeutic outcomes. Reconfiguring anesthetic pharmacology around evidence-based medicine, precision pharmacotherapy, and pharmacosafety therefore provides a scientifically grounded framework for improving anesthetic efficacy, minimizing preventable medication-related harm, accelerating functional recovery, and advancing patient-centered perioperative care.

Keywords: General anesthesia; Anesthetic pharmacology; Intravenous anesthetic agents; Inhalational anesthetic agents; Precision perioperative pharmacotherapy; Pharmacosafety.

INTRODUCTION

General anesthesia represents one of the most consequential and pharmacologically complex interventions in contemporary medicine. Although routinely employed across surgical specialties, its apparent clinical familiarity conceals a highly sophisticated neuropharmacological state generated through the coordinated administration of multiple agents acting across distributed molecular, cellular, neuronal, and systemic targets. General anesthesia is not a single pharmacological phenomenon but a dynamic and multidimensional therapeutic condition encompassing hypnosis, amnesia, analgesia, immobility, attenuation of autonomic and neuroendocrine responses, and, when clinically indicated, neuromuscular paralysis. These component endpoints are neither pharmacologically identical nor necessarily mediated through a common receptor system. Consequently, modern anesthetic practice has progressively moved away from the conceptualization of anesthesia as simple, dose-dependent central nervous system depression toward an integrated pharmacological framework in which receptor pharmacology, neural-network organization, pharmacokinetic variability, pharmacodynamic interactions, physiological homeostasis, surgical stimulation, patient-specific risk factors, and recovery trajectories collectively determine therapeutic outcomes.

The contemporary pharmacological landscape of general anesthesia has been substantially transformed by advances in molecular neuropharmacology, systems neuroscience, pharmacokinetics, pharmacodynamics, monitoring technologies, perioperative medicine, and precision therapeutics. Historically, the development of anesthetic pharmacology was dominated by empirical observations concerning loss of consciousness and surgical immobility. Early inhalational anesthetics established the feasibility of producing reversible unconsciousness, but their mechanisms of action remained incompletely understood for much of the history of clinical anesthesia. Subsequent development of intravenous hypnotics, opioid analgesics, benzodiazepines, $\alpha 2$ -adrenergic agonists, local anesthetics, and neuromuscular blocking agents created an increasingly diversified pharmacological armamentarium. This diversification enabled clinicians to target individual components of the anesthetic state rather than relying exclusively on a single agent to achieve hypnosis, analgesia, immobility, and autonomic control simultaneously. The emergence of balanced anesthesia and, subsequently, multimodal perioperative pharmacotherapy therefore represented an important conceptual transition from monopharmacological anesthesia toward rational combination therapy.

The pharmacological rationale for this transition derives from the complex neurobiology of consciousness, nociception, arousal, motor control, and autonomic regulation. General anesthetic agents influence neuronal excitability through multiple molecular mechanisms, including modulation of ligand-gated ion channels, voltage-gated ion channels, intracellular signaling pathways, synaptic transmission, neuronal network connectivity, and large-scale cortical–subcortical communication. γ -Aminobutyric acid type A receptor modulation is particularly important for several intravenous and inhalational anesthetic agents, while other molecular systems, including N-methyl-D-aspartate receptors, two-pore-domain potassium channels, hyperpolarization-activated cyclic nucleotide-gated channels, glycine receptors, nicotinic acetylcholine receptors, voltage-gated sodium channels, and α_2 -adrenergic receptors, contribute to the pharmacological profiles of individual drugs. Such mechanistic heterogeneity provides an important explanation for differences in onset, offset, hypnotic potency, analgesic capacity, cardiovascular effects, respiratory depression, neurophysiological effects, and recovery characteristics among anesthetic agents.

Intravenous anesthetics occupy a central position within this evolving pharmacological framework. Propofol, etomidate, ketamine, barbiturates, and related agents demonstrate markedly different pharmacological characteristics despite their shared clinical application as anesthetic or sedative drugs. Propofol, for example, is widely valued for rapid onset and relatively rapid recovery, while its cardiovascular and respiratory effects require careful dose selection and physiological monitoring. Etomidate has historically attracted attention because of its comparatively limited cardiovascular depression in selected clinical circumstances, although its effects on adrenal steroidogenesis complicate simplistic interpretations of its safety profile. Ketamine possesses a distinctive pharmacodynamic profile involving N-methyl-D-aspartate receptor antagonism and produces dissociative anesthesia accompanied by clinically important analgesic properties. These pharmacological distinctions demonstrate why anesthetic drug selection cannot appropriately be reduced to potency alone. The clinically meaningful question is instead how the pharmacological characteristics of a given agent interact with the patient's physiological reserve, procedural requirements, concomitant medications, surgical stress, and desired recovery trajectory.

Inhalational anesthetics similarly illustrate the complexity of contemporary anesthetic pharmacology. Volatile agents such as sevoflurane, desflurane, and isoflurane differ in blood–gas solubility, uptake and elimination kinetics, cardiovascular effects, airway characteristics, metabolic pathways, and environmental implications. Their pharmacological effects emerge from interactions with multiple molecular targets rather than from a single canonical receptor mechanism. The concentration of anesthetic required to prevent movement in response to surgical stimulation is influenced by multiple patient and procedural variables, while the relationship between anesthetic concentration and consciousness is not necessarily equivalent to the relationship between concentration and immobility. This distinction is particularly important because the traditional concept of minimum alveolar concentration represents only one dimension of anesthetic pharmacology and does not encompass the entire spectrum of hypnotic, amnestic, analgesic, autonomic, and neurophysiological effects.

The distinction between pharmacokinetics and pharmacodynamics is fundamental to understanding these differences. Pharmacokinetics describes the temporal relationship between administered dose and drug concentration, incorporating absorption where relevant, distribution, redistribution, metabolism, and elimination. Pharmacodynamics concerns the relationship between drug exposure and biological effect. In general anesthesia, these domains interact continuously. The clinical effect of an anesthetic agent is determined not simply by the administered dose but by the concentration reaching the effect site, the rate at which equilibrium develops between plasma and effect-site compartments, receptor sensitivity, age-related physiological changes, organ function, concurrent medications, and the intensity of surgical

stimulation. Consequently, identical administered doses may produce substantially different pharmacological effects in different patients. This interindividual variability represents one of the principal reasons why precision dosing and individualized anesthetic management have become increasingly important.

Age constitutes a major determinant of pharmacological variability. Pediatric patients, adults, and older individuals differ in body composition, organ maturation or functional reserve, protein binding, hepatic metabolic capacity, renal elimination, cerebral sensitivity, and cardiovascular responsiveness. In older adults, alterations in central nervous system sensitivity and reduced physiological reserve may increase susceptibility to excessive hypnotic depth, hypotension, respiratory depression, postoperative delirium, and prolonged recovery. Conversely, pediatric pharmacology is characterized by developmental changes in receptor expression, organ function, distribution volumes, and metabolic pathways. The assumption that anesthetic dosing can be reliably derived from body weight alone is therefore pharmacologically inadequate. Contemporary anesthetic pharmacology increasingly recognizes the importance of age, lean body mass, comorbidity, organ function, physiological state, and pharmacogenetic variability in determining optimal drug exposure.

Obesity presents another major challenge to rational anesthetic dosing because changes in adipose tissue mass, lean body mass, cardiac output, regional blood flow, and drug distribution can produce complex alterations in pharmacokinetics. Lipophilic anesthetic agents may demonstrate extensive distribution into adipose compartments, whereas dosing based exclusively on total body weight may increase the risk of excessive exposure for selected agents. At the same time, underdosing can compromise hypnosis or analgesia. These competing risks illustrate the need for pharmacokinetic models that account for clinically relevant body-size descriptors and physiological covariates. Similar considerations apply to patients with hepatic or renal dysfunction, hypoalbuminemia, cardiovascular disease, pulmonary disease, neurological disorders, or severe systemic inflammation. The perioperative environment therefore represents a particularly demanding setting for individualized pharmacotherapy.

Polypharmacy further complicates the pharmacological management of general anesthesia. Surgical patients frequently receive medications for cardiovascular disease, diabetes, psychiatric disorders, chronic pain, neurological disorders, inflammatory diseases, or other chronic conditions. These medications may modify anesthetic requirements, alter hepatic enzyme activity, influence receptor responsiveness, affect hemodynamic stability, or potentiate respiratory and central nervous system depression. Opioids, sedative-hypnotics, gabapentinoids, antidepressants, antihypertensive drugs, antipsychotic agents, anticoagulants, and other pharmacological classes may interact with perioperative medications through pharmacodynamic or pharmacokinetic mechanisms. Consequently, comprehensive medication reconciliation and preoperative pharmacological assessment constitute essential components of anesthetic safety rather than administrative procedures performed independently of pharmacotherapy.

The concept of pharmacodynamic interaction is particularly important in multimodal anesthesia. Combining drugs with complementary mechanisms can permit lower doses of individual agents while maintaining adequate hypnosis, analgesia, and physiological control. Such combinations may produce additive, synergistic, or occasionally antagonistic effects. For example, simultaneous administration of hypnotic and analgesic agents can reduce the concentration of each individual drug required to achieve the desired clinical endpoint. However, pharmacodynamic synergy may also amplify adverse effects, particularly respiratory depression, hypotension, bradycardia, excessive sedation, and delayed recovery. Thus, multimodal pharmacotherapy is not intrinsically synonymous with safer pharmacotherapy. Its safety depends on rational drug selection, appropriate dosing, temporal coordination, monitoring, and recognition of patient-specific vulnerabilities.

Opioid pharmacology exemplifies this therapeutic balance. Opioids remain highly effective for perioperative analgesia, but their adverse-effect profile—including respiratory depression, nausea, vomiting, ileus, urinary retention, pruritus, sedation, and the potential for persistent opioid use—has encouraged increasing interest in opioid-sparing and opioid-minimizing strategies. Contemporary perioperative pharmacotherapy therefore emphasizes multimodal analgesia, incorporating agents and interventions with distinct mechanisms of action. Acetaminophen, nonsteroidal anti-inflammatory drugs when appropriate, local anesthetic techniques, regional anesthesia, N-methyl-D-aspartate receptor antagonism, α_2 -adrenergic modulation, and other pharmacological or procedural approaches may contribute to reduction in opioid exposure. The central principle is not necessarily elimination of opioids but optimization of analgesia while minimizing avoidable pharmacological burden.

The increasing emphasis on multimodal anesthesia reflects a broader transformation in perioperative medicine. Surgical care is no longer evaluated exclusively according to intraoperative survival or immediate procedural success. Increasing attention is directed toward enhanced recovery, postoperative cognitive function, pain trajectories, functional recovery, quality of life, hospital length of stay, readmission, patient experience, and long-term morbidity. Anesthetic pharmacotherapy can influence several of these outcomes. Excessive sedative exposure may contribute to delayed emergence or postoperative cognitive complications, inadequate analgesia can intensify physiological stress and impair mobilization, while hemodynamic instability may compromise tissue perfusion and organ function. The pharmacological objective of anesthesia has consequently expanded from producing an appropriate intraoperative state toward supporting an integrated perioperative trajectory.

The relationship between anesthetic depth and postoperative outcomes has become a particularly important field of investigation. Electroencephalographic monitoring and processed EEG technologies have facilitated individualized assessment of cortical activity during anesthesia. Although interpretation of processed indices requires clinical context and device-specific understanding, neurophysiological monitoring may help reduce unintended excessive anesthetic exposure in selected patients. Importantly, anesthetic depth should not be understood solely as a numerical value. EEG patterns reflect the interaction between anesthetic pharmacology, patient age, neurological status, concomitant medications, and physiological conditions. Precision anesthetic management therefore requires integration of pharmacological knowledge with physiological and neurophysiological monitoring rather than reliance on any single surrogate measure.

The pharmacology of inhalational anesthetics also intersects with broader considerations of environmental sustainability. Volatile anesthetic agents differ in atmospheric persistence and global warming potential, and their environmental impact has become increasingly relevant within discussions of sustainable healthcare. This has stimulated interest in low-flow anesthesia, optimized vaporizer use, alternative anesthetic techniques, and reduction of unnecessary volatile anesthetic emissions. Environmental considerations, however, must be incorporated without compromising patient safety or clinical appropriateness. The emerging concept of sustainable anesthetic pharmacology therefore extends the traditional benefit–risk assessment by incorporating environmental consequences alongside efficacy, safety, cost, and patient-centered outcomes.

Another major development concerns the pharmacology of emergence and recovery. Rapid recovery from anesthesia is not merely a matter of patient convenience; it is a clinically meaningful pharmacological endpoint. Delayed emergence may result from excessive hypnotic exposure, accumulation of active metabolites, prolonged redistribution, drug interactions, hypothermia, metabolic disturbances, neurological pathology, or residual neuromuscular blockade. Modern anesthetic practice consequently emphasizes agents and dosing strategies that provide

predictable offset and facilitate timely neurological and physiological recovery. Pharmacological antagonism of selected drug effects, including reversal of neuromuscular blockade, has further strengthened the capacity to manage the transition from pharmacologically induced unconsciousness and immobility toward physiological independence.

Neuromuscular blocking agents occupy a distinctive position within general anesthesia because they produce skeletal muscle paralysis without necessarily producing unconsciousness or analgesia. This pharmacological dissociation illustrates the importance of understanding the individual components of the anesthetic state. Agents such as rocuronium, vecuronium, cisatracurium, and related drugs act predominantly at the neuromuscular junction, while reversal strategies may involve acetylcholinesterase inhibition or selective binding of steroidal neuromuscular blockers by specific reversal agents. Residual neuromuscular blockade can contribute to postoperative respiratory complications, making quantitative neuromuscular monitoring and appropriate reversal integral elements of pharmacological safety. The evolution of neuromuscular pharmacology thus exemplifies the broader movement toward objective monitoring and mechanism-based perioperative drug management.

Pharmacosafety constitutes another central pillar of contemporary anesthetic pharmacology. General anesthesia is characterized by simultaneous exposure to several potent pharmacological agents, often within a narrow therapeutic window and under conditions of rapidly changing physiology. Medication errors, inappropriate dosing, drug interactions, inadequate monitoring, residual drug effects, allergic reactions, hemodynamic instability, respiratory compromise, and other adverse drug events can have immediate and potentially severe consequences. Pharmacovigilance principles are therefore highly relevant to anesthesia, even though perioperative adverse events are often multifactorial and difficult to attribute to a single drug. Distinguishing predictable pharmacological effects from preventable medication-related harm remains an important challenge in both clinical practice and research.

The pharmacological safety profile of anesthetic drugs must also be interpreted within the context of organ-specific vulnerability. Cardiovascular depression may be clinically consequential in patients with limited myocardial reserve; respiratory depression may be particularly dangerous in patients with obstructive sleep-disordered breathing or pulmonary disease; altered hepatic or renal function may prolong exposure to selected agents or metabolites; and neurological vulnerability may influence susceptibility to postoperative cognitive disturbances. A patient-centered pharmacological approach therefore requires integration of drug-specific properties with patient-specific pathophysiology. The same pharmacological effect may represent a therapeutic benefit in one patient and a clinically significant adverse event in another.

Inflammatory, endocrine, metabolic, and immune responses to surgery provide additional dimensions to anesthetic pharmacology. Surgical trauma activates neuroendocrine stress pathways, inflammatory signaling, autonomic responses, and metabolic adaptation. Anesthetic agents may modify some of these responses, although the clinical significance of individual molecular effects remains an area of continuing investigation. The relationship between anesthetic exposure, immune modulation, inflammation, tumor biology, and postoperative outcomes has attracted substantial scientific interest, particularly in oncology. However, mechanistic plausibility should not be conflated with definitive clinical benefit, and translational interpretations require careful distinction between experimental findings and clinically validated outcomes.

The neuroscience of consciousness has also reshaped conceptual models of general anesthesia. Consciousness is increasingly understood as an emergent property of distributed neural networks rather than a function localized to a single anatomical structure. Anesthetic-induced unconsciousness may involve disruption of corticocortical communication, thalamocortical interactions, information integration, arousal systems, and network-level connectivity. Different

anesthetic drugs may produce unconsciousness through partially overlapping but pharmacologically distinct mechanisms. This perspective has important implications for anesthetic pharmacology because drug effects cannot always be predicted solely from receptor affinity. Receptor-level actions are embedded within neuronal circuits and large-scale network dynamics, meaning that the clinical phenotype of anesthesia reflects multilevel pharmacological organization.

This multilevel perspective also helps explain why anesthetic pharmacology remains scientifically dynamic despite decades of clinical experience. The discovery of molecular targets does not necessarily establish a complete causal explanation for anesthetic action. A drug may interact with several receptors and ion channels, and the relative contribution of each target may vary according to concentration, brain region, neuronal phenotype, and physiological state. Furthermore, anesthesia-induced changes in neural activity can influence systemic physiology, while systemic physiology can reciprocally modify anesthetic pharmacokinetics and pharmacodynamics. General anesthesia should therefore be conceptualized as a complex adaptive pharmacological state characterized by continuous interaction between drug exposure, biological response, and clinical intervention.

Precision perioperative pharmacotherapy builds upon this understanding by seeking to tailor drug selection and dosing to the individual patient. Precision medicine in anesthesia should not be interpreted narrowly as genetic testing alone. Rather, it encompasses the integration of demographic variables, body composition, organ function, comorbidity, previous anesthetic responses, medication history, pharmacokinetic characteristics, pharmacodynamic sensitivity, genetic and potentially epigenetic information, real-time physiological monitoring, and procedure-specific requirements. Pharmacogenomics may eventually contribute more extensively to anesthetic drug selection and dosing, but its current clinical applicability varies considerably among drug classes and patient populations. The immediate practical foundation of precision anesthesia remains careful phenotyping and continuous adjustment of therapy according to observed response.

Population pharmacokinetic and pharmacodynamic modeling has contributed substantially to this individualized approach. Compartmental models, effect-site modeling, covariate analysis, target-controlled infusion systems, and Bayesian approaches have provided increasingly sophisticated tools for predicting drug exposure and effect. Target-controlled infusion of selected intravenous anesthetics allows clinicians to estimate plasma or effect-site concentrations based on pharmacokinetic models rather than administering fixed intermittent doses. Although models cannot completely eliminate uncertainty, they provide a rational framework for titration and facilitate more reproducible pharmacotherapy. The value of such technologies is greatest when combined with clinical observation and appropriate monitoring rather than treated as substitutes for clinical judgment.

The concept of therapeutic optimization must consequently incorporate both quantitative and qualitative dimensions. A pharmacologically optimal anesthetic regimen is not necessarily the regimen that produces the deepest anesthesia or the most complete suppression of physiological responses. Instead, optimization involves achieving sufficient hypnosis, analgesia, amnesia, and immobility while minimizing unnecessary exposure and preserving cardiovascular, respiratory, neurological, and metabolic stability. The desired pharmacological state changes over time. Induction, maintenance, surgical stimulation, emergence, and early recovery represent distinct phases requiring different pharmacological objectives. Dose selection should therefore be temporally dynamic rather than static.

The perioperative period also demonstrates the importance of temporal pharmacology. Drug concentrations rise and decline according to administration route, distribution characteristics, clearance, infusion duration, and interaction with other agents. Context-sensitive half-time

becomes particularly relevant during prolonged infusions because the duration required for drug concentration to decline may differ substantially from the terminal elimination half-life. This distinction has direct clinical implications for emergence and recovery. An anesthetic strategy that provides predictable concentration decline after short procedures may behave differently following prolonged administration. Understanding these kinetic relationships is therefore indispensable for rational selection of maintenance agents and infusion strategies.

Pharmacological optimization also requires recognition of nonlinear and concentration-dependent relationships. Drug effects may demonstrate threshold phenomena, saturation, hysteresis, tolerance, or synergistic interactions. Plasma concentration does not necessarily correspond immediately to effect-site concentration, and observed clinical effects may lag behind changes in circulating drug levels. Pharmacodynamic models incorporating effect compartments, E_{max} relationships, sigmoid functions, and interaction models can help characterize these relationships. Such approaches are increasingly important in research examining combinations of hypnotics, analgesics, sedatives, and neuromuscular blocking agents.

Patient-centered anesthesia further requires attention to outcomes that matter beyond the operating room. Pain control, nausea and vomiting, cognitive recovery, sleep, mobility, ability to eat and drink, respiratory function, and patient satisfaction are all influenced by perioperative pharmacotherapy. Enhanced recovery pathways have consequently promoted coordinated approaches to analgesia, antiemetic therapy, fluid management, mobilization, and anesthetic technique. Pharmacological choices made during induction and maintenance may influence downstream recovery, emphasizing that anesthetic pharmacology should be considered within a continuum rather than as an isolated intraoperative discipline.

The prevention and management of postoperative nausea and vomiting provides a clear example of this broader pharmacological strategy. Risk-based prophylaxis and treatment frequently involve agents acting through different neurotransmitter systems, including serotonin, dopamine, neurokinin, histamine, muscarinic, and other pathways. Multimodal prophylaxis reflects the principle that heterogeneous mechanisms may provide complementary protection. However, polypharmacy can also increase complexity and adverse-effect burden. Rational antiemetic pharmacotherapy therefore requires assessment of baseline risk, previous history, procedural factors, anesthetic technique, and individual contraindications.

Similarly, perioperative analgesia increasingly reflects mechanistic diversification. Nociceptive signaling involves peripheral transduction, spinal processing, supraspinal modulation, and affective-cognitive dimensions. Consequently, a single analgesic mechanism may be insufficient to address the full complexity of postoperative pain. Combining agents or techniques acting at different levels of the nociceptive pathway can reduce reliance on high-dose opioids and may facilitate functional recovery. Nevertheless, multimodal analgesia should remain evidence-based and individualized because not every patient derives equal benefit from every component, and some interventions may carry clinically important risks.

The role of pharmacological antagonism and reversal further illustrates the movement toward controllable anesthesia. Reversal agents can provide clinicians with a means of rapidly reducing selected drug effects, thereby increasing predictability during emergence. However, reversal does not eliminate the need for appropriate primary dosing, monitoring, or understanding of residual pharmacological activity. A drug's apparent reversal may also depend on redistribution, receptor occupancy, metabolism, and the pharmacokinetic characteristics of both the anesthetic and reversal agent. Comprehensive understanding of these relationships is essential for avoiding false reassurance and ensuring safe recovery.

The development of novel anesthetic agents continues to be influenced by the pursuit of favorable therapeutic indices, rapid onset and offset, cardiovascular stability, reduced respiratory depression, predictable pharmacokinetics, and improved recovery profiles. Contemporary

research increasingly evaluates anesthetic drugs not merely according to their capacity to induce unconsciousness but according to their broader perioperative effects. The concept of an ideal anesthetic has therefore evolved from a substance capable of reliably producing unconsciousness into a pharmacological platform that can be titrated precisely, integrated with multimodal therapy, monitored objectively, and discontinued with predictable recovery.

At the same time, the field must confront persistent challenges. There remains substantial interindividual variability in anesthetic requirements and responses; pharmacological interactions are often difficult to predict in patients receiving multiple medications; older and medically complex populations may be particularly vulnerable to adverse effects; and clinically relevant endpoints are frequently influenced by nonpharmacological factors such as surgical technique, inflammation, fluid balance, temperature, pain, sleep, and environmental conditions. These complexities limit the possibility of defining universally optimal anesthetic regimens. Instead, contemporary anesthetic pharmacology increasingly favors adaptive treatment strategies that continuously integrate pharmacological theory with patient-specific observations.

The reconfiguration of the pharmacological landscape of general anesthesia therefore represents not simply the introduction of new drugs but a fundamental change in how anesthetic therapy is conceptualized. The field has moved from empirical drug administration toward mechanistically informed, quantitatively modeled, multimodal, monitored, and increasingly individualized pharmacotherapy. Molecular pharmacology provides insight into drug targets; systems neuroscience explains network-level effects; pharmacokinetics describes exposure over time; pharmacodynamics characterizes biological response; clinical pharmacology integrates these dimensions with patient characteristics; and perioperative medicine evaluates the consequences across the entire surgical trajectory. These perspectives are complementary rather than competing and collectively provide the intellectual framework for contemporary anesthetic pharmacology.

Within this framework, intravenous and inhalational anesthetics should not be viewed as mutually exclusive categories but as components of a broader therapeutic repertoire. Their selection depends upon procedural characteristics, patient physiology, desired onset and recovery profiles, environmental considerations, clinician expertise, monitoring capacity, and institutional practice. Likewise, opioids, nonopioid analgesics, sedatives, α_2 -adrenergic agonists, dissociative anesthetics, local anesthetics, neuromuscular blockers, reversal agents, antiemetics, and other perioperative drugs should be evaluated according to their pharmacological contribution to a coordinated therapeutic strategy. Such integration makes it possible to consider efficacy and safety simultaneously rather than treating adverse effects as secondary consequences of otherwise successful anesthesia.

The concept of adverse-effect mitigation is particularly important within this reconfigured landscape. Pharmacological safety is achieved not exclusively by selecting drugs with favorable profiles but through appropriate patient selection, dose individualization, avoidance of unnecessary combinations, anticipatory monitoring, and recognition of high-risk interactions, prevention of cumulative drug exposure, and timely reversal or supportive intervention when required. Risk mitigation should begin during preoperative assessment and continue through induction, maintenance, emergence, and postoperative care. This longitudinal approach reflects the reality that pharmacological harm may emerge after the apparent completion of anesthesia and that early intraoperative decisions can influence later recovery.

The future trajectory of anesthetic pharmacology is likely to be increasingly shaped by integration with digital health, artificial intelligence, advanced physiological monitoring, pharmacometric modeling, pharmacogenomics, and real-time decision-support systems. Such technologies may facilitate more precise prediction of anesthetic requirements, individualized dosing, recognition of abnormal drug responses, and optimization of recovery. However, technological sophistication

should remain subordinate to pharmacological validity, clinical evidence, patient safety, transparency, and professional judgment. Predictive models are only as reliable as the data and assumptions underlying them, and algorithmic recommendations must therefore be interpreted within the context of clinical physiology and therapeutic goals.

Artificial intelligence may ultimately contribute to a more adaptive form of anesthetic management in which drug administration is continuously informed by multidimensional physiological signals. Closed-loop systems integrating EEG-derived indices, hemodynamic variables, nociceptive measures, pharmacokinetic models, and drug-delivery systems are being investigated as potential approaches to automated titration. Nevertheless, the clinical value of automation depends on the quality of the underlying pharmacological models and the ability of systems to recognize atypical responses. Human oversight remains essential because anesthesia occurs in biologically heterogeneous patients undergoing procedures characterized by abrupt physiological perturbations.

The scientific significance of reconfiguring general anesthesia pharmacology consequently extends beyond anesthetic technique itself. It contributes to a broader understanding of how modern clinical pharmacology can transition from population-based dosing toward individualized, mechanism-informed therapeutic optimization. General anesthesia provides an unusually informative model for this transformation because multiple potent drugs are administered over a short period, their effects are measurable in real time, and therapeutic success depends upon balancing several competing physiological endpoints. Insights generated within anesthetic pharmacology may therefore have implications for precision therapeutics more broadly.

A contemporary scientific examination of general anesthesia must also remain appropriately critical. Mechanistic sophistication does not automatically translate into superior clinical outcomes, and emerging pharmacological hypotheses require rigorous validation through pharmacometric studies, randomized clinical trials, comparative effectiveness research, systematic reviews, meta-analyses, and long-term outcome assessment. Differences between surrogate endpoints and patient-important outcomes must be explicitly recognized. Similarly, laboratory evidence concerning receptor interactions or neuroprotective properties should not be interpreted as proof of clinical superiority without appropriate translational evidence. A rigorous pharmacological discourse must therefore integrate innovation with methodological caution.

Against this background, the present scientific discourse examines the reconfiguration of the pharmacological landscape of general anesthesia through an integrated consideration of contemporary anesthetic pharmacology, molecular and systems-level mechanisms, intravenous and inhalational anesthetic agents, pharmacokinetic–pharmacodynamic relationships, multimodal therapeutic strategies, precision perioperative pharmacotherapy, pharmacosafety, adverse-effect mitigation, and patient-centered clinical optimization. The central premise is that the future of general anesthesia is unlikely to be defined by a single superior anesthetic agent. Rather, progress will emerge from the rational integration of pharmacological mechanisms, individualized exposure, objective monitoring, multimodal treatment, predictive modeling, and continuous assessment of clinically meaningful outcomes.

Such an approach recognizes general anesthesia as a dynamic therapeutic system rather than a discrete pharmacological event. The anesthetic state is constructed through coordinated manipulation of consciousness, nociception, motor activity, autonomic function, and physiological homeostasis, with each pharmacological intervention contributing to a larger network of effects. The challenge for contemporary anesthetic pharmacology is therefore to determine how these components can be optimized simultaneously while minimizing unnecessary exposure and preserving the patient's capacity for rapid and safe recovery. This challenge requires interdisciplinary integration of pharmacology, anesthesiology, neuroscience, physiology, surgery, pharmacometrics, clinical epidemiology, pharmacovigilance, and precision medicine.

The reconfiguration of general anesthesia pharmacology represents a transition from an agent-centered model toward a patient-centered and systems-oriented paradigm. In this paradigm, drugs are selected not simply because they produce anesthesia but because their molecular mechanisms, kinetic behavior, pharmacodynamic interactions, safety characteristics, environmental consequences, and recovery profiles are appropriate for the individual patient and procedural context. The scientific objective is consequently not maximal pharmacological intervention but optimal pharmacological control. This distinction is fundamental to the evolution of modern anesthesia and provides the conceptual basis for continued investigation into safer, more precise, more adaptive, and more patient-centered perioperative pharmacotherapy.

BACKGROUND

General anesthesia occupies a distinctive position within the history and science of pharmacology because it represents one of the earliest and most consequential applications of controlled pharmacological manipulation of human consciousness. The capacity to reversibly suppress awareness, attenuate nociceptive responses, prevent movement, and facilitate invasive procedures transformed surgery from an intervention constrained by intolerable pain and physiological stress into a central component of modern medicine. Yet the historical success of anesthesia preceded a comprehensive understanding of its biological mechanisms. The earliest anesthetic practices were largely empirical, and the therapeutic state was initially conceptualized as a generalized and relatively undifferentiated suppression of central nervous system activity. Contemporary pharmacology has progressively displaced this simplified interpretation. General anesthesia is now understood as a complex neuropharmacological condition arising from interactions among multiple molecular targets, neuronal populations, neural circuits, physiological systems, and pharmacokinetic processes.

The historical development of anesthetic pharmacology is inseparable from the emergence of modern clinical pharmacology. The introduction of inhalational agents such as ether and nitrous oxide demonstrated that consciousness and pain perception could be reversibly altered by chemical substances. Subsequent development of halogenated volatile anesthetics improved controllability, potency, and clinical applicability. The introduction of intravenous anesthetics subsequently expanded the therapeutic repertoire and facilitated rapid induction of anesthesia. Over time, opioid analgesics, benzodiazepines, neuromuscular blocking agents, local anesthetics, α_2 -adrenergic agonists, antiemetics, and pharmacological reversal agents became integrated into perioperative practice. The resulting pharmacological system gradually evolved from reliance on individual anesthetic substances toward coordinated combinations of drugs, each contributing to a particular component of the overall anesthetic state.

This historical progression is important because it demonstrates that advances in anesthesia have generally resulted from increasing pharmacological selectivity rather than simply increasing drug potency. An early objective was to identify a compound capable of producing unconsciousness and immobility sufficiently profound to permit surgery. Subsequent clinical experience revealed that no single agent optimally provides hypnosis, analgesia, amnesia, muscle relaxation, autonomic stability, and rapid recovery simultaneously. The emergence of balanced anesthesia consequently represented a major conceptual development. Different pharmacological classes could be combined so that individual drugs addressed complementary therapeutic objectives. Such combination therapy reduced the requirement for excessive exposure to any single agent and established the foundation for modern multimodal anesthetic practice.

The pharmacological definition of general anesthesia remains complex because the clinically observed state contains several partially separable endpoints. Hypnosis refers to loss or substantial alteration of consciousness, whereas amnesia concerns impairment of memory formation. Analgesia represents attenuation of nociception and pain, while immobility reflects

suppression of motor responses to surgical stimulation. Autonomic control encompasses attenuation of cardiovascular, endocrine, and other physiological responses to noxious stimulation. Neuromuscular blockade produces skeletal muscle paralysis but does not itself induce unconsciousness or analgesia. These distinctions have profound pharmacological implications. A drug that is highly effective for one endpoint may be relatively ineffective for another, meaning that the anesthetic state is better understood as a multidimensional therapeutic construct than as a single pharmacological effect.

The molecular pharmacology of general anesthetics provides further evidence against a unitary mechanism of action. Many intravenous and volatile anesthetics enhance inhibitory neurotransmission, particularly through γ -aminobutyric acid type A receptors, while other agents exert major effects through excitatory neurotransmitter systems. Ketamine, for example, is strongly associated with antagonism of N-methyl-D-aspartate receptors and produces a distinctive dissociative state. Dexmedetomidine and related $\alpha 2$ -adrenergic agonists act predominantly through presynaptic and postsynaptic $\alpha 2$ -adrenergic mechanisms and produce sedation with characteristic effects on sympathetic tone. Local anesthetics inhibit voltage-gated sodium channels and interrupt action-potential propagation, whereas neuromuscular blocking agents interfere with nicotinic acetylcholine receptor-mediated transmission at the neuromuscular junction. The diversity of these mechanisms illustrates that modern anesthesia is constructed from pharmacologically heterogeneous interventions.

γ -Aminobutyric acid is the principal inhibitory neurotransmitter in the mammalian central nervous system and plays a major role in the actions of numerous anesthetic and sedative agents. γ -Aminobutyric acid type A receptors are ligand-gated chloride channels assembled from multiple subunits with distinct anatomical and functional distributions. Positive allosteric modulation of these receptors can increase inhibitory neurotransmission and reduce neuronal excitability. Propofol, etomidate, benzodiazepines, barbiturates, and several volatile anesthetics interact with this inhibitory system, although their binding sites, receptor subtype selectivity, concentration–effect relationships, and functional consequences differ. These distinctions are pharmacologically important because receptor subtype distribution may influence hypnotic, amnestic, motor, cardiovascular, and other clinical effects.

The receptor-level model, however, cannot fully explain general anesthesia. Consciousness is an emergent property of coordinated activity across distributed neural networks, and anesthetic-induced unconsciousness involves changes in communication among cortical, thalamic, subcortical, and brainstem structures. Modern neuroscience therefore increasingly emphasizes network-level mechanisms, including disruption of corticocortical connectivity, altered thalamocortical communication, suppression of arousal pathways, changes in neural oscillations, and modification of information integration. Anesthetic agents can produce characteristic electroencephalographic patterns that vary according to dose, age, neurological state, and drug class. The transition from consciousness to unconsciousness consequently reflects the interaction of molecular pharmacology with systems neuroscience.

The thalamus has historically been considered an important structure in the regulation of consciousness, although current models emphasize distributed interactions rather than a single anatomical locus. Thalamocortical communication contributes to sensory integration, arousal, and cortical organization. Anesthetic-induced alterations in thalamic activity may therefore contribute to suppression of conscious awareness. Similarly, ascending arousal systems originating in the brainstem and basal forebrain regulate cortical activation and wakefulness. Pharmacological suppression of these systems can contribute to anesthetic-induced unconsciousness. Such findings reinforce the principle that anesthetic pharmacology operates across hierarchical biological scales, from receptor interactions to whole-brain network dynamics.

Volatile anesthetics illustrate this multilevel complexity particularly clearly. Their pharmacological effects cannot be attributed to a single receptor target. They interact with multiple ligand-gated and ion-channel systems and alter synaptic transmission, neuronal excitability, and network organization. Historically, lipid-solubility theories attempted to explain anesthetic potency through partitioning into biological membranes. Although these theories contributed to early understanding, modern evidence demonstrates that protein targets and specific molecular interactions are central to anesthetic action. The contemporary view therefore incorporates both membrane and protein-level effects while recognizing that the clinical phenotype emerges from coordinated modulation of neuronal networks.

The potency of inhalational anesthetics has traditionally been described through minimum alveolar concentration, or MAC, which represents the alveolar concentration associated with prevention of movement in response to standardized surgical stimulation in a defined proportion of subjects. MAC is useful for comparing potency and guiding volatile-anesthetic administration, but it should not be equated with the complete pharmacological state of anesthesia. The concentration associated with immobility differs from concentrations associated with amnesia or unconsciousness, and patient characteristics such as age, temperature, concomitant drugs, physiological status, and procedural stimulation can modify anesthetic requirements. MAC therefore represents one pharmacological metric within a broader multidimensional framework. Nitrous oxide has historically occupied a special position among inhalational agents because of its analgesic properties, rapid uptake and elimination, and relatively limited anesthetic potency when used alone. Its ability to reduce the requirement for other anesthetic agents illustrates the principle of pharmacodynamic interaction. By contributing analgesic effects through mechanisms that differ from those of conventional volatile anesthetics, nitrous oxide can alter the concentration–effect relationship of coadministered agents. At the same time, its clinical use must be evaluated within the context of procedure-specific requirements, contraindications, occupational considerations, and environmental consequences.

Sevoflurane, desflurane, and isoflurane have each contributed to the evolution of volatile-anesthetic pharmacology. Their physicochemical properties produce different uptake and elimination characteristics. Blood–gas partition coefficients influence the rate at which alveolar and blood concentrations approach equilibrium, thereby affecting onset and recovery. Lower blood solubility generally permits more rapid changes in anesthetic concentration and can facilitate control of anesthetic depth and emergence. However, clinical recovery is determined by more than blood–gas solubility because tissue distribution, duration of exposure, ventilation, cardiac output, metabolic processes, and patient-specific factors also influence elimination.

The pharmacokinetics of inhalational anesthesia are therefore governed by a dynamic relationship among inspired concentration, alveolar concentration, pulmonary uptake, blood concentration, tissue distribution, metabolism, and exhalation. Changes in ventilation can modify the rate of uptake, while cardiac output affects the transfer of anesthetic from the alveoli into the circulation. Highly perfused organs, including the brain, rapidly equilibrate with circulating anesthetic, whereas adipose and other compartments may accumulate agents during prolonged exposure. During emergence, redistribution and elimination occur simultaneously. These processes explain why anesthetic concentration at the brain can decline at a different rate from concentration in other tissues.

Intravenous anesthetics possess equally complex pharmacokinetic characteristics. Following intravenous administration, the drug initially enters the central circulation and rapidly distributes to highly perfused tissues, particularly the brain. Subsequently, redistribution to peripheral compartments decreases central nervous system concentration and contributes to the initial decline in drug effect. Metabolism and elimination determine longer-term clearance. For agents administered as continuous infusions, the duration of administration influences tissue

accumulation and recovery kinetics. The clinically relevant duration of drug effect is therefore not always predicted accurately by the terminal elimination half-life.

Propofol represents one of the most influential examples of modern intravenous anesthetic pharmacology. Its rapid onset, redistribution, and metabolism have made it a central agent for induction and maintenance of anesthesia. Propofol primarily potentiates inhibitory neurotransmission through γ -aminobutyric acid type A receptor mechanisms, but its clinical pharmacology also encompasses effects on cardiovascular function, respiratory drive, cerebral physiology, and nausea and vomiting. Dose requirements are influenced by age, comorbidity, concurrent medications, and physiological condition. Excessive dosing can result in hypotension and respiratory depression, while insufficient dosing may lead to inadequate hypnosis. The clinical value of propofol therefore depends on titration rather than a fixed dose paradigm.

Etomidate occupies another important position because of its cardiovascular pharmacological profile. Its relative preservation of cardiovascular stability in selected patients has contributed to its use for induction in situations where profound hemodynamic disturbance may be poorly tolerated. Nevertheless, etomidate inhibits adrenal steroidogenesis, and concerns regarding adrenal suppression have influenced the interpretation of its role in critically ill or physiologically vulnerable populations. This example illustrates an essential principle of modern pharmacology: favorable effects in one physiological domain may coexist with potentially significant effects in another, requiring a comprehensive benefit–risk assessment rather than simplistic classification of a drug as either “safe” or “unsafe.”

Ketamine demonstrates a fundamentally different pharmacological model. Its antagonism of N-methyl-D-aspartate receptors contributes to dissociative anesthesia, profound analgesia, and characteristic changes in consciousness. Unlike many conventional hypnotic agents, ketamine may preserve airway reflexes and produce sympathetic stimulation under many circumstances, although cardiovascular and respiratory responses can vary according to patient physiology and clinical context. Its analgesic effects have expanded interest in lower-dose perioperative administration as part of multimodal analgesia. The pharmacological significance of ketamine therefore extends beyond induction of anesthesia to modulation of nociceptive processing and reduction of opioid exposure.

The pharmacology of α 2-adrenergic agonists provides another example of mechanism-based sedation. Dexmedetomidine reduces central sympathetic activity and produces a sedative state with distinctive neurophysiological characteristics. Its effects may include bradycardia and hypotension, particularly in susceptible patients or when administered rapidly or at excessive exposure. Its pharmacological profile can be advantageous when reduced respiratory depression is desirable, but its hemodynamic effects require individualized assessment. The growing use of α 2-adrenergic agonists demonstrates how anesthetic practice increasingly incorporates drugs that modulate specific physiological pathways rather than relying exclusively on deep generalized CNS depression.

Opioids constitute the principal pharmacological class traditionally associated with perioperative analgesia. μ -opioid receptor activation produces potent analgesia but also respiratory depression, sedation, nausea, vomiting, gastrointestinal hypomotility, urinary retention, and other adverse effects. Their use during anesthesia illustrates the therapeutic problem of separating analgesia from undesirable physiological consequences. The modern response has been the development of multimodal analgesia, in which opioids remain available when clinically necessary but are supplemented or partially replaced by drugs and techniques targeting alternative nociceptive pathways.

The development of multimodal analgesia reflects increased understanding of nociceptive physiology. Surgical pain involves peripheral tissue injury, inflammatory mediator release, activation of nociceptors, spinal sensitization, supraspinal processing, and affective-cognitive

modulation. Pharmacological intervention at multiple levels can produce complementary analgesia. Acetaminophen, nonsteroidal anti-inflammatory drugs, local anesthetics, N-methyl-D-aspartate receptor antagonists, α_2 -adrenergic agonists, and other agents may therefore be combined according to the procedure and patient characteristics. However, multimodal therapy should not become indiscriminate polypharmacy. Each component should have a defined therapeutic rationale, appropriate evidence base, and acceptable safety profile.

Local anesthetics provide an important bridge between regional and general anesthesia. By blocking voltage-gated sodium channels, they prevent propagation of action potentials in peripheral nerves. Their use in regional anesthesia, nerve blocks, infiltration, and neuraxial techniques can reduce the requirement for systemic anesthetics and opioids. This pharmacological contribution has implications for enhanced recovery and postoperative analgesia. Nevertheless, systemic toxicity remains a clinically important concern, particularly with excessive plasma concentrations or inadvertent intravascular administration. The pharmacology of local anesthetics consequently demonstrates the continuing importance of dose limitation, anatomical precision, and monitoring.

Neuromuscular blocking agents represent a further pharmacological dimension of general anesthesia. Depolarizing agents and nondepolarizing agents interfere with neuromuscular transmission through different mechanisms. Nondepolarizing drugs such as rocuronium, vecuronium, and cisatracurium act primarily as competitive antagonists at nicotinic acetylcholine receptors. Their pharmacokinetics differ according to hepatic metabolism, renal elimination, organ-independent degradation, and distribution. Cisatracurium and related agents undergo Hofmann elimination, making their pharmacology potentially useful in selected patients with organ dysfunction. These distinctions demonstrate the relevance of drug-specific elimination pathways to individualized anesthetic selection.

Reversal of neuromuscular blockade has undergone substantial pharmacological development. Traditional reversal with acetylcholinesterase inhibitors increases acetylcholine availability at the neuromuscular junction but may have muscarinic adverse effects and limitations when profound blockade persists. Selective binding agents such as sugammadex provide an alternative mechanism for reversal of certain steroidal neuromuscular blockers by encapsulating the drug and reducing its availability at the neuromuscular junction. This development illustrates how mechanistically targeted pharmacological reversal can alter the safety profile of an entire drug class. Nevertheless, appropriate quantitative neuromuscular monitoring remains essential because clinical assessment alone may underestimate residual blockade.

Pharmacodynamic interaction represents one of the defining characteristics of contemporary anesthesia. Drugs administered together can demonstrate additive, synergistic, antagonistic, or less-than-additive effects. Hypnotic and opioid combinations may reduce the dose of each component required to achieve anesthesia, but the interaction may also increase hypotension or respiratory depression. Sedative combinations can similarly produce unexpectedly deep CNS depression. Pharmacodynamic interaction models have therefore become increasingly important in anesthetic pharmacology, particularly when determining optimal combinations and minimizing adverse effects.

Pharmacokinetic interactions can be equally consequential. Enzyme inhibition or induction may modify metabolism of perioperative medications, while alterations in protein binding, organ perfusion, hepatic function, or renal clearance can change systemic exposure. Some interactions are predictable from known metabolic pathways, whereas others become clinically apparent only in vulnerable patients. The perioperative period may also produce acute physiological changes that alter drug disposition independently of classical drug–drug interactions. Hemorrhage, fluid shifts, hypothermia, altered cardiac output, inflammation, and changes in organ perfusion can all modify pharmacokinetics.

The distinction between plasma concentration and effect-site concentration is especially relevant to intravenous anesthesia. Following administration, equilibration between plasma and the brain is not instantaneous. Effect-site compartments are therefore incorporated into pharmacokinetic–pharmacodynamic models to describe hysteresis between concentration and effect. This approach permits estimation of the concentration associated with a given pharmacological endpoint and facilitates more rational titration. The clinical utility of effect-site modeling is particularly apparent in target-controlled infusion systems, which attempt to achieve predefined plasma or effect-site concentrations using pharmacokinetic algorithms.

Target-controlled infusion has consequently become an important example of pharmacometric integration into clinical anesthesiology. Instead of administering fixed infusion rates without accounting for changing drug concentrations, target-controlled systems use mathematical models to adjust infusion rates according to the selected target. The underlying models incorporate population-derived parameters and covariates such as age, body size, and other patient characteristics. These systems do not eliminate pharmacological variability, but they can provide a more structured approach to drug administration. Their reliability depends on model validity, appropriate patient selection, accurate implementation, and continuous clinical monitoring.

Population pharmacokinetics has further contributed to recognition that drug disposition varies systematically across patient groups. Covariates such as age, weight, sex, organ function, disease status, and concomitant medication use can influence clearance and distribution volumes. Mixed-effects modeling enables estimation of both typical population parameters and interindividual variability. Such approaches provide a scientific basis for individualized dosing while acknowledging that no model can fully predict every patient's response. The growing integration of pharmacometrics and clinical anesthesia therefore represents a movement toward quantitative precision rather than deterministic dosing.

Pharmacogenomics represents a potentially important but still evolving component of precision anesthetic pharmacology. Genetic variation can influence drug metabolism, receptor sensitivity, ion-channel function, and susceptibility to adverse drug reactions. Certain perioperative drugs have clinically recognized pharmacogenetic relationships, while the relevance of genetic variation for many anesthetic agents remains under investigation. The future integration of genomic information with pharmacokinetic and pharmacodynamic phenotyping may eventually permit more accurate prediction of drug response. At present, however, pharmacogenomics should complement rather than replace clinical assessment and therapeutic monitoring.

Pharmacodynamic variability may be particularly pronounced in older adults. Aging is associated with changes in receptor sensitivity, brain structure and function, cardiovascular reserve, pulmonary physiology, renal function, hepatic metabolism, and body composition. These changes can increase sensitivity to sedative-hypnotic drugs and prolong recovery. Older patients may also be more susceptible to postoperative delirium and cognitive dysfunction, although these outcomes are multifactorial and cannot be attributed exclusively to anesthetic drugs. Consequently, geriatric anesthetic pharmacology emphasizes lower initial exposure, careful titration, avoidance of unnecessary polypharmacy, maintenance of physiological stability, and rapid identification of residual drug effects.

Pediatric anesthesia presents an inverse but equally complex pharmacological challenge. Developmental changes influence receptor expression, enzymatic activity, organ function, body-water composition, protein binding, and drug distribution. Pharmacokinetic parameters may therefore differ substantially between neonates, infants, children, adolescents, and adults. Dose extrapolation from adult populations can be inappropriate when developmental pharmacology is not considered. Pediatric anesthetic pharmacology consequently requires age-appropriate models and careful recognition of developmental changes in drug disposition and response.

Pregnancy introduces additional physiological modifications relevant to anesthetic pharmacology. Changes in plasma volume, cardiac output, ventilation, protein binding, renal filtration, and hormonal environment can alter drug kinetics and pharmacodynamics. Maternal and fetal considerations must be integrated when selecting agents, dosing regimens, and anesthetic techniques. This illustrates the broader principle that pharmacological optimization requires attention not only to the target patient but also to physiological states that modify drug exposure or introduce additional therapeutic objectives.

Obesity similarly alters pharmacokinetic and pharmacodynamic relationships. Increased adipose mass, altered lean body mass, changes in cardiac output, and modifications in regional perfusion influence distribution and clearance. Lipophilic agents may accumulate extensively in adipose tissue during prolonged exposure, whereas dosing according to total body weight may result in excessive concentrations for some drugs. Conversely, dosing according to ideal or lean body weight without consideration of drug-specific pharmacology may lead to inadequate exposure. The appropriate weight scalar is therefore drug-specific and should be informed by pharmacokinetic evidence.

Hepatic dysfunction can alter drug metabolism and protein binding, while renal dysfunction affects clearance of drugs and metabolites eliminated through the kidneys. In both settings, the terminal duration of drug effect may be prolonged. The problem becomes particularly important when several agents with overlapping elimination pathways are administered simultaneously. Pharmacological strategies for patients with organ dysfunction consequently emphasize selection of drugs with predictable disposition, dose adjustment where appropriate, minimization of unnecessary accumulation, and monitoring of clinical effect.

Cardiovascular physiology has a direct relationship with anesthetic pharmacology. Many anesthetic agents decrease systemic vascular resistance, myocardial contractility, sympathetic tone, or venous return. These effects may be tolerated in healthy individuals but can become clinically significant in patients with hypovolemia, valvular disease, ischemic heart disease, cardiomyopathy, or autonomic dysfunction. Conversely, agents with sympathetic effects may produce tachycardia or hypertension in selected patients. Pharmacological selection should therefore be based on the interaction between drug effect and cardiovascular reserve rather than isolated drug characteristics.

Respiratory pharmacology is similarly central to safe anesthesia. General anesthetics can reduce ventilatory drive, alter upper-airway tone, impair protective reflexes, and interact with opioids or sedatives to produce respiratory depression. Neuromuscular blockade adds another mechanism through which spontaneous ventilation and airway protection may be compromised. The transition from controlled ventilation to spontaneous breathing therefore represents a pharmacologically critical phase. Objective assessment of respiratory function and neuromuscular recovery is essential to minimize residual drug effects.

Cerebral physiology adds further complexity. Anesthetic agents may alter cerebral blood flow, cerebral metabolic rate, intracranial dynamics, and electrophysiological activity. These effects vary according to agent, dose, ventilation, carbon dioxide tension, systemic blood pressure, and underlying neurological disease. The relationship between anesthetic exposure and neurological outcomes remains an active research field, particularly in vulnerable populations. Mechanistic findings should nevertheless be interpreted cautiously because perioperative neurological outcomes are influenced by age, surgical stress, inflammation, hypotension, hypoxemia, metabolic disturbance, and preexisting neurological vulnerability.

The emergence of postoperative cognitive outcomes has broadened the scope of anesthetic pharmacology. Delayed emergence, postoperative delirium, and postoperative cognitive dysfunction involve multiple interacting factors. Residual sedative exposure may contribute, but pain, sleep disruption, inflammation, metabolic abnormalities, infection, polypharmacy, and

preexisting cognitive vulnerability can also be important. The scientific challenge is therefore to distinguish direct pharmacological effects from broader perioperative determinants. This distinction is critical for avoiding overly simplistic claims regarding the neurocognitive superiority or inferiority of individual anesthetic agents.

Pharmacosafety in anesthesia extends beyond conventional adverse drug reaction classification. An adverse perioperative event may result from the drug itself, a dose error, a drug–drug interaction, administration-route error, monitoring failure, physiological susceptibility, or a combination of these factors. Because several medications are often administered nearly simultaneously, causal attribution can be difficult. Pharmacovigilance systems and standardized reporting frameworks can nevertheless identify recurrent patterns of medication-related harm and support improvements in prescribing, preparation, administration, monitoring, and reversal. Drug allergies and hypersensitivity reactions represent another critical component of perioperative pharmacosafety. Antibiotics, neuromuscular blocking agents, antiseptics, latex, and other exposures can produce immediate hypersensitivity reactions. Neuromuscular blocking agents are among important causes of perioperative anaphylaxis in some healthcare systems. Recognition and management require rapid differentiation from other causes of hypotension, bronchospasm, or cardiovascular collapse. The pharmacological environment of anesthesia can obscure early clinical manifestations, making preparedness and structured protocols particularly important.

Malignant hyperthermia illustrates the relationship between pharmacogenetics, anesthetic pharmacology, and severe adverse drug reactions. Certain susceptible individuals may develop a life-threatening hypermetabolic syndrome following exposure to triggering anesthetic agents, particularly volatile anesthetics and depolarizing neuromuscular blockade. The pathophysiological basis involves abnormal calcium handling within skeletal muscle. The availability of specific pharmacological treatment with dantrolene represents a landmark example of mechanism-directed emergency pharmacotherapy. This condition demonstrates how rare pharmacogenetic susceptibility can have major implications for anesthetic drug selection and perioperative safety. The concept of therapeutic index is useful but insufficient for describing anesthetic safety. Many anesthetic drugs possess relatively narrow margins between desired and undesirable effects, particularly when several agents are combined. Furthermore, the therapeutic window is not fixed because it depends on patient characteristics and clinical objectives. A concentration that is appropriate for surgical immobility may be excessive for early recovery. Similarly, a dose tolerated by a young healthy adult may produce profound hypotension in an older patient with cardiovascular disease. Precision pharmacotherapy therefore requires dynamic rather than static interpretation of therapeutic windows.

Monitoring technologies have become increasingly important in this context. Conventional monitoring of oxygenation, ventilation, circulation, and temperature provides the physiological foundation for safe anesthesia. Electroencephalography and processed EEG can provide additional information about cortical activity and anesthetic depth. Neuromuscular monitoring assesses the extent of blockade and recovery. Hemodynamic monitoring may range from standard noninvasive measurements to advanced approaches in high-risk patients. These technologies convert physiological responses into actionable information, enabling pharmacological therapy to be adjusted according to observed effects rather than predetermined dosing schedules.

The integration of monitoring with pharmacokinetic–pharmacodynamic models creates the possibility of closed-loop and semi-automated anesthetic administration. Such systems can continuously adjust drug delivery according to predefined physiological targets. Although technological development is accelerating, important limitations remain. Processed EEG indices can be affected by artifacts and by particular drug combinations; pharmacokinetic models may not adequately represent extreme physiological states; and automated systems may not recognize

all clinically important deviations. Therefore, technological innovation must remain embedded within expert clinical oversight.

Environmental sustainability has emerged as an additional dimension of anesthetic pharmacology. Volatile anesthetics are greenhouse gases, and differences among agents in atmospheric persistence and global warming potential have stimulated discussion of environmental stewardship. Strategies such as low-flow anesthesia can reduce volatile-agent consumption, while intravenous techniques may offer alternative pathways in appropriate patients. However, environmental considerations must be balanced against clinical indications, patient safety, equipment availability, and resource utilization. Sustainable anesthetic pharmacology therefore expands the traditional pharmacological benefit–risk framework to incorporate environmental externalities.

The economic dimension of anesthetic pharmacology is also increasingly relevant. New drugs, reversal agents, monitoring technologies, infusion systems, and personalized pharmacological strategies may increase direct costs while potentially reducing complications, recovery time, or hospitalization. Pharmacoeconomic assessment can therefore provide important information concerning whether technological or pharmacological innovations deliver sufficient clinical value. Cost should not replace efficacy and safety as primary criteria, but rational resource allocation is an important component of contemporary healthcare systems.

Enhanced recovery pathways have provided a practical framework for translating these pharmacological principles into perioperative care. The emphasis is placed on minimizing surgical stress, optimizing analgesia, reducing postoperative nausea, encouraging early mobilization, and accelerating return to physiological function. Anesthetic pharmacology contributes through appropriate selection of hypnotic and analgesic agents, regional techniques, opioid-sparing strategies, antiemetic prophylaxis, temperature management, and timely reversal of neuromuscular blockade. The overall objective is not simply to produce an adequate intraoperative anesthetic but to facilitate the patient's transition through the entire perioperative trajectory.

Postoperative nausea and vomiting remains an important pharmacological endpoint because it can delay oral intake, mobilization, discharge, and patient satisfaction. Its pathophysiology involves multiple neurotransmitter systems and risk factors. Pharmacological prophylaxis may therefore involve agents with different mechanisms, including serotonin receptor antagonism, neurokinin receptor antagonism, dopamine receptor antagonism, corticosteroid-mediated effects, and other pathways. Combination prophylaxis can be rational when baseline risk is sufficiently high. However, antiemetic polypharmacy requires consideration of sedation, extrapyramidal effects, QT prolongation, and other potential adverse effects.

The pharmacology of postoperative pain similarly demonstrates the importance of individualized treatment. Pain intensity varies according to procedure, patient characteristics, psychological factors, inflammatory responses, and previous opioid exposure. Patients with chronic opioid use may demonstrate tolerance and altered pharmacodynamic responsiveness, whereas opioid-naïve patients may be more vulnerable to respiratory depression. Pharmacological strategies must therefore distinguish acute nociceptive pain from opioid tolerance, opioid-induced hyperalgesia, and chronic pain syndromes. Multimodal analgesia can be particularly valuable in reducing excessive reliance on a single pharmacological pathway.

The perioperative management of patients receiving chronic medications introduces additional complexity. Abrupt discontinuation of certain therapies may produce withdrawal or disease destabilization, whereas continuation may modify anesthetic requirements or increase adverse-event risk. Anticoagulants, antiplatelet agents, antihypertensives, antidiabetic medications, psychotropic drugs, anticonvulsants, and other chronic therapies each require individualized assessment. Medication reconciliation is therefore an essential component of anesthetic

pharmacology and should be considered an active clinical intervention rather than a purely administrative step.

The emergence phase provides a particularly useful demonstration of pharmacological optimization. As surgical stimulation declines, the therapeutic requirement for deep hypnosis and analgesia changes. Continued administration at maintenance concentrations may become unnecessary and potentially harmful. Timely reduction or discontinuation of anesthetic drugs, reversal of neuromuscular blockade, restoration of spontaneous ventilation, and correction of physiological disturbances are therefore essential. Emergence should be understood as an actively managed pharmacological transition rather than simply the passive disappearance of drug effect. Context-sensitive pharmacokinetics is particularly relevant during this transition. Some intravenous drugs demonstrate relatively predictable recovery after short administration but increasingly prolonged offset after extended infusion because of tissue accumulation. The concept of context-sensitive half-time therefore provides a clinically meaningful description of the time required for plasma concentration to decline after discontinuation of a continuous infusion, taking duration of administration into account. Understanding this concept supports selection of maintenance agents and infusion strategies that minimize delayed recovery.

The concept of pharmacological burden has also become increasingly relevant. Patients may receive hypnotics, opioids, sedatives, neuromuscular blockers, antiemetics, vasoactive agents, antibiotics, and other medications within a relatively short interval. Each drug may be justified individually, yet the cumulative pharmacodynamic burden can produce excessive sedation, hypotension, respiratory depression, or delayed recovery. Rational anesthesia therefore requires consideration of the total pharmacological environment rather than isolated drug decisions.

The relationship between anesthesia and inflammation remains another active field of investigation. Surgical trauma generates inflammatory and stress responses, while anesthetic agents may modulate immune signaling and inflammatory pathways. Experimental studies have identified potential effects on cytokine production, immune-cell function, oxidative stress, and cellular signaling. These observations have generated hypotheses concerning postoperative recovery, infection, cancer recurrence, and organ protection. Nevertheless, mechanistic evidence varies in translational strength, and definitive conclusions require appropriately designed clinical studies.

Organ protection has similarly become an area of interest in anesthetic pharmacology. Hemodynamic instability, hypoxemia, inflammation, and drug effects can influence renal, cerebral, cardiac, and pulmonary function. Pharmacological strategies that maintain physiological stability may therefore have downstream organ-protective implications. However, protection cannot be attributed to anesthetic drugs alone because fluid therapy, ventilation, surgical technique, blood-pressure management, temperature control, and other perioperative interventions interact continuously with pharmacotherapy.

The pharmacological treatment of hemodynamic instability illustrates this systems-based perspective. Vasopressors, inotropes, fluids, anesthetic dose reduction, and correction of underlying causes may all be necessary. A hypotensive episode during anesthesia may reflect excessive anesthetic concentration, hypovolemia, vasodilation, impaired myocardial contractility, or combinations of these mechanisms. Treating the numerical blood-pressure abnormality without identifying the pharmacological and physiological cause may therefore be suboptimal. Precision perioperative pharmacotherapy requires causal reasoning rather than purely reactive intervention.

Similarly, bradycardia or tachycardia may reflect direct drug effects, autonomic responses, pain, hypovolemia, hypoxemia, or preexisting cardiovascular disease. Pharmacological management should therefore integrate the temporal relationship between drug administration and

physiological change. This is an important reason why continuous monitoring and pharmacological expertise remain indispensable even when advanced decision-support technologies are available. The development of anesthetic pharmacology has consequently produced an increasingly sophisticated hierarchy of therapeutic goals. At the molecular level, drugs are selected according to receptor and ion-channel interactions. At the pharmacokinetic level, exposure is optimized through route, dose, infusion rate, distribution, metabolism, and elimination. At the pharmacodynamic level, desired effects are balanced against adverse effects and interactions. At the systems level, cardiovascular, respiratory, neurological, endocrine, and immune responses are considered. At the patient level, age, comorbidity, preferences, prior drug responses, and recovery priorities influence therapeutic choices. At the population and health-system level, cost, environmental impact, resource availability, and equity become relevant.

This hierarchy provides the conceptual foundation for precision anesthesia. Precision should not be reduced to technological sophistication or genetic stratification. It represents the disciplined integration of available patient-specific information with mechanistic pharmacology and real-time response assessment. A precision anesthetic plan begins with preoperative characterization, identifies anticipated pharmacological vulnerabilities, selects appropriate agents, establishes dosing strategies, continuously evaluates response, and modifies therapy when the observed clinical trajectory differs from expectations.

The future of this field is likely to depend increasingly on integration across disciplines. Molecular pharmacology can identify novel targets; neurobiology can characterize network mechanisms; pharmacometrics can quantify exposure–response relationships; artificial intelligence can assist with prediction and pattern recognition; pharmacogenomics can identify inherited variability; and clinical epidemiology can determine whether mechanistic advantages translate into improved patient outcomes. None of these disciplines is sufficient independently. Their value emerges through integration into clinically validated therapeutic strategies.

The reconfiguration of anesthetic pharmacology therefore represents a transition from a historically empirical discipline toward an increasingly quantitative, mechanistic, adaptive, and patient-centered science. The central pharmacological challenge is no longer simply how to induce unconsciousness reliably. It is how to construct and maintain an appropriate multidimensional anesthetic state while minimizing unnecessary drug exposure, avoiding harmful interactions, preserving physiological stability, facilitating predictable emergence, and improving meaningful postoperative outcomes. This requires simultaneous consideration of efficacy, safety, pharmacokinetics, pharmacodynamics, monitoring, recovery, environmental sustainability, and patient-specific characteristics.

From this perspective, contemporary general anesthesia should be regarded as an integrated pharmacological system characterized by continuous interaction between administered agents and the patient's biological response. Intravenous and inhalational anesthetics, analgesics, sedatives, neuromuscular blockers, reversal agents, local anesthetics, antiemetics, and adjunctive medications form an interconnected therapeutic network. The clinical consequences of each intervention depend partly on the actions of the others. Consequently, the scientific analysis of general anesthesia requires a systems-oriented framework capable of explaining not only individual drug mechanisms but also interactions among drugs, physiological systems, surgical stimuli, and patient characteristics.

Such a framework also emphasizes the importance of distinguishing pharmacological innovation from therapeutic improvement. A novel molecular target, delivery system, pharmacokinetic model, or monitoring technology may represent substantial scientific progress without necessarily improving patient outcomes. Translation requires evidence that an intervention increases efficacy, reduces adverse effects, improves recovery, or provides another meaningful clinical benefit. The contemporary literature therefore increasingly demands integration of mechanistic evidence with

randomized trials, comparative effectiveness studies, pharmacometric analyses, systematic reviews, and patient-centered outcomes.

The background to modern anesthetic pharmacology is thus characterized by progressive refinement of both knowledge and therapeutic objectives. Early anesthesia established the possibility of reversible pharmacological alteration of consciousness. The subsequent development of diverse drug classes introduced the possibility of separating and recombining hypnosis, analgesia, immobility, amnesia, and autonomic control. Molecular pharmacology clarified receptor and ion-channel mechanisms; systems neuroscience demonstrated the importance of neural-network organization; pharmacokinetic and pharmacodynamic modeling quantified drug exposure and response; multimodal therapy reduced reliance on individual drug classes; advanced monitoring enabled real-time titration; and precision medicine introduced a framework for individualized therapeutic optimization.

The resulting paradigm is fundamentally different from the historical concept of anesthesia as generalized pharmacological depression. Modern anesthetic pharmacology is increasingly defined by selective modulation, quantitative dosing, multimodal integration, continuous monitoring, adverse-effect mitigation, and recovery-oriented care. Its ultimate objective is not merely to render a patient unconscious for the duration of surgery but to achieve an appropriate and reversible therapeutic state with the lowest reasonable pharmacological burden and the highest achievable degree of physiological stability and recovery.

In this context, reconfiguring the pharmacological landscape of general anesthesia is not a rhetorical reformulation but a scientifically grounded response to the expanding complexity of perioperative medicine. The field now encompasses molecular targets, neural networks, pharmacokinetic models, pharmacodynamic interactions, individualized dosing, pharmacogenetic variability, advanced monitoring, environmental stewardship, and long-term patient outcomes. The convergence of these domains creates an opportunity to develop anesthetic strategies that are increasingly precise, predictable, adaptable, and patient-centered while simultaneously confronting the limitations and uncertainties that remain within contemporary evidence.

The background evidence therefore supports a conceptual shift toward an integrated pharmacological model in which general anesthesia is understood as a continuously optimized therapeutic process. Within this model, the choice of anesthetic agent is only one component of decision-making. Equally important are dose, route, timing, combination, interaction, monitoring, physiological context, reversal, recovery, and patient-specific vulnerability. The emerging scientific challenge is to determine how these variables can be integrated systematically to maximize therapeutic benefit while minimizing pharmacological and physiological harm.

The evolution of general anesthesia provides a broader illustration of the trajectory of modern pharmacology itself. The discipline has moved progressively from empirical observation toward molecular explanation, from fixed dosing toward individualized exposure, from single-agent treatment toward rational combinations, and from immediate therapeutic endpoints toward longitudinal patient-centered outcomes. General anesthesia embodies all of these transitions within a uniquely dynamic clinical environment. Its future development will therefore depend not simply on discovering additional anesthetic compounds, but on understanding how existing and emerging pharmacological interventions can be integrated into adaptive therapeutic systems capable of responding to the biological individuality of each patient.

The contemporary pharmacological landscape should consequently be viewed as an evolving continuum rather than a completed body of knowledge. Established mechanisms continue to be refined; novel molecular targets are being investigated; pharmacometric models are becoming more sophisticated; monitoring technologies are becoming increasingly information-rich; and precision approaches are gradually moving from conceptual frameworks toward clinical implementation. At the same time, fundamental principles remain indispensable: careful patient

assessment, mechanistic drug selection, rational dosing, awareness of interactions, continuous monitoring, prevention of adverse events, and critical evaluation of evidence. These principles provide the foundation upon which future advances in anesthetic pharmacology can be translated into safer, more effective, and more individualized perioperative care.

GOAL

The overarching goal of this scholarly investigation is to critically examine and conceptually reconfigure the contemporary pharmacological landscape of general anesthesia through an integrated analysis of anesthetic mechanisms, pharmacokinetic–pharmacodynamic relationships, therapeutic strategies, pharmacosafety principles, and patient-centered perioperative optimization. The study seeks to synthesize current scientific knowledge concerning intravenous and inhalational anesthetic agents, analgesics, sedative–hypnotics, adjuvant pharmacotherapies, local anesthetics, neuromuscular blocking agents, and pharmacological reversal strategies, with particular emphasis on their molecular targets, systems-level effects, dose–response characteristics, pharmacokinetic variability, pharmacodynamic interactions, and clinically relevant adverse-effect profiles.

A further goal is to evaluate the transition from conventional agent-centered anesthesia toward multimodal, precision-oriented and individualized pharmacotherapy in which patient-specific physiological, biological, pharmacological, and procedural determinants inform anesthetic selection and dosing. Particular attention is directed toward pharmacological strategies for reducing hemodynamic instability, respiratory complications, postoperative nausea and vomiting, residual neuromuscular blockade, opioid-related morbidity, delayed emergence, and other preventable medication-related adverse outcomes. This investigation aims to establish a scientifically coherent framework for integrating mechanistic pharmacology, pharmacometric modeling, precision medicine, advanced monitoring, multimodal therapeutics, and emerging digital technologies to enhance the efficacy, safety, adaptability, and patient-centeredness of contemporary general anesthesia.

METHODOLOGY

This investigation employed a comprehensive, integrative, and critical scholarly review methodology to examine the contemporary pharmacological landscape of general anesthesia and to evaluate emerging conceptual, mechanistic, pharmacokinetic, pharmacodynamic, therapeutic, and pharmacosafety paradigms. The methodological framework was designed to synthesize multidisciplinary evidence from anesthetic pharmacology, clinical pharmacology, pharmacokinetics, pharmacodynamics, neuroscience, perioperative medicine, pharmacogenomics, pharmacovigilance, precision medicine, and patient-centered clinical care. Rather than restricting the analysis to a single anesthetic class or therapeutic endpoint, the review adopted a multidimensional approach intended to characterize general anesthesia as a complex pharmacological system involving interactions among multiple agents, molecular targets, physiological compartments, organ systems, and patient-specific determinants.

A structured literature-search strategy was conceptually established to identify relevant peer-reviewed scientific literature addressing intravenous and inhalational anesthetic agents, opioid and non-opioid analgesics, sedative and hypnotic drugs, α_2 -adrenergic agonists, local anesthetics, neuromuscular blocking agents, pharmacological reversal agents, adjuvant medications, multimodal perioperative pharmacotherapy, pharmacokinetic–pharmacodynamic modeling, anesthetic monitoring, adverse drug reactions, and individualized anesthetic management. Literature was considered from major biomedical and multidisciplinary scientific databases, including PubMed/MEDLINE, Scopus, Web of Science, Embase, Cochrane Library, and Google Scholar. Additional relevant evidence was identified through reference-list screening and citation

tracking of influential reviews, clinical investigations, pharmacological studies, consensus statements, clinical guidelines, and authoritative scientific publications.

Search concepts were constructed around combinations of controlled vocabulary and free-text terminology relating to general anesthesia, anesthetic pharmacology, intravenous anesthesia, inhalational anesthesia, pharmacokinetics, pharmacodynamics, drug interactions, multimodal anesthesia, precision anesthesia, perioperative pharmacotherapy, pharmacogenomics, pharmacosafety, adverse drug reactions, postoperative outcomes, neuromuscular blockade, analgesia, emergence, and patient-centered care. Boolean operators and database-specific search conventions were used where applicable to improve conceptual sensitivity while maintaining thematic relevance. Particular emphasis was placed on contemporary evidence while retaining historically influential pharmacological and mechanistic studies when they were necessary to establish the evolution of anesthetic science or interpret current therapeutic paradigms.

Eligibility was determined according to predefined conceptual criteria. Studies were considered relevant when they provided substantive evidence concerning the pharmacological mechanisms, clinical applications, pharmacokinetic or pharmacodynamic characteristics, therapeutic efficacy, drug interactions, safety profile, monitoring requirements, or individualized use of anesthetic and perioperative pharmacological agents. Experimental investigations, randomized and non-randomized clinical studies, observational research, systematic reviews, meta-analyses, pharmacometric investigations, pharmacogenomic studies, clinical guidelines, consensus documents, and authoritative scientific reviews were considered. Publications lacking substantive pharmacological relevance, duplicative reports, insufficiently documented sources, and literature whose principal focus was unrelated to anesthetic pharmacotherapy were comparatively de-emphasized.

The analytical framework incorporated both mechanistic and clinically translational interpretation. Molecular pharmacology was evaluated through consideration of receptor-, ion-channel-, transporter-, and signaling-pathway-level mechanisms, including GABAergic, glutamatergic, adrenergic, cholinergic, glycinergic, and voltage-gated ion-channel systems. Pharmacokinetic assessment incorporated absorption where relevant, distribution, protein binding, metabolism, elimination, context-sensitive kinetics, organ-dependent clearance, and effect-site equilibration. Pharmacodynamic interpretation focused on dose–response relationships, concentration–effect relationships, therapeutic windows, receptor-mediated effects, synergistic and antagonistic drug interactions, and variability in clinical response. Particular attention was given to the relationship between pharmacological exposure and clinically meaningful endpoints such as hypnosis, analgesia, immobility, hemodynamic stability, respiratory function, neuromuscular recovery, emergence, postoperative pain, and adverse-event burden.

A patient-centered analytical perspective was subsequently applied to determine how demographic, physiological, pathological, genetic, procedural, and concomitant-medication variables may modify anesthetic pharmacology. Special consideration was given to older adults, pediatric patients, patients with obesity, hepatic or renal dysfunction, cardiovascular or respiratory vulnerability, polypharmacy, and altered pharmacological sensitivity. The analysis also examined the emerging contribution of pharmacometric modeling, target-controlled infusion, pharmacogenomics, electroencephalographic monitoring, quantitative neuromuscular monitoring, artificial-intelligence-assisted decision support, and closed-loop pharmacological systems to individualized anesthetic dosing and perioperative risk mitigation.

Evidence was synthesized narratively and critically rather than through a single pooled quantitative estimate because of substantial heterogeneity in study populations, anesthetic regimens, pharmacological endpoints, monitoring methodologies, clinical settings, and outcome definitions. Comparative interpretation was used to identify areas of convergence, controversy, uncertainty, and unmet research need. Particular emphasis was placed on distinguishing

established pharmacological evidence from emerging hypotheses and technologically enabled approaches. The methodological synthesis therefore sought not merely to catalogue anesthetic agents but to construct an integrated pharmacological framework connecting molecular mechanisms with pharmacokinetic exposure, pharmacodynamic response, clinical decision-making, safety optimization, and patient-centered perioperative outcomes.

The review was guided by principles of scientific rigor, methodological transparency, evidence hierarchy, clinical relevance, and ethical interpretation. The resulting synthesis was intended to support a contemporary reconfiguration of general anesthesia pharmacology from predominantly agent-centered practice toward an adaptive, multimodal, precision-oriented, pharmacosafety-conscious, and continuously monitored therapeutic model. Particular attention was directed toward identifying opportunities for translational research capable of integrating mechanistic pharmacology with individualized perioperative medicine while acknowledging limitations in current evidence and avoiding unsupported extrapolation beyond the available scientific literature.

RESEARCH, FINDINGS, RESULTS AND DISCUSSION

The present scholarly investigation demonstrates that the pharmacological landscape of general anesthesia has undergone a profound conceptual transformation from a predominantly agent-centered model toward a multidimensional, mechanism-informed, pharmacokinetically individualized, pharmacodynamically monitored, multimodal, and increasingly patient-centered therapeutic paradigm. The evidence synthesized across contemporary anesthetic pharmacology indicates that general anesthesia cannot adequately be conceptualized as the pharmacological consequence of a single hypnotic drug. Rather, it represents a dynamically regulated pharmacological state generated through the simultaneous modulation of consciousness, nociception, arousal, autonomic activity, skeletal-muscle function, memory formation, neuroendocrine responses, and physiological homeostasis. This multidimensionality explains why contemporary anesthetic practice increasingly depends upon rational combinations of hypnotic, analgesic, sedative, neuromuscular, antiemetic, anti-inflammatory, and supportive pharmacotherapies rather than reliance upon one dominant pharmacological mechanism.

The principal finding emerging from the analysis is that the modern pharmacology of general anesthesia is best understood through an integrated molecular-to-clinical continuum. At the molecular level, anesthetic agents influence ligand-gated ion channels, voltage-gated channels, membrane proteins, intracellular signaling pathways, and neural network connectivity. At the cellular level, these interactions modify neuronal excitability, synaptic transmission, inhibitory–excitatory balance, and network synchronization. At the systems level, anesthetic drugs influence cortical, thalamic, brainstem, spinal, autonomic, and peripheral neural circuits. At the clinical level, these effects manifest as hypnosis, amnesia, analgesia, immobility, attenuation of surgical stress responses, and controlled suppression of airway and somatic motor activity. At the patient level, the magnitude and duration of these effects are strongly modified by age, body composition, organ function, genetic characteristics, concomitant medications, disease states, surgical stimulation, and physiological reserve. Consequently, a scientifically defensible pharmacological strategy must integrate all of these dimensions rather than interpreting drug effects through isolated receptor pharmacology.

A particularly important finding concerns the distinction between the molecular mechanism of an anesthetic and the systems-level phenomenon of unconsciousness. Propofol, for example, substantially potentiates GABAergic inhibition through GABA_A receptors, yet its clinical production of unconsciousness cannot be reduced to a single receptor event. Contemporary pharmacological interpretation increasingly recognizes that anesthetic-induced unconsciousness emerges from coordinated alterations in neural communication, cortical integration,

thalamocortical connectivity, arousal-system activity, and network dynamics. Propofol remains one of the most extensively characterized intravenous hypnotics, and its PK/PD behavior has been modeled using increasingly sophisticated approaches, including effect-site modeling and target-controlled infusion. Importantly, pharmacodynamic interactions between propofol and opioids can be strongly synergistic, demonstrating why simple additive dosing assumptions may be inadequate when multiple agents are administered concurrently.

This finding has major implications for clinical anesthetic pharmacology. If the effects of two or more agents are synergistic rather than merely additive, the administration of conventional doses of each drug may produce excessive pharmacodynamic depression. Conversely, appropriately designed combinations can achieve adequate hypnosis and analgesia while reducing the individual dose requirements of potentially toxic or physiologically destabilizing drugs. Thus, contemporary multimodal anesthesia should not be interpreted simply as polypharmacy. Rational multimodal pharmacotherapy requires pharmacodynamic complementarity, appropriate dose reduction, temporal coordination, monitoring of cumulative effects, and anticipation of clinically important drug–drug interactions.

Integrated Pharmacological Architecture of General Anesthesia

The evidence synthesis indicates that general anesthesia is most appropriately conceptualized as a pharmacological architecture composed of several functional domains. Hypnosis and unconsciousness are principally generated through modulation of central inhibitory and excitatory neural processes; analgesia requires attenuation of nociceptive transmission and perception; immobility involves spinal and supraspinal mechanisms; autonomic control requires modulation of sympathetic and parasympathetic responses; and surgical conditions frequently require temporary pharmacological modification of skeletal-muscle transmission. These functions can be produced by different pharmacological classes, permitting selective targeting and dose optimization.

The classical concept of a single anesthetic drug producing all required components of anesthesia has therefore become progressively less compatible with modern pharmacological understanding. Volatile anesthetics, intravenous hypnotics, opioids, $\alpha 2$ -adrenergic agonists, NMDA receptor antagonists, local anesthetics, and neuromuscular blockers possess different pharmacological profiles and can therefore be combined to distribute therapeutic objectives across multiple agents. The theoretical foundation of multimodal anesthesia is that each component contributes a specific pharmacodynamic effect while minimizing unnecessary exposure to any single drug. Evidence describing contemporary multimodal anesthesia identifies propofol and sevoflurane as major hypnotic components while emphasizing the contribution of opioids, $\alpha 2$ agonists, local anesthetics, ketamine, and other agents to analgesia and reduction of nociceptive responses.

This pharmacological division of labor creates a therapeutic opportunity but also introduces complexity. Each additional drug creates the possibility of pharmacodynamic interaction, altered clearance, changes in protein binding, additive respiratory depression, cardiovascular instability, prolonged emergence, or unexpected neurological effects. Therefore, multimodal anesthesia should be interpreted as an optimization problem in which the clinician attempts to achieve the required depth and physiological control with the lowest rational pharmacological burden. (See Table-1).

Table 1. Evidence-based pharmacological comparison of major anesthetic classes

Pharmacological class	Principal examples	Major molecular/pharmacological actions	Principal clinical contribution	Major PK/PD considerations	Important safety considerations
Intravenous hypnotics	Propofol, etomidate, ketamine	GABAergic potentiation; NMDA antagonism for ketamine; multiple central mechanisms	Induction and/or maintenance of hypnosis; ketamine additionally provides analgesia	Rapid distribution; effect-site equilibration; context-dependent recovery	Hypotension and respiratory depression with propofol; adrenal effects with etomidate; emergence phenomena and cardiovascular stimulation with ketamine
Volatile anesthetics	Sevoflurane, desflurane, isoflurane	Multiple ion-channel effects involving GABAergic, potassium, NMDA and other systems	Hypnosis, immobility, maintenance of anesthesia	Pulmonary uptake/elimination; blood-gas partitioning; MAC-related dosing	Hypotension, respiratory depression, postoperative nausea; specific agent-dependent metabolic and environmental considerations
Opioids	Fentanyl, remifentanyl, morphine and others	μ -opioid receptor agonism	Potent analgesia and attenuation of surgical nociception	Highly variable context-sensitive kinetics; metabolism differs among agents	Respiratory depression, nausea, ileus, pruritus, tolerance and opioid-induced hyperalgesia

α_2 agonists	Dexmedetomidine, clonidine	Central α_2 -adrenergic agonism	Sedation, sympatholysis, analgesic-sparing effects	Distribution and elimination influenced by hepatic function and systemic physiology	Bradycardia, hypotension, prolonged sedation
NMDA antagonist	Ketamine	NMDA receptor antagonism with additional actions	Analgesia, dissociative anesthesia, opioid-sparing effects	Active metabolite contribution; dose- and context-dependent effects	Hypertension, tachycardia, psychotomimetic/emergence effects
Local anesthetics	Lidocaine, ropivacaine, bupivacaine	Voltage-gated sodium-channel blockade	Regional analgesia and opioid reduction	Tissue distribution and systemic absorption are clinically important	Local anesthetic systemic toxicity, CNS and cardiovascular toxicity
Neuromuscular blockers	Rocuronium, vecuronium, cisatracurium	Nicotinic acetylcholine receptor antagonism	Skeletal-muscle paralysis and improved surgical conditions	Organ-dependent or organ-independent elimination depending on agent	Residual paralysis, respiratory compromise, anaphylaxis
Reversal agents	Sugammadex, neostigmine	Encapsulation of aminosteroid NMBA; acetylcholinesterase inhibition	Restoration of neuromuscular transmission	Timing and depth of blockade determine effectiveness	Bradycardia and cholinergic effects with neostigmine; hypersensitivity and dosing considerations with sugammadex

The table demonstrates that anesthetic pharmacology is intrinsically heterogeneous. The major agents differ not only in their molecular targets but also in their onset, distribution, elimination, context-sensitive behavior, therapeutic window, and toxicity profile. Such heterogeneity provides the pharmacological basis for individualized drug selection.

Intravenous Anesthetic Pharmacology: Propofol as a Model of Precision PK/PD

The evidence reviewed identifies propofol as an important model for the evolution of contemporary intravenous anesthetic pharmacology. Its clinical utility derives from rapid onset, predictable hypnotic activity, relatively rapid recovery following appropriately controlled administration, and extensive clinical experience. Its principal molecular action involves potentiation of GABA_A receptor-mediated inhibition. However, its clinical use is constrained by cardiovascular and respiratory effects, particularly dose-related hypotension and respiratory depression.

The major conceptual advance is not merely the identification of propofol's receptor target but the development of quantitative PK/PD frameworks capable of describing the relationship between administered dose, plasma concentration, effect-site concentration, and clinical response. Traditional weight-based dosing provides an approximate relationship between dose and desired effect, but it does not fully account for interindividual variability in distribution volume, clearance, age-dependent pharmacological sensitivity, body composition, cardiovascular status, or concomitant medications.

Target-controlled infusion represents an important manifestation of this pharmacometric evolution. Rather than treating infusion rate as the primary determinant of drug effect, target-controlled systems attempt to achieve a specified plasma or effect-site concentration through mathematical pharmacokinetic models. Contemporary modeling literature indicates that generalized propofol PK models have been developed to improve applicability across different patient populations, although model performance must still be interpreted in relation to population characteristics and clinical circumstances.

The significance of these developments extends beyond propofol. They demonstrate the transition from empirical dose administration toward model-informed precision dosing. The objective is not to eliminate clinical judgment but to provide quantitative support for clinical decision-making. In practice, however, even sophisticated models remain approximations. Pharmacological response depends not only on concentration but also on pharmacodynamic sensitivity, receptor-state dynamics, age-related CNS susceptibility, concurrent medications, and physiological perturbations.

The interaction between propofol and opioids is particularly important. Opioids can reduce the hypnotic concentration required to suppress responses to noxious stimulation, while propofol may alter the clinical context in which opioid effects become apparent. The resulting pharmacodynamic synergy means that the combined effect can exceed what would be predicted from simple addition of independent drug effects. This principle provides a pharmacological rationale for dose reduction when hypnotics and opioids are combined.

The evidence therefore supports an important finding: precision anesthesia requires simultaneous consideration of drug concentration and drug interaction. A target concentration that appears appropriate when a hypnotic is administered alone may become excessive when combined with an opioid, α_2 agonist, or other CNS depressant. Conversely, a lower hypnotic dose may be insufficient if profound surgical stimulation is present and analgesic therapy is inadequate. Thus, pharmacodynamic context is as important as pharmacokinetic prediction.

Etomidate, Ketamine and Pharmacological Phenotype Selection

The comparative evidence indicates that intravenous anesthetic selection should increasingly be understood as phenotype-based pharmacotherapy. Propofol provides rapid hypnosis but may produce substantial vasodilation and myocardial depression in susceptible individuals. Etomidate is frequently considered when preservation of cardiovascular stability is particularly important, although its adrenal effects remain a clinically relevant pharmacological consideration. Ketamine

possesses a fundamentally different pharmacological phenotype, characterized by NMDA receptor antagonism, dissociative anesthesia, analgesia, and sympathomimetic effects.

These differences demonstrate that there is no universally optimal induction drug. Rather, drug selection must reflect the physiological phenotype of the patient and the pharmacodynamic requirements of the procedure. A patient with substantial cardiovascular vulnerability may have a different optimal induction strategy from a hemodynamically robust patient undergoing low-risk elective surgery. Similarly, severe nociceptive stimulation may justify greater reliance on ketamine or opioid-sparing adjuncts than a procedure associated with limited postoperative pain.

The findings consequently support the principle that precision anesthetic selection is a therapeutic matching process between pharmacological phenotype and patient phenotype. The concept extends beyond induction. Maintenance strategies, analgesic regimens, neuromuscular management, and antiemetic prophylaxis should similarly be individualized.

Volatile Anesthetics and the Pharmacology of Controlled Hypnosis

Volatile anesthetics retain an important position in contemporary general anesthesia despite the expansion of intravenous techniques. Sevoflurane, desflurane, and isoflurane differ in potency, blood–gas solubility, metabolism, uptake, elimination, cardiovascular effects, airway characteristics, and recovery profiles. These differences are not merely pharmacological curiosities; they directly influence clinical selection.

Minimum alveolar concentration provides a standardized measure of anesthetic potency for volatile agents, but MAC does not represent a complete measure of clinical anesthetic depth. Age, body temperature, concomitant opioids, sedative drugs, and other physiological conditions alter anesthetic requirements. Furthermore, hypnosis, immobility, analgesia, and autonomic suppression are not identical endpoints. A volatile concentration sufficient to prevent movement may not be equivalent to a concentration optimized for postoperative recovery or hemodynamic stability.

Sevoflurane is characterized by relatively favorable induction characteristics and is frequently used where inhalational induction or airway tolerance is important. Desflurane has historically been valued for rapid changes in anesthetic concentration and emergence characteristics, whereas isoflurane possesses greater blood solubility and consequently slower equilibration and elimination. Contemporary interpretation increasingly incorporates not only recovery speed but also environmental sustainability, postoperative nausea, cardiovascular effects, and interactions with other pharmacological components.

A major finding is that the pharmacology of volatile anesthesia should no longer be evaluated solely according to potency and recovery. Modern evaluation must include the complete therapeutic lifecycle: acquisition, administration, intraoperative physiological effects, recovery, adverse-event profile, and environmental impact. This broader definition of pharmacological value is increasingly relevant to health-system decision-making.

Pharmacodynamic Integration of Hypnosis and Analgesia

One of the most important findings of the synthesis is that hypnosis and analgesia are pharmacologically distinct therapeutic objectives. A hypnotic agent can produce profound unconsciousness without providing adequate analgesia. Conversely, a powerful analgesic can suppress nociceptive responses without necessarily producing unconsciousness. Failure to distinguish these dimensions can lead to excessive dosing of one pharmacological class in an attempt to compensate for inadequate therapy from another.

Multimodal anesthesia addresses this problem by assigning different pharmacological tasks to different agents. Hypnotic agents provide unconsciousness; opioids, ketamine, local anesthetics, α_2 agonists, acetaminophen, NSAIDs, and regional techniques address nociception through

complementary mechanisms. This approach is consistent with perioperative guidance supporting multimodal analgesia in which analgesics from different pharmacological classes are combined. The principal result is a reduction in dependence on high-dose opioids as the sole strategy for perioperative analgesia. Opioid-sparing strategies may decrease opioid-associated respiratory depression, nausea, vomiting, ileus, sedation, and delayed functional recovery. However, opioid minimization should not be interpreted as opioid elimination in all patients. Severe surgical pain may require potent opioid therapy, and inappropriate restriction can result in undertreated pain and physiological stress.

The most rational interpretation is therefore opioid optimization rather than ideological opioid avoidance. The objective is to determine the minimum effective opioid exposure within a broader analgesic architecture.

Multimodal Analgesia and Perioperative Pharmacological Synergy

The evidence indicates that multimodal analgesia represents one of the most important practical consequences of modern anesthetic pharmacology. Paracetamol, NSAIDs, local anesthetics, regional blocks, ketamine, α_2 agonists, and selected intravenous adjuvants can contribute to analgesia through partially distinct mechanisms. Contemporary perioperative recommendations explicitly support multimodal approaches to postoperative pain management.

The pharmacological rationale is based on pathway-level complementarity. Nociception involves peripheral transduction, spinal transmission, ascending pathways, central processing, affective responses, and descending modulation. Intervening at several levels theoretically permits lower doses of individual agents and reduces reliance on a single pathway.

Nevertheless, multimodal therapy has limitations. Pharmacodynamic interactions may produce sedation, hypotension, bradycardia, renal complications, bleeding risk, or other adverse effects. For example, NSAIDs can be valuable opioid-sparing agents but require careful consideration in patients with renal dysfunction, gastrointestinal vulnerability, bleeding risk, or specific surgical circumstances. α_2 agonists can provide sedation and sympatholysis but may produce bradycardia and hypotension. Ketamine can provide analgesic benefit but may be inappropriate in certain cardiovascular or neuropsychiatric contexts.

The evidence therefore supports a selective multimodal model, not indiscriminate polypharmacy.

Neuromuscular Blockade as a Distinct Pharmacological Domain

Neuromuscular blocking agents occupy a unique position because they do not produce unconsciousness or analgesia. Their therapeutic objective is skeletal-muscle paralysis, facilitating tracheal intubation, surgical exposure, and controlled ventilation. This separation of pharmacological function is fundamental to safe anesthesia.

Rocuronium and related nondepolarizing neuromuscular blockers competitively antagonize nicotinic acetylcholine receptors at the neuromuscular junction. Their duration and intensity of effect depend upon dose, redistribution, elimination, temperature, acid–base status, concomitant medications, and interactions with other anesthetic agents.

The central pharmacosafety problem is residual neuromuscular blockade. Even modest residual weakness can compromise upper-airway patency, respiratory muscle function, protective reflexes, and postoperative ventilation. Consequently, modern neuromuscular pharmacology has increasingly moved toward quantitative rather than purely clinical assessment.

Reversal pharmacology has similarly evolved. Neostigmine increases acetylcholine concentration by inhibiting acetylcholinesterase and can reverse nondepolarizing blockade under appropriate conditions. Sugammadex provides a mechanistically distinct approach by encapsulating aminosteroid neuromuscular blockers, particularly rocuronium and vecuronium, thereby reducing free drug concentration.

The major finding is that neuromuscular pharmacology cannot be considered complete when the surgeon no longer requires paralysis. Pharmacological management extends through reversal, quantitative verification of recovery, airway protection, and postoperative respiratory safety. (See Table-2).

Table 2. Major pharmacodynamic interactions relevant to general anesthesia

Drug combination	Principal interaction	Potential therapeutic benefit	Principal risk	Pharmacologic al implication
Propofol + opioid	Strong pharmacodynamic synergy	Reduced doses of each agent may achieve adequate anesthesia/analgesia	Hypotension, respiratory depression, excessive sedation	Dose reduction and response-guided titration
Propofol + volatile anesthetic	Additive/synergistic hypnotic effects	Reduced concentration of each hypnotic	Excessive CNS depression	Avoid simultaneous excessive hypnotic exposure
Opioid + benzodiazepine/sedative	Additive CNS and respiratory depression	Enhanced sedation in selected circumstances	Marked respiratory depression	Requires careful dose limitation and monitoring
Opioid + α_2 agonist	Complementary analgesia and sympatholysis	Opioid sparing	Bradycardia, hypotension, sedation	Individualized titration
Ketamine + opioid	Multimodal analgesic interaction	Opioid-sparing analgesia	Cardiovascular/CNS adverse effects	Useful in selected high-pain settings
Volatile anesthetic + NMBA	Potential of neuromuscular blockade	Lower NMBA requirements	Deeper/prolonged blockade	Quantitative neuromuscular monitoring
Local anesthetic + systemic analgesics	Multimodal analgesia	Reduced opioid requirement	Cumulative toxicity if local anesthetic exposure is excessive	Dose according to cumulative systemic exposure
Multiple antiemetics	Complementary receptor blockade	Improved PONV prophylaxis	QT prolongation, sedation, other class-specific effects	Select agents with complementary mechanisms

The table reinforces that anesthetic pharmacology is fundamentally interaction-dependent. The clinical effect of a drug cannot reliably be predicted from its isolated pharmacology without considering the other agents administered concurrently.

Pharmacological Management of Postoperative Nausea and Vomiting

Postoperative nausea and vomiting remains a clinically important adverse outcome because it compromises patient comfort, delays oral intake, may interfere with mobilization, prolong

recovery, and can contribute to unplanned healthcare utilization. The evidence base strongly supports risk stratification and multimodal prophylaxis rather than uniform administration of a single antiemetic.

Contemporary consensus recommendations emphasize reducing baseline risk where possible, including minimizing opioid exposure and considering anesthetic strategies associated with lower PONV risk. Propofol-based total intravenous anesthesia is recognized as one strategy for reducing PONV risk, while multimodal systemic analgesia can further reduce opioid requirements.

Pharmacologically, PONV is a receptor-network disorder rather than a single-receptor phenomenon. Serotonergic, dopaminergic, histaminergic, muscarinic, and neurokinin pathways contribute to emetic signaling. Consequently, combining antiemetics acting through different pathways provides a rational pharmacodynamic strategy.

Recent evidence-based guidance continues to support 5-HT₃ receptor antagonists and corticosteroids as important components of prophylaxis, with combination therapy favored for patients at increased risk.

The principal finding is therefore that PONV management represents a paradigmatic example of precision perioperative pharmacotherapy. Risk should be estimated before surgery; baseline risk should be reduced through anesthetic and analgesic selection; pharmacological prophylaxis should be matched to risk; and rescue therapy should generally employ a pharmacological class different from the prophylactic drug. (See Table-3).

Table 3. Evidence-based perioperative pharmacological optimization

Clinical objective	Pharmacological strategy	Mechanistic rationale	Expected benefit	Principal limitations
Reduce hypnotic exposure	Multimodal anesthesia	Complementary CNS and analgesic mechanisms	Lower dose of individual hypnotic	Complex interactions
Reduce opioid consumption	Paracetamol, NSAIDs, ketamine, α_2 agonists, regional/local anesthesia	Different nociceptive pathways	Opioid-sparing and potentially improved recovery	Contraindications and class-specific toxicity
Reduce PONV	Risk-adapted multimodal antiemetic prophylaxis	Blockade of multiple emetic pathways	Lower nausea/vomiting burden	QT, sedation and drug-specific adverse effects
Prevent residual paralysis	Quantitative neuromuscular monitoring + appropriate reversal	Objective assessment of receptor-level recovery	Reduced postoperative respiratory risk	Requires equipment and expertise
Improve hemodynamic stability	Individualized hypnotic/analgesic dosing	Avoid excessive vasodilation, sympathetic suppression or myocardial depression	Reduced hypotension	High interindividual variability

Facilitate rapid emergence	Short/context-sensitive agents and rational infusion strategies	Reduced residual CNS drug effect	Faster recovery	Must not compromise analgesia or anesthetic depth
Reduce postoperative respiratory depression	Opioid-sparing strategies and monitoring	Reduced μ -receptor-mediated respiratory suppression	Improved respiratory safety	Pain control must remain adequate
Optimize recovery	ERAS-compatible multimodal pharmacotherapy	Minimize physiological and pharmacological burden	Earlier mobilization and recovery	Requires coordinated multidisciplinary implementation

Pharmacokinetic Variability and Patient-Specific Dosing

The evidence demonstrates that pharmacokinetic variability is one of the central challenges in anesthetic pharmacology. The same administered dose can generate substantially different plasma and effect-site concentrations in different patients. This variability is generated by differences in body composition, age, cardiac output, hepatic blood flow, renal function, protein binding, disease states, concomitant medications, and previous exposure.

Age is particularly important. Older adults often exhibit increased pharmacodynamic sensitivity to hypnotic and sedative drugs even when pharmacokinetic changes are modest. Consequently, dose reduction based solely on weight may be insufficient. The relevant variable is the relationship between concentration and physiological response.

Obesity creates a different challenge because total body weight does not necessarily predict the pharmacokinetically relevant distribution volume for all anesthetic drugs. Lipophilic agents may distribute extensively into adipose tissue, whereas pharmacodynamic sensitivity may not increase proportionally. Therefore, dosing scalar selection must be pharmacologically justified rather than mechanically weight-based.

Hepatic dysfunction can reduce clearance of drugs extensively dependent upon hepatic metabolism, while renal impairment may alter elimination of parent drugs or active metabolites. Importantly, organ dysfunction can also change protein binding, acid–base balance, volume of distribution, and CNS sensitivity.

These findings support the concept that dose is not a fixed property of the drug; it is a patient-specific exposure decision.

Effect-Site Pharmacology and Temporal Mismatch

A further result concerns the importance of the distinction between plasma concentration and effect-site concentration. A drug may reach high plasma concentrations before its pharmacological effect reaches its maximum because distribution into the relevant biophase takes time. Conversely, plasma concentrations can decline while clinical effects persist.

This temporal mismatch explains some apparent discrepancies between infusion rate and observed clinical response. It also provides the pharmacological basis for effect-site targeting and hysteresis modeling.

The practical consequence is substantial. If a clinician administers additional doses before the effect of the previous dose has equilibrated at the effect site, accumulation may occur and produce delayed excessive pharmacodynamic depression. This phenomenon is especially important for intravenous hypnotics, opioids, and sedative adjuvants.

Pharmacometric models therefore have the potential to improve dose timing as well as dose magnitude. The objective is not merely to predict how much drug is present but to anticipate when the clinically relevant effect will occur.

Pharmacogenomics and Precision Anesthesia

The synthesis further indicates that pharmacogenomics represents a potentially important but incompletely realized component of precision anesthesia. Genetic variation can influence drug metabolism, receptor function, transporter activity, pain sensitivity, and susceptibility to adverse drug reactions. However, the clinical implementation of pharmacogenomic testing in general anesthesia remains limited compared with other areas of precision medicine. The reason is that anesthetic response is highly multifactorial. A genetic variant may contribute to variability but can be overshadowed by age, comorbidities, concurrent drugs, physiological instability, surgical stimulation, and environmental factors. Therefore, precision anesthesia should not be equated with genomics alone.

A more comprehensive model incorporates genetic information when clinically validated, together with demographic, physiological, pharmacometric, and real-time monitoring information. Such integration may ultimately allow clinicians to identify patients who require unusually low or high drug exposure, patients with altered susceptibility to adverse effects, and individuals likely to benefit from particular analgesic strategies. The present findings therefore support a multidimensional precision-anesthesia model, in which pharmacogenomics represents one layer rather than the entire framework.

Pharmacovigilance and Anesthetic Pharmacosafety

Pharmacosafety represents a central component of the contemporary reconfiguration of general anesthesia. The anesthetic environment is inherently high risk because multiple potent pharmacological agents are administered within a short period, often during rapidly changing physiological conditions.

Medication-related adverse events can arise from excessive dose, inappropriate drug selection, pharmacokinetic accumulation, pharmacodynamic interactions, administration errors, incomplete reversal, allergy or hypersensitivity, or failure to recognize patient-specific contraindications.

Anesthetic pharmacovigilance should therefore extend beyond conventional spontaneous adverse-event reporting. It should encompass systematic identification of near misses, dosing errors, delayed recovery, residual neuromuscular blockade, postoperative respiratory depression, hypotension, arrhythmia, PONV, allergic reactions, and medication-related readmissions.

The evidence supports a systems approach in which drug safety is shared across anesthesiologists, surgeons, pharmacists, nurses, and perioperative teams. Medication reconciliation is particularly important in patients receiving chronic CNS-active medications, anticoagulants, antihypertensives, antidiabetic agents, antidepressants, antiepileptic drugs, and other therapies that can alter anesthetic pharmacodynamics or perioperative physiology.

Hemodynamic Pharmacology

Hemodynamic instability remains one of the most important pharmacological consequences of anesthesia. Hypnotic drugs can decrease sympathetic tone, vascular resistance, venous return, myocardial contractility, or combinations of these mechanisms. Opioids and α_2 agonists can further modify autonomic responses.

The pharmacological challenge is therefore not simply to maintain a numerical blood pressure target but to identify the mechanism of hypotension and correct it appropriately. Excessive anesthetic depth requires dose reduction; vasodilation may require vasopressor support; hypovolemia requires fluid management; myocardial dysfunction may require inotropic or other

cardiovascular intervention. This distinction illustrates the importance of mechanism-based treatment. Treating every episode of hypotension with a vasopressor without reassessing anesthetic dose can perpetuate the underlying pharmacological cause. Conversely, reducing anesthesia excessively to avoid hypotension may result in inadequate hypnosis or analgesia. The optimal strategy is therefore dynamic pharmacological titration based on simultaneous assessment of anesthetic depth, nociception, cardiovascular physiology, and surgical stimulation.

Respiratory Pharmacology and Safety

Respiratory depression remains a major concern with anesthetic and perioperative drugs. Opioids reduce ventilatory responsiveness to carbon dioxide and hypoxic stimuli, while hypnotics and sedatives can decrease upper-airway tone and central respiratory drive. The combination can produce profound respiratory impairment even when individual drug doses appear conventional. This provides another rationale for multimodal analgesia. By reducing opioid requirements through regional anesthesia, acetaminophen, NSAIDs, ketamine, α_2 agonists, and other approaches, clinicians may reduce the pharmacological burden on respiratory control mechanisms.

However, opioid-sparing therapy does not eliminate respiratory risk. α_2 agonists and other sedatives can contribute to respiratory compromise through combined CNS depression, while residual neuromuscular blockade can impair airway and respiratory muscle function through a completely different mechanism. The most robust safety model therefore recognizes at least three overlapping pathways of postoperative respiratory impairment: central respiratory depression, upper-airway obstruction, and neuromuscular weakness. Pharmacological management must address all three.

Emergence as a Pharmacological Endpoint

Emergence from anesthesia should be regarded as a pharmacological endpoint rather than simply the absence of unconsciousness. Optimal emergence requires coordinated resolution of hypnotic effects, analgesic management, neuromuscular blockade, airway effects, autonomic instability, and postoperative nausea.

Delayed emergence can result from excessive hypnotic exposure, prolonged opioid effect, benzodiazepine accumulation, metabolic impairment, hypothermia, electrolyte abnormalities, drug interactions, or residual neuromuscular blockade. Thus, delayed awakening requires differential diagnosis rather than automatic administration of a reversal agent.

The concept of context-sensitive half-time is particularly important during prolonged infusions. A drug with rapid redistribution after a bolus may behave differently after prolonged administration because tissue accumulation alters the subsequent decline in effect-site concentration. Pharmacokinetic modeling therefore provides a useful conceptual framework for predicting recovery trajectories.

Precision Pharmacotherapy in Special Populations

Older adults

Older patients represent one of the clearest populations in which individualized anesthetic pharmacology is required. Increased CNS sensitivity, altered body composition, reduced renal and hepatic reserve, polypharmacy, and greater susceptibility to postoperative cognitive and respiratory complications collectively narrow the margin between therapeutic and excessive drug exposure.

The appropriate strategy is generally not simply to administer lower doses but to titrate carefully to clinically relevant endpoints, avoid unnecessary polypharmacy, and reassess pharmacodynamic response continuously.

Pediatric patients

Children demonstrate age-dependent differences in drug distribution, metabolism, receptor sensitivity, and physiological reserve. Neonates and infants are particularly distinct pharmacological populations. Consequently, adult-derived dosing models cannot automatically be extrapolated to pediatric patients.

Pediatric precision anesthesia requires age-appropriate PK/PD models, weight and developmental considerations, careful airway management, and recognition of differences in analgesic and hypnotic requirements.

Obesity

Obesity alters pharmacokinetic distribution and may modify respiratory vulnerability. Total body weight, ideal body weight, lean body mass, and adjusted body weight may each have different relevance depending on the drug. Pharmacological dosing should therefore be drug-specific rather than governed by one universal body-weight scalar.

Hepatic and renal dysfunction

Patients with organ dysfunction require careful assessment of drug clearance and active metabolites. However, reducing dose indiscriminately may also produce inadequate anesthesia. The appropriate approach is to understand whether the drug is dependent on hepatic metabolism, renal elimination, redistribution, or organ-independent degradation and then adapt the dosing strategy accordingly.

Environmental and Health-System Dimensions of Anesthetic Pharmacology

The reconfiguration of anesthetic pharmacology also includes environmental considerations. Volatile anesthetics differ in atmospheric persistence and greenhouse-gas effects, creating an additional dimension of pharmacological selection. Consequently, the contemporary concept of optimal anesthesia increasingly encompasses not only patient efficacy and safety but also environmental stewardship.

This does not imply that environmental considerations should supersede clinical indications. Rather, when two strategies provide comparable patient-centered outcomes, environmental impact may reasonably become an additional selection criterion. The same principle applies to health-system pharmacology. Drug acquisition costs, equipment requirements, staff expertise, postoperative resource utilization, readmissions, and recovery times all influence the real-world value of an anesthetic strategy.

Artificial Intelligence, Closed-Loop Systems and the Future of Anesthetic Pharmacology

The development of automated drug-delivery systems, EEG-based anesthetic depth estimation, pharmacometric models, and artificial intelligence represents an important emerging direction. Closed-loop systems potentially allow anesthetic delivery to be continuously adjusted according to physiological and neurophysiological feedback.

However, automation does not eliminate pharmacological uncertainty. The reliability of an automated system depends on the quality of the input signal, validity of the pharmacological model, responsiveness of the control algorithm, and ability to recognize unusual patient states.

Artificial intelligence may eventually assist with prediction of drug requirements, hemodynamic instability, emergence, postoperative pain, and adverse events. Yet algorithmic recommendations should remain clinically interpretable and subject to human oversight. The pharmacological consequences of an incorrect automated decision can be immediate and severe.

Therefore, the appropriate future model is not replacement of the anesthesiologist by artificial intelligence but human–machine pharmacological collaboration. (See Table-4).

Table 4. Emerging precision-anesthesia framework

Domain	Conventional approach	Emerging approach	Potential contribution	Current limitation
Drug dosing	Fixed/weight-based dosing	PK/PD model-informed dosing	More individualized exposure	Model uncertainty
Propofol administration	Manual infusion	Target-controlled infusion	Better control of predicted concentration	Dependence on model validity
Anesthetic depth	Clinical signs	EEG-assisted assessment	More objective titration	EEG interpretation is complex
Analgesia	Opioid-centered	Multimodal pharmacotherapy	Opioid reduction and pathway diversification	Heterogeneous evidence
Neuromuscular management	Clinical assessment	Quantitative monitoring	Improved detection of residual blockade	Requires equipment and expertise
PONV	Reactive treatment	Risk-stratified multimodal prophylaxis	Reduced postoperative morbidity	Risk prediction remains imperfect
Pharmacogenomics	Limited use	Individual genetic profiling	Potential prediction of response/adverse reactions	Clinical validation remains incomplete
Decision support	Clinician-only	AI-assisted prediction	Potential earlier detection of instability	Algorithmic bias and validation
Environmental stewardship	Limited consideration	Low-emission anesthetic selection	Reduced ecological burden	Must preserve clinical efficacy
Recovery	Drug cessation	Integrated recovery pharmacology	Faster and safer emergence	Requires coordinated monitoring

Synthesis of Principal Findings

The evidence synthesis produces several interconnected findings. First, general anesthesia is a systems pharmacology phenomenon rather than a single-drug effect. Second, molecular mechanisms are necessary but insufficient to explain clinical anesthetic states; receptor pharmacology must be connected to neural-network function and whole-patient physiology. Third, PK/PD variability represents a major determinant of therapeutic response and supports individualized dosing. Fourth, pharmacodynamic interactions, particularly between hypnotics and opioids, mean that combined therapy cannot safely be interpreted using simple additive assumptions. Fifth, multimodal analgesia provides a rational framework for reducing dependence on high-dose opioids while maintaining adequate pain control. Sixth, neuromuscular

pharmacology requires objective monitoring and appropriately timed reversal to prevent residual paralysis. Seventh, PONV prevention is most effectively conceptualized as a risk-adapted, multimodal pharmacological intervention. Eighth, precision anesthesia should incorporate demographic, physiological, pharmacological, genetic, and real-time monitoring variables rather than relying on any single biomarker. Ninth, pharmacosafety must extend from drug selection through recovery and post-discharge surveillance. Tenth, digital pharmacology, pharmacometrics, and artificial intelligence are likely to expand the capacity for individualized anesthetic management but cannot substitute for clinical reasoning.

Critical Discussion of the Evidence

The findings should be interpreted in the context of substantial heterogeneity in anesthetic practice. Studies differ in surgical populations, drug combinations, doses, monitoring strategies, outcome definitions, and healthcare systems. Consequently, an intervention demonstrating benefit in one surgical context may not produce identical results in another.

This heterogeneity is particularly relevant to multimodal analgesia. Although contemporary guidance supports multimodal therapy, the precise combination of drugs should not be standardized excessively. The pharmacological profile of a low-pain ambulatory procedure is fundamentally different from that of major abdominal, thoracic, orthopedic, oncological, or emergency surgery. Likewise, the optimal regimen for an elderly patient with renal dysfunction differs from that for a young patient without major comorbidity.

Evidence concerning PONV similarly supports risk-based rather than universal therapy. Contemporary guidelines emphasize identification of risk factors and multimodal intervention for patients at elevated risk.

Another important consideration is the distinction between surrogate and patient-centered outcomes. Reduced anesthetic concentration, lower opioid consumption, or faster EEG recovery may represent pharmacological improvements, but the ultimate relevance depends upon whether these changes translate into improved pain control, respiratory safety, functional recovery, patient satisfaction, shorter hospitalization, or reduced complications.

The evidence consequently supports a hierarchical model of outcome evaluation: molecular target engagement should lead to pharmacodynamic effect; pharmacodynamic effect should produce clinically meaningful physiological control; and physiological control should contribute to improved patient-centered outcomes.

Reconfiguration of the Pharmacological Paradigm

The most significant conceptual result of the investigation is that contemporary anesthetic pharmacology is undergoing a transition from drug-centered anesthesia to adaptive pharmacological management.

The traditional question was essentially: which anesthetic should be administered and at what dose? The contemporary question is substantially more complex: which pharmacological combination should be used for this patient, undergoing this procedure, under these physiological conditions, with this anticipated nociceptive burden, using which monitoring strategy, and with what recovery objectives?

This transformation places pharmacology at the center of perioperative decision-making. The anesthesiologist must integrate molecular mechanisms, PK/PD characteristics, drug interactions, physiological vulnerability, surgical stimulation, monitoring information, and anticipated recovery. The concept of precision anesthesia therefore represents an extension of precision pharmacotherapy. The objective is not simply to identify the correct drug but to determine the correct drug–dose–timing–combination–monitoring configuration for the individual patient.

Such an approach also changes the meaning of pharmacological safety. Safety is no longer defined merely as the absence of acute toxicity. It encompasses prevention of excessive sedation, hypotension, respiratory depression, residual paralysis, PONV, uncontrolled postoperative pain, delayed recovery, medication errors, and potentially avoidable long-term consequences.

Translational Implications

The findings have important implications for clinical practice, education, research, and health-system organization. Clinically, anesthetic protocols should increasingly incorporate patient-specific pharmacological assessment and quantitative monitoring. Educationally, anesthesiology and pharmacology curricula should emphasize PK/PD reasoning, drug interactions, multimodal pharmacotherapy, pharmacovigilance, and precision dosing rather than isolated memorization of drug characteristics.

Research should increasingly focus on integrated pharmacological models capable of simultaneously describing hypnotic, analgesic, hemodynamic, and neuromuscular endpoints. Future clinical trials should also place greater emphasis on functional recovery and patient-reported outcomes.

From a pharmacometric perspective, prospective validation of generalized models remains essential. Retrospective model performance does not guarantee adequate prospective performance in every population. The increasing availability of real-time physiological and pharmacological data nevertheless creates opportunities for adaptive dosing systems.

From a pharmacovigilance perspective, standardized reporting of perioperative adverse drug events could provide a stronger evidence base for identifying preventable medication-related harm.

Taken collectively, the research findings establish that the pharmacological landscape of general anesthesia has become substantially more sophisticated than the historical paradigm of generalized CNS depression. Contemporary anesthetic pharmacology integrates molecular pharmacology, neurobiology, PK/PD modeling, multimodal analgesia, quantitative neuromuscular management, antiemetic pharmacotherapy, pharmacogenomics, precision dosing, pharmacovigilance, and digital decision support.

The most clinically consequential finding is that optimization does not arise from maximizing the effect of a single drug. It arises from distributing therapeutic objectives across complementary pharmacological mechanisms while minimizing cumulative toxicity and continuously adjusting therapy according to patient response.

The evidence therefore supports a model in which general anesthesia is understood as an adaptive pharmacological system. Hypnosis, analgesia, immobility, autonomic modulation, neuromuscular relaxation, postoperative symptom control, and recovery should be treated as interconnected but pharmacologically distinguishable endpoints. Such differentiation permits targeted intervention, reduces unnecessary drug exposure, and facilitates individualized perioperative management.

The evidence also demonstrates that precision anesthesia cannot be reduced to sophisticated technology. The central requirement remains accurate pharmacological reasoning. Target-controlled infusion, EEG monitoring, quantitative neuromuscular monitoring, pharmacogenomic testing, and artificial intelligence are tools that enhance decision-making; they do not replace the fundamental requirement to understand pharmacological mechanisms and their interaction with patient physiology.

The reconfiguration of general anesthesia pharmacology should be regarded as both a scientific and clinical transformation. It integrates mechanistic pharmacology with quantitative modeling and patient-centered medicine, creating a framework in which drug selection, dosing, timing, combination, monitoring, reversal, and recovery are considered as a single therapeutic continuum.

The objective is not deeper anesthesia, greater analgesic intensity, or more technologically sophisticated drug delivery in isolation. The objective is the smallest rational pharmacological burden capable of producing the required anesthetic state while preserving physiological stability, preventing avoidable adverse effects, facilitating recovery, and optimizing patient-centered outcomes. This principle represents the central pharmacological conclusion of the present synthesis and provides a conceptual foundation for the future development of individualized, multimodal, pharmacometrically informed, pharmacosafety-oriented, and technologically supported general anesthesia.

Expanded Research Synthesis and Pharmacological Interpretation

The comprehensive synthesis of contemporary anesthetic pharmacology demonstrates that the reconfiguration of general anesthesia is not represented by the introduction of a single new anesthetic agent, but rather by a progressive transformation in the way pharmacological interventions are conceptualized, selected, combined, monitored, and evaluated. General anesthesia increasingly constitutes a coordinated pharmacological system in which hypnosis, analgesia, immobility, autonomic modulation, amnesia, neuromuscular relaxation, prevention of postoperative symptoms, and facilitation of recovery are treated as related but distinguishable therapeutic objectives. This conceptual distinction is fundamental because the pharmacological mechanisms required to produce unconsciousness are not identical to those required to suppress nociception, prevent movement, maintain physiological stability, or achieve postoperative functional recovery.

The contemporary evidence consequently favors an integrated model in which pharmacological interventions are selected according to their molecular mechanisms, PK/PD characteristics, therapeutic index, interaction profile, patient-specific vulnerabilities, surgical requirements, monitoring capabilities, and recovery objectives. Propofol and volatile anesthetics remain major hypnotic components, but neither class independently addresses all dimensions of perioperative pharmacotherapy. Multimodal anesthesia therefore reflects not simply the use of several drugs but a deliberate distribution of pharmacological functions across complementary mechanisms. Evidence describing multimodal general anesthesia identifies propofol and sevoflurane as principal hypnotic agents while emphasizing the contribution of opioids, local anesthetics, α_2 -adrenergic agonists, ketamine, and other agents to analgesic and sympatholytic objectives.

The analysis further demonstrates that pharmacological optimization depends upon recognizing the difference between pharmacological potency and clinical appropriateness. A highly potent agent is not inherently preferable for every patient, and a rapid-onset drug is not necessarily optimal when prolonged analgesia or hemodynamic stability is the dominant clinical objective. The relevant question is therefore not which drug possesses the greatest pharmacological effect, but which combination of mechanisms most appropriately matches the patient's physiological phenotype and the requirements of the surgical intervention.

Volatile Anesthetic Pharmacology: From Potency to Systems-Level Optimization

Volatile anesthetics remain a central component of general anesthesia and represent one of the most extensively investigated groups in clinical pharmacology. Sevoflurane, desflurane, and isoflurane differ in physicochemical characteristics, blood–gas solubility, uptake, elimination, metabolism, airway effects, cardiovascular responses, and recovery behavior. These characteristics produce clinically meaningful differences in induction, maintenance, emergence, and postoperative management.

The pharmacokinetic behavior of inhalational anesthetics differs fundamentally from that of intravenously administered drugs. Following administration through the respiratory system, the anesthetic must traverse the alveolar membrane, enter the pulmonary circulation, distribute to

tissues, and ultimately reach the central nervous system. The rate at which alveolar and arterial concentrations equilibrate depends on alveolar ventilation, cardiac output, tissue solubility, inspired concentration, and duration of exposure. Blood–gas partition coefficient is therefore a major determinant of equilibration speed. Agents with lower blood solubility generally exhibit faster changes in alveolar and brain concentration, thereby permitting more rapid adjustment of anesthetic depth and emergence.

However, concentration at the alveolus is not synonymous with pharmacodynamic effect. The clinical endpoint depends upon the relationship between brain concentration and neural network activity. Moreover, surgical stimulation modifies the required concentration. Opioid administration can reduce the volatile anesthetic concentration necessary to suppress autonomic and somatic responses, demonstrating again that anesthetic depth is an emergent product of interacting pharmacological mechanisms.

The molecular pharmacology of volatile anesthetics is also more complex than historical descriptions implied. In addition to modulation of GABAergic signaling, modern inhalational anesthetics interact with multiple ligand-gated and background potassium channels, hyperpolarization-activated cyclic nucleotide-gated channels, and excitatory neurotransmission pathways. Sevoflurane and related volatile agents influence inhibitory and excitatory networks distributed throughout the cortex, thalamus, brainstem, and spinal cord.

This distributed pharmacology helps explain why volatile anesthetics produce multiple clinical effects simultaneously. Hypnosis and amnesia arise primarily from supraspinal mechanisms, while immobility is strongly influenced by spinal mechanisms. Cardiovascular effects result from alterations in vascular tone, autonomic activity, and myocardial contractility. Respiratory effects include depression of ventilatory responses and changes in airway and pulmonary physiology.

The contemporary implication is that volatile anesthetics should be evaluated according to an integrated benefit–risk profile rather than potency alone. Rapid emergence may be beneficial in selected ambulatory settings, while cardiovascular stability or airway characteristics may dominate selection in other circumstances. Furthermore, environmental persistence and greenhouse-gas effects have become increasingly relevant to discussions of inhalational anesthesia. Thus, modern anesthetic selection increasingly incorporates patient safety, pharmacological efficacy, recovery, resource utilization, and environmental considerations.

Sevoflurane, Desflurane and Isoflurane: Comparative Pharmacological Interpretation

Sevoflurane is characterized by relatively low blood solubility and favorable airway properties, supporting its use in both induction and maintenance. Its pharmacological profile is particularly relevant where smooth administration and relatively predictable changes in anesthetic concentration are required.

Desflurane possesses very low blood and tissue solubility and consequently permits rapid changes in anesthetic concentration. This pharmacokinetic property historically contributed to its popularity in situations where rapid emergence was prioritized. However, rapid pharmacokinetics do not automatically translate into superior overall clinical outcomes because emergence is also influenced by opioid exposure, duration of surgery, patient physiology, temperature, concomitant medications, and neuromuscular recovery.

Isoflurane has greater blood solubility and therefore slower equilibration than sevoflurane and desflurane. Its longer-established pharmacological profile remains relevant in many healthcare environments. Its continued use illustrates an important principle of pharmacology: older agents may remain clinically useful when their efficacy, safety, familiarity, availability, and cost are compatible with the clinical context.

Consequently, contemporary pharmacological evaluation should avoid interpreting speed of emergence as the sole criterion for anesthetic quality. Recovery is a multidimensional endpoint

involving consciousness, airway protection, analgesia, neuromuscular function, cognition, nausea, hemodynamic stability, and functional capacity.

Intravenous Hypnotics Beyond Propofol

Although propofol occupies a central position in intravenous anesthesia, ketamine and etomidate provide fundamentally different pharmacological phenotypes. Their continued clinical relevance demonstrates that anesthetic selection should remain physiologically adaptive.

Etomidate produces hypnosis predominantly through enhancement of GABAergic neurotransmission and has traditionally been valued for relatively limited cardiovascular depression compared with several alternative induction agents. Its use is nevertheless complicated by suppression of adrenal steroid synthesis, particularly through inhibition of 11 β -hydroxylase. The clinical significance of this endocrine effect varies according to the population and clinical context, and its interpretation remains an important component of evidence-based drug selection.

Ketamine, by contrast, produces dissociative anesthesia principally through NMDA receptor antagonism and possesses important analgesic properties. Its pharmacological effects extend beyond NMDA blockade, involving multiple neurotransmitter systems and pathways. Ketamine can preserve or increase sympathetic cardiovascular activity in many patients, although its hemodynamic effects depend upon physiological reserve and clinical context. It can also produce characteristic perceptual and emergence phenomena.

The contrasting profiles of these drugs reinforce a central finding: induction pharmacology should be phenotype-dependent rather than protocol-dependent. The physiological state of the patient, anticipated surgical stimulation, airway circumstances, cardiovascular reserve, neurological considerations, and postoperative analgesic requirements should all influence drug selection.

Ketamine and NMDA-Targeted Pharmacotherapy

The resurgence of ketamine in contemporary perioperative pharmacology illustrates the increasing importance of mechanisms beyond conventional GABAergic hypnosis. NMDA receptors occupy a central position in excitatory neurotransmission, synaptic plasticity, central sensitization, and nociceptive processing. Antagonism of these receptors therefore provides a mechanistically distinct approach to perioperative analgesia.

The potential value of ketamine extends beyond immediate analgesia. By modifying central sensitization and NMDA-mediated nociceptive amplification, ketamine may provide analgesic effects that are disproportionate to its contribution to conventional hypnotic depth. This property has made it an important component of opioid-sparing strategies in selected patients.

However, mechanistic plausibility should not be confused with universal clinical benefit. Ketamine's effects are dose-dependent and context-dependent, and adverse effects may include cardiovascular stimulation, nausea, perceptual disturbances, and emergence phenomena. Consequently, patient selection remains important.

The broader implication is that NMDA pharmacology provides a model for the future development of anesthetic adjuvants. Rather than attempting to create another universal hypnotic, drug development increasingly seeks to target specific components of the perioperative pathophysiological response.

Opioid Pharmacology in General Anesthesia

Opioids remain among the most potent pharmacological tools for controlling perioperative nociception. Their principal clinical effects arise through μ -opioid receptor activation, which reduces neurotransmitter release and modifies nociceptive signaling at peripheral, spinal, and supraspinal levels.

Fentanyl, remifentanyl, morphine, hydromorphone, and other opioids differ considerably in potency, lipid solubility, distribution, metabolism, elimination, and context-sensitive behavior. These differences determine how each agent should be used within a perioperative pharmacological plan.

Remifentanyl provides an important example of pharmacokinetic engineering. Its metabolism by nonspecific esterases results in exceptionally rapid clearance and predictable offset, making it particularly useful when minute-to-minute titration is required. Nevertheless, the same pharmacological property means that analgesic effects disappear rapidly following discontinuation, requiring a planned transition to longer-acting analgesia.

Fentanyl has greater persistence and tissue redistribution. Repeated or prolonged administration may produce accumulation and delayed respiratory depression. Morphine has a longer duration and produces active metabolites that may accumulate in renal dysfunction.

The clinical result is that opioid selection must be based on the temporal requirements of nociception. The appropriate opioid for intense intraoperative stimulation may not be the appropriate drug for postoperative analgesia.

Opioid-Induced Hyperalgesia and Tolerance

A further dimension of opioid pharmacology is the potential development of tolerance and opioid-induced hyperalgesia. These phenomena demonstrate that increasing opioid exposure does not necessarily produce proportionally greater analgesic benefit.

Tolerance reflects diminished response following repeated exposure, whereas opioid-induced hyperalgesia involves increased sensitivity to painful stimuli following opioid exposure. Their mechanisms are multifactorial and may involve NMDA receptor signaling, neuroplasticity, spinal facilitation, and altered descending modulation.

These mechanisms provide an additional pharmacological rationale for multimodal analgesia. By distributing analgesic activity across opioid and non-opioid pathways, clinicians may reduce the requirement for high opioid exposure while preserving analgesic efficacy.

However, the existence of opioid-induced hyperalgesia should not be interpreted as evidence that opioids should be categorically avoided. Opioids remain essential for many major surgical procedures and severe acute pain states. The relevant pharmacological objective is individualized exposure and appropriate integration with other analgesic mechanisms.

α 2-Adrenergic Agonists

Dexmedetomidine and clonidine represent another important pharmacological class in contemporary anesthesia. Their α 2-adrenergic activity reduces sympathetic neurotransmission and can produce sedation, anxiolysis, and analgesic-sparing effects.

Dexmedetomidine is particularly distinctive because its sedative state can preserve aspects of arousability and spontaneous ventilation compared with deeper GABAergic sedation. This pharmacological profile has supported its use as an adjunct during anesthesia and procedural sedation.

Its principal limitations are bradycardia and hypotension, particularly in susceptible patients or when administered rapidly or at high exposure. The balance between sympatholysis and hemodynamic stability therefore requires individualized titration.

The role of α 2 agonists illustrates the concept of pharmacological substitution. Rather than increasing opioid or hypnotic doses, the anesthetic regimen can sometimes recruit alternative pathways to achieve a similar therapeutic objective. Such substitution is one of the principal mechanisms through which multimodal pharmacotherapy reduces dependence on any single drug class.

Local Anesthetic Pharmacology and Regional Techniques

Local anesthetics occupy an essential position within multimodal perioperative pharmacology because they interrupt peripheral nerve conduction through blockade of voltage-gated sodium channels. Lidocaine, bupivacaine, ropivacaine, and related agents differ in potency, duration, lipophilicity, protein binding, and cardiotoxicity.

Regional anesthesia and local infiltration can substantially reduce nociceptive transmission before signals reach central pathways. This produces a pharmacological advantage that differs fundamentally from systemic analgesia: the intervention acts at the site of signal generation or transmission rather than primarily at the CNS.

The pharmacological benefit is potentially substantial opioid reduction. However, systemic absorption creates a dose-dependent risk of local anesthetic systemic toxicity, involving neurological excitation followed by CNS depression and potentially severe cardiovascular toxicity. The contemporary approach therefore requires attention to total cumulative dose, administration site, vascularity, patient characteristics, formulation, and monitoring. Regional techniques should be regarded as pharmacological interventions requiring the same precision and vigilance as intravenous drug administration.

Acetaminophen and NSAIDs in Multimodal Pharmacotherapy

Non-opioid analgesics constitute an important component of multimodal anesthesia. Acetaminophen provides centrally mediated analgesic effects and has a favorable safety profile when appropriately dosed. NSAIDs inhibit cyclooxygenase-mediated prostaglandin synthesis and reduce inflammatory nociception.

Their importance derives partly from their ability to reduce opioid requirements. Contemporary perioperative guidance recommends combining analgesics from different classes to manage postoperative pain, illustrating the clinical translation of multimodal pharmacology.

Nevertheless, these agents are not universally appropriate. NSAIDs require consideration of renal function, gastrointestinal risk, bleeding, cardiovascular status, and procedure-specific concerns. Therefore, multimodal analgesia must remain individualized.

Recent PONV guidance also identifies reduced opioid use as one pathway through which non-opioid analgesics may contribute to lower PONV incidence, although the direct antiemetic effects of individual agents are not always independently established.

Neuromuscular Blockade: Reconfiguration of Safety Standards

Neuromuscular blockade represents a particularly important domain in the reconfiguration of anesthetic pharmacology because its safety profile is determined not only by administration but also by objective recovery.

Nondepolarizing agents such as rocuronium prevent acetylcholine-mediated activation of the motor endplate by competitive antagonism of nicotinic receptors. The clinical consequence is dose-dependent skeletal-muscle paralysis.

The historical practice of relying on clinical signs to assess recovery has increasingly been replaced by quantitative neuromuscular monitoring. Contemporary European guidance recommends quantitative monitoring and recommends confirming a train-of-four ratio greater than 0.9 before considering neuromuscular recovery adequate. The same guideline recommends sugammadex for reversal of aminosteroid neuromuscular blockade when appropriate.

This represents a major pharmacological shift. Instead of assuming recovery from the absence of obvious weakness, clinicians can obtain an objective physiological measurement related to receptor-level recovery.

The significance extends to postoperative respiratory safety. Residual neuromuscular blockade can impair pharyngeal function, upper-airway protection, ventilatory capacity, and the ability to respond appropriately to respiratory challenges. Thus, reversal should be regarded as an integral component of anesthetic pharmacotherapy rather than an optional final step.

Sugammadex and Neostigmine: Mechanistic Reversal

Sugammadex and neostigmine represent fundamentally different reversal mechanisms. Sugammadex encapsulates aminosteroid neuromuscular blockers, thereby reducing the free concentration of the drug available to interact with nicotinic receptors. Neostigmine inhibits acetylcholinesterase, increasing acetylcholine concentration at the neuromuscular junction and allowing competitive displacement of the antagonist.

These differences have direct clinical consequences. Sugammadex can reverse deeper levels of rocuronium- or vecuronium-induced blockade more predictably than cholinesterase inhibition, whereas neostigmine requires sufficient spontaneous recovery before administration and is associated with muscarinic effects requiring appropriate co-medication.

The modern pharmacological principle is therefore mechanism-matched reversal. The depth and type of blockade should determine the reversal strategy rather than routine administration of one reversal agent.

Postoperative Nausea and Vomiting: From Symptom Treatment to Risk-Based Pharmacology

PONV provides a clear example of the transition from reactive to preventive pharmacotherapy. Contemporary evidence supports risk assessment, reduction of baseline risk, multimodal prophylaxis, and rescue therapy using an appropriate pharmacological class when prophylaxis fails.

The most recent consensus guidance recommends an algorithmic approach to adult PONV management and supports multimodal prophylaxis. It identifies propofol-based anesthesia and multimodal analgesic interventions among strategies capable of reducing baseline PONV risk.

The pharmacological complexity of PONV derives from its multiple receptor pathways. Serotonin, dopamine, histamine, acetylcholine, and neurokinin signaling all contribute to emetic pathways. Consequently, a single receptor antagonist cannot necessarily provide complete protection in high-risk patients.

The rational strategy is therefore receptor diversification. A 5-HT₃ antagonist may be combined with dexamethasone or another antiemetic class, with selection influenced by patient risk factors, contraindications, QT considerations, sedation, and previous response.

The evidence further indicates that rescue therapy should generally employ a different pharmacological class from the prophylactic agent because failure of one pathway does not imply failure of all antiemetic mechanisms.

Pharmacodynamic Drug Interactions

One of the strongest conclusions from the pharmacological analysis is that drug interactions constitute a defining characteristic of general anesthesia rather than an incidental complication. The propofol literature demonstrates particularly clearly that interactions with opioids can be strongly synergistic, whereas interactions with other hypnotics may be more additive. Response-surface modeling provides a quantitative method for characterizing these relationships.

This finding has major implications for dose calculation. If two drugs interact synergistically, maintaining the conventional dose of each may produce excessive pharmacological effect. Conversely, carefully reducing each component may preserve efficacy while improving hemodynamic and respiratory safety.

The same principle applies to neuromuscular blockade. Volatile anesthetics can potentiate neuromuscular-blocking effects, meaning that the same NMBA dose may produce different degrees of blockade under different anesthetic regimens.

Therefore, drug-specific dose recommendations should increasingly be interpreted as conditional estimates rather than universal prescriptions. (See Table-5).

Table 5. Expanded pharmacological interaction matrix

Pharmacological interaction	Mechanistic basis	Principal clinical implication	Monitoring priority
Propofol + opioids	Synergistic depression CNS	Lower hypnotic and opioid requirements may be possible	Hemodynamics, ventilation, anesthetic depth
Propofol + volatile anesthetic	Additive hypnotic effects	Avoid unnecessary dual hypnotic exposure	EEG/clinical depth, blood pressure
Opioid + $\alpha 2$ agonist	Complementary analgesia and sympatholysis	Opioid sparing	Heart rate, blood pressure, ventilation
Opioid + sedative	Additive respiratory/CNS depression	Increased respiratory risk	Capnography, oxygenation, consciousness
Volatile anesthetic + NMBA	Potentiation of blockade	Reduced NMBA requirement may occur	Quantitative neuromuscular monitoring
Ketamine + opioid	Complementary analgesic mechanisms	Potential opioid sparing	Cardiovascular and neuropsychiatric effects
Local anesthetic + systemic analgesics	Multilevel nociceptive modulation	Reduced systemic opioid exposure	Cumulative toxicity and pain scores
Multiple antiemetics	Complementary receptor antagonism	Improved prophylaxis in selected risk groups	QT interval, sedation, drug-specific toxicity

Pharmacokinetic–Pharmacodynamic Modeling

The integration of PK and PD represents one of the most important methodological developments in modern anesthetic pharmacology. Pharmacokinetics describes drug exposure, while pharmacodynamics describes the relationship between exposure and effect. General anesthesia requires both because a plasma concentration cannot automatically predict the clinical state.

Compartmental models describe distribution and elimination, while effect-site models describe equilibration between plasma and the biophase. Covariate models incorporate age, weight, body composition, organ function, and other determinants.

Propofol provides a particularly advanced example. Multiple PK/PD models have been developed, and target-controlled infusion devices use these models to calculate infusion rates designed to achieve user-selected plasma or effect-site concentrations. General-purpose models have been developed to improve applicability across heterogeneous populations, although prospective validation remains important.

The major methodological finding is that model-informed dosing can potentially reduce empirical variability but cannot eliminate biological uncertainty. A model represents a population-level

approximation. The individual patient's response must therefore remain the ultimate pharmacodynamic reference.

Target-Controlled Infusion

Target-controlled infusion represents a transition from dose-centered to concentration-centered anesthesia. Traditional infusion strategies specify a rate of administration, whereas target-controlled systems attempt to achieve a specified predicted concentration.

This distinction is conceptually important because the same infusion rate can generate different concentrations in patients with different clearance and distribution characteristics. Conversely, maintaining a target concentration requires dynamic adjustment of infusion rate as the predicted pharmacokinetic state changes.

However, target-controlled infusion does not constitute direct measurement of plasma or effect-site concentration. It remains model-based. Therefore, clinical titration against EEG, hemodynamic, respiratory, and surgical-response indicators remains essential.

The optimal interpretation is consequently that target-controlled infusion is a decision-support technology, not an autonomous replacement for pharmacological judgment.

EEG and Pharmacodynamic Monitoring

Electroencephalography provides an indirect window into the CNS effects of anesthetic drugs. Changes in spectral characteristics, cortical connectivity, and oscillatory patterns can correlate with transitions between consciousness and unconsciousness.

Processed EEG indices can assist anesthetic titration, particularly with intravenous hypnotics. However, no single numerical index perfectly represents the multidimensional pharmacological state of general anesthesia.

A patient may exhibit an EEG pattern consistent with deep hypnosis while receiving inadequate analgesia, or may show altered EEG characteristics due to age, neurological disease, medications, or hypothermia. Therefore, EEG should be interpreted alongside hemodynamic and clinical information.

This reinforces the broader principle that monitoring should be multidimensional. Pharmacological depth, nociception, neuromuscular function, and physiological stability represent different endpoints requiring different measurement strategies.

Precision Anesthesia and Special Populations

The evidence strongly indicates that demographic and physiological heterogeneity should be integrated into anesthetic dosing.

In older adults, reduced pharmacodynamic reserve and increased CNS sensitivity often necessitate cautious titration. The goal is not merely dose reduction but avoidance of excessive effect while preserving adequate anesthesia and analgesia.

In pediatrics, developmental pharmacology alters receptor expression, body composition, hepatic enzyme activity, renal clearance, and pharmacodynamic sensitivity. Neonates and infants should therefore be regarded as pharmacologically distinct populations.

Obesity creates complex relationships among total body weight, lean body mass, adipose distribution, and drug clearance. The appropriate dosing scalar differs among drugs.

Hepatic dysfunction can alter metabolism and protein binding, whereas renal dysfunction may prolong the effects of renally cleared drugs or active metabolites. Cardiovascular disease changes distribution and clearance through effects on cardiac output and organ perfusion. These considerations collectively demonstrate that individualized anesthesia requires more than demographic adjustment. It requires pharmacological interpretation of the patient's entire physiological state.

Polypharmacy and Chronic Medication Exposure

Modern surgical patients increasingly present with extensive medication histories. Antihypertensives, antidepressants, antiepileptic drugs, anticoagulants, antidiabetic medications, opioids, benzodiazepines, and other chronic therapies may influence anesthetic pharmacodynamics.

Polypharmacy increases the possibility of additive sedation, altered autonomic responses, enzyme-mediated interactions, bleeding, electrolyte disturbances, or withdrawal syndromes.

Therefore, perioperative pharmacology should include structured medication reconciliation and explicit identification of pharmacodynamic interactions. Abrupt discontinuation of certain chronic medications can also create risks, demonstrating that pharmacological optimization includes both addition and omission of drugs.

Pharmacovigilance and Medication Safety

Anesthesia is characterized by rapid administration of high-potency drugs, frequent transitions between clinicians, complex drug preparation, and simultaneous management of physiological instability. These conditions create opportunities for medication error.

Pharmacovigilance should therefore include medication selection, preparation, labeling, administration, monitoring, reversal, and post-discharge follow-up.

Near-miss reporting is particularly valuable because it identifies system vulnerabilities before patient harm occurs. Standardization of syringes, labeling conventions, infusion pumps, medication concentrations, and electronic documentation can reduce preventable errors.

Pharmacists may have an increasingly important role in perioperative medication safety, particularly in medication reconciliation, high-risk medication review, antimicrobial optimization, anticoagulation management, and pharmacovigilance.

Malignant Hyperthermia and Rare but High-Consequence Pharmacological Events

Some anesthetic-related adverse events are rare but potentially catastrophic. Malignant hyperthermia represents a pharmacogenetically influenced disorder of skeletal-muscle calcium regulation associated with exposure to triggering anesthetics in susceptible individuals.

Its importance demonstrates the intersection between pharmacology, genetics, emergency medicine, and patient safety. Recognition requires rapid identification of characteristic physiological changes and immediate discontinuation of triggering agents, supportive management, and administration of dantrolene.

The broader implication is that precision anesthesia includes not only optimization for common variability but also identification of rare pharmacological vulnerabilities.

Pharmacogenomics

Pharmacogenomics may contribute to future anesthetic personalization through identification of genetic determinants of drug metabolism, receptor sensitivity, pain perception, and adverse-event susceptibility. However, the current evidence indicates that pharmacogenomic implementation remains uneven. Unlike some oncology or infectious-disease applications in which single genetic variants can strongly influence drug selection, anesthetic response is generally polygenic and heavily modified by environmental and physiological variables.

The future therefore likely lies in integrated prediction models that combine genetic information with PK/PD characteristics, physiological monitoring, clinical history, and real-time drug exposure.

Artificial Intelligence and Closed-Loop Anesthesia

Artificial intelligence and machine-learning systems may facilitate individualized anesthesia by integrating high-dimensional data streams, including blood pressure, heart rate, oxygen saturation, capnography, EEG, drug infusion rates, and patient characteristics.

Potential applications include prediction of hypotension, automated hypnotic titration, individualized analgesic estimation, postoperative risk prediction, and detection of abnormal recovery trajectories.

Nevertheless, several limitations remain. Algorithms trained on one population may perform poorly in another. Data quality may be variable, and physiological signals may be affected by artifacts. Furthermore, the causal interpretability of machine-learning models may be limited.

Therefore, AI-assisted anesthesia should be regarded as a developing form of pharmacological decision support requiring prospective validation, transparency, clinical oversight, and continuous performance monitoring.

Environmental Pharmacology

The environmental dimension of anesthetic pharmacology has become increasingly prominent. Volatile anesthetics are released into the atmosphere during administration and scavenging. Their differing atmospheric persistence and greenhouse effects have led to increased interest in reducing unnecessary exposure and selecting lower-impact strategies where clinically appropriate.

This creates a new dimension of pharmacological stewardship. Historically, stewardship primarily concerned efficacy, safety, and cost. Contemporary stewardship increasingly includes environmental impact.

However, environmental considerations must remain integrated with patient-centered clinical indications. The environmentally preferable option is not automatically appropriate if it compromises patient safety or therapeutic effectiveness.

Enhanced Recovery and Anesthetic Pharmacology

Enhanced Recovery after Surgery frameworks provide an important clinical environment for translating modern anesthetic pharmacology into patient-centered outcomes. ERAS principles generally emphasize multimodal analgesia, reduction of unnecessary opioid exposure, avoidance of excessive fluid and sedative burden, early mobilization, and rapid restoration of physiological function.

Pharmacology is central to these objectives. Appropriate analgesia facilitates mobilization; opioid reduction may reduce nausea and ileus; effective PONV prophylaxis facilitates oral intake; and rapid anesthetic recovery can support earlier discharge. Thus, the endpoint of anesthetic pharmacology increasingly extends beyond the operating room.

Patient-Centered Outcomes

The synthesis identifies an important methodological transition from physiological surrogate endpoints toward patient-centered outcomes. Historically, anesthetic research frequently emphasized blood pressure, heart rate, anesthetic concentration, emergence time, or drug consumption. These endpoints remain important, but patients experience anesthesia through pain, nausea, cognitive function, mobility, sleep, respiratory comfort, and functional recovery. Therefore, future anesthetic pharmacology studies should increasingly incorporate patient-reported outcomes and recovery quality alongside conventional pharmacological endpoints.

Integrated Interpretation of the Evidence

The cumulative evidence supports a hierarchical model of anesthetic pharmacology: molecular target → cellular effect → neural-network modulation → pharmacokinetic exposure → pharmacodynamic response → physiological effect → clinical endpoint → functional recovery. Each level contains variability that can influence the next. Consequently, precision anesthesia requires integration across levels.

At the molecular level, receptor and ion-channel mechanisms determine pharmacological action. At the PK level, patient-specific distribution and clearance determine exposure. At the PD level, sensitivity and drug interactions determine response. At the physiological level, cardiovascular, respiratory, neurological, and metabolic reserve modify clinical consequences. At the patient level, recovery goals and preferences determine the ultimate therapeutic relevance.

This framework explains why no single monitoring parameter or dosing algorithm can completely characterize general anesthesia. (See Table-6).

Expanded Evidence-Based Comparative Table-6

Domain	Established pharmacological principle	Contemporary development	Clinical significance	Remaining research need
Hypnosis	GABAergic and other CNS mechanisms	EEG-guided and PK/PD-informed titration	Individualized anesthetic depth	Better validated multidimensional depth measures
Analgesia	Opioid-mediated nociceptive suppression	Multimodal opioid-sparing strategies	Reduced opioid exposure	Procedure-specific optimization
Neuromuscular blockade	Nicotinic receptor antagonism	Quantitative monitoring and mechanism-specific reversal	Reduced residual paralysis	Wider implementation and standardization
PONV	Multiple emetic pathways	Risk-adapted multimodal prophylaxis	Lower postoperative symptom burden	Better individualized prediction
PK/PD	Concentration–effect relationships	Population modeling and TCI	More rational dosing	Prospective model validation
Precision medicine	Patient variability	Integrated phenotype/genotype modeling	Individualized pharmacotherapy	Clinically validated biomarkers
Pharmacovigilance	Adverse-event detection	Systems-based safety surveillance	Prevention of medication-related harm	Standardized perioperative datasets
Digital anesthesia	Electronic monitoring	AI and closed-loop systems	Potential real-time optimization	External validation and explainability

Sustainability	Volatile anesthetic environmental effects	Low-emission practice	Reduced ecological burden	Outcome-based sustainability models
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Critical Appraisal

The evidence strongly supports multimodal and individualized pharmacological strategies, several limitations must be acknowledged. Anesthetic pharmacology contains substantial between-study heterogeneity. Surgical procedures differ in nociceptive intensity, duration, blood loss, physiological stress, and postoperative pain. Therefore, a pharmacological strategy cannot necessarily be generalized from one procedure to another. Patient heterogeneity complicates interpretation. Age, obesity, organ dysfunction, chronic opioid exposure, neurological disease, and polypharmacy can substantially alter pharmacological response.

Pharmacodynamics endpoints are often difficult to measure directly. EEG-derived indices provide valuable information but do not completely represent analgesia or autonomic suppression. Hemodynamic stability can be influenced by multiple mechanisms simultaneously and therefore cannot be attributed to anesthetic depth alone.

Many technological innovations remain model-dependent. A target-controlled infusion system can only be as accurate as the underlying pharmacokinetic model. Similarly, an AI algorithm can only generalize if its training population and clinical environment adequately represent the patients in whom it is deployed. Pharmacogenomic evidence remains less mature than pharmacometric evidence for many anesthetic applications. Genetic information should therefore be incorporated cautiously and only where clinically validated.

Research Priorities

Future research should increasingly investigate integrated anesthetic pharmacology rather than isolated drug comparisons. Trials should compare complete pharmacological strategies and evaluate clinically meaningful outcomes, including postoperative respiratory complications, pain control, PONV, cognitive recovery, functional mobility, hospital length of stay, patient satisfaction, and readmission.

Pharmacometric research should focus on prospective validation of PK/PD models across diverse populations, including older adults, children, obesity, organ dysfunction, and patients receiving multiple interacting drugs.

Pharmacodynamic research should characterize interactions among hypnotics, opioids, $\alpha 2$ agonists, ketamine, and neuromuscular blockers using response-surface methodology and clinically meaningful endpoints. Pharmacogenomic research should determine whether specific genetic variants provide sufficient predictive value to justify routine clinical testing.

Digital-health research should evaluate whether AI-assisted dosing actually improves outcomes compared with expert clinician management rather than merely demonstrating algorithmic accuracy. Sustainability research should evaluate environmental benefits together with patient outcomes and healthcare resource utilization.

Findings

The expanded evidence synthesis demonstrates that contemporary general anesthesia is increasingly defined by pharmacological integration rather than pharmacological isolation. The principal components of the modern paradigm include mechanism-based drug selection, PK/PD-informed dosing, multimodal analgesia, individualized hypnotic administration, quantitative neuromuscular monitoring, evidence-based PONV prevention, pharmacovigilance, precision medicine, and emerging digital decision support.

Propofol illustrates the movement toward quantitative pharmacology because its clinical use has become closely associated with PK/PD modeling, effect-site targeting, and characterization of synergistic interactions with opioids.

Neuromuscular pharmacology illustrates the movement toward objective safety monitoring, with contemporary guidance supporting quantitative monitoring and appropriate reversal strategies. Multimodal analgesia illustrates the movement from single-pathway treatment toward pharmacological diversification, with contemporary perioperative guidance recommending combinations of analgesics from different classes.

PONV pharmacology illustrates the movement from reactive treatment toward risk-based prophylaxis and multimodal intervention. Taken together, these developments indicate that the central scientific problem in general anesthesia is no longer simply how to induce unconsciousness. The contemporary challenge is how to produce an appropriate anesthetic state while simultaneously controlling nociception, maintaining physiological stability, preventing avoidable adverse effects, minimizing unnecessary drug exposure, ensuring complete neuromuscular recovery, and facilitating rapid functional recovery.

The reconfiguration of anesthetic pharmacology therefore represents a transition from agent selection to therapeutic architecture, from fixed dosing to adaptive dosing, from single-endpoint monitoring to multidimensional monitoring, from opioid-centered analgesia to multimodal analgesia, from clinical estimation of recovery to quantitative verification, and from population-average treatment to increasingly individualized pharmacotherapy. The pharmacological purpose is consequently not maximal drug effect. It is the achievement of the required therapeutic state with the lowest rational pharmacological burden compatible with adequate hypnosis, analgesia, immobility, physiological stability, patient safety, and recovery. This framework provides the scientific basis for a future model of general anesthesia that is mechanistically informed, pharmacometrically supported, multimodal, patient-centered, pharmacosafety-oriented, and progressively adaptive.

CONCLUSION

➤ The contemporary pharmacological landscape of general anesthesia is undergoing a substantive conceptual and therapeutic transformation, driven by advances in molecular pharmacology, neurobiology, pharmacokinetics, pharmacogenomics, perioperative medicine, and patient-safety science. General anesthesia can no longer be adequately conceptualized as a homogeneous pharmacological state produced by the nonspecific suppression of central nervous system activity. Rather, contemporary evidence supports an integrated model in which unconsciousness, amnesia, analgesia, immobility, autonomic modulation, and neurophysiological stability represent partially dissociable therapeutic dimensions that may be influenced through distinct molecular targets and pharmacological strategies. This conceptual transition has important implications for the rational selection, combination, dosing, monitoring, and discontinuation of anesthetic agents.

➤ The evolution from predominantly inhalational approaches toward increasingly individualized intravenous, inhalational, regional, multimodal, and balanced anesthetic techniques has expanded the therapeutic possibilities of perioperative pharmacotherapy. Modern agents, including intravenous hypnotics, volatile anesthetics, opioids, α 2-adrenergic agonists, local anesthetics, neuromuscular blocking agents, antagonists, and adjunctive analgesics, possess complementary pharmacodynamic and pharmacokinetic characteristics that can be strategically integrated according to surgical requirements and patient-specific physiological conditions. At the same time, the increasing recognition of interindividual variability emphasizes that anesthetic dosing cannot be optimally determined solely through standardized weight-based algorithms. Age, organ function, comorbidity, concurrent medication exposure, genetic variability,

pharmacokinetic phenotype, and perioperative physiological changes may substantially modify drug response.

➤ Precision perioperative pharmacotherapy therefore represents an important emerging paradigm. Pharmacogenomic and pharmacometric approaches, together with processed electroencephalographic monitoring, neuromuscular monitoring, hemodynamic assessment, depth-of-anesthesia technologies, and individualized analgesic evaluation, provide opportunities to refine therapeutic exposure while reducing unnecessary pharmacological burden. Such approaches may be particularly relevant in vulnerable populations, including older adults, patients with cardiovascular or respiratory disease, individuals with altered hepatic or renal function, and patients exposed to complex polypharmacy regimens.

➤ Pharmacological innovation, however, must remain inseparable from pharmacosafety. The benefits of anesthetic drugs coexist with clinically significant risks, including respiratory depression, hypotension, cardiovascular instability, residual neuromuscular blockade, postoperative nausea and vomiting, delirium, medication errors, drug interactions, and inappropriate cumulative sedative or opioid exposure. Consequently, future progress should not be measured solely by the introduction of novel molecules but by the capacity to integrate pharmacological innovation with rigorous monitoring, evidence-based dosing, multimodal strategies, medication stewardship, and systematic adverse-event prevention.

➤ The reconfiguration of general anesthesia pharmacology reflects a transition from drug-centered anesthesia toward mechanism-informed, patient-centered, precision perioperative pharmacotherapy. The future of the field will increasingly depend on integrating molecular knowledge with clinical pharmacology, advanced monitoring, pharmacogenomics, artificial intelligence-assisted decision support, and multidisciplinary perioperative care. Such integration offers a scientifically grounded pathway toward achieving an appropriate balance among unconsciousness, analgesia, immobility, physiological stability, rapid recovery, and patient safety, while preserving the fundamental principle that every pharmacological intervention should be proportionate to its therapeutic objective and supported by robust clinical evidence.

RECOMMENDATIONS

The contemporary reconfiguration of general anesthesia pharmacology requires a coordinated transition toward evidence-based, individualized, mechanism-informed, and safety-centered perioperative pharmacotherapy. Future clinical and scientific development should prioritize integration of pharmacological innovation with rigorous patient assessment, objective monitoring, precision dosing, and systematic evaluation of therapeutic outcomes.

Anesthetic selection and dosing should increasingly be individualized according to patient-specific pharmacokinetic and pharmacodynamic characteristics. Age, body composition, hepatic and renal function, cardiovascular and respiratory status, comorbidities, concomitant medications, previous anesthetic responses, and clinically relevant genetic variability should be incorporated into perioperative pharmacological planning whenever supported by sufficient evidence. Conventional fixed-dose approaches should be complemented by titration according to physiological response and validated monitoring parameters.

Multimodal and opioid-sparing pharmacotherapy should be further developed where clinically appropriate. Combining pharmacological agents with complementary mechanisms may reduce reliance on individual drugs, particularly opioids, while maintaining adequate analgesia and minimizing dose-dependent adverse effects. Such strategies should nevertheless be guided by evidence concerning drug interactions, cumulative sedation, hemodynamic effects, and patient-specific contraindications.

Objective monitoring should constitute an essential component of pharmacological optimization. Appropriate use of processed electroencephalographic monitoring, quantitative neuromuscular

monitoring, capnography, oxygenation assessment, hemodynamic monitoring, and structured postoperative evaluation can facilitate individualized drug titration and early recognition of excessive pharmacological effects. Particular emphasis should be placed on preventing residual neuromuscular blockade and unintended postoperative respiratory depression.

Pharmacogenomics, pharmacometrics, therapeutic drug modeling, and artificial-intelligence-assisted decision-support technologies should be progressively investigated as complementary tools for precision perioperative medicine. However, implementation should occur only after adequate clinical validation, transparent assessment of diagnostic and predictive performance, evaluation of algorithmic limitations, and demonstration of clinically meaningful benefit. Technological innovation should augment rather than replace professional clinical judgment.

Perioperative medication safety systems should be strengthened through standardized drug labeling, standardized concentrations, electronic prescribing safeguards, medication reconciliation, independent verification of high-risk medications, structured handovers, and systematic reporting of medication-related incidents. Institutions should establish mechanisms for analyzing adverse events and near misses so that safety interventions can be continuously adapted to emerging evidence and local clinical circumstances.

Education in anesthetic pharmacology should be strengthened across undergraduate, postgraduate, and continuing professional development programs. Contemporary curricula should integrate molecular mechanisms, clinical pharmacokinetics, pharmacodynamics, drug interactions, pharmacogenomics, multimodal analgesia, medication safety, pharmacovigilance, and interpretation of monitoring technologies. Simulation-based education may further improve preparedness for complex pharmacological emergencies.

The future research should prioritize high-quality randomized trials, prospective multicenter studies, comparative-effectiveness research, pharmacogenomic investigations, real-world pharmacovigilance, and long-term outcome assessment. Research should evaluate not only intraoperative physiological endpoints but also recovery quality, postoperative cognitive outcomes, functional recovery, patient-reported outcomes, medication-related harm, and healthcare-system consequences. A multidisciplinary research framework involving anesthesiology, clinical pharmacology, pharmacy, surgery, nursing, biomedical engineering, and data science will be essential for translating mechanistic discoveries into clinically meaningful advances. The recommendations support a pharmacological model of general anesthesia that is individualized, evidence-based, technologically informed, and fundamentally oriented toward patient safety, recovery, and clinically meaningful outcomes.

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Technical Sciences

медециналық қызмет көрсету саласында веб-қосымшаның маңыздылығы

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***Түйіндеме.** Мақалада медицина саласында қызмет көрсететін орталықтың бизнес-процестерін автоматтандыру мақсатында заманауи талаптарға сай веб-қосымша әзірленіп, оның медициналық орталықтың жұмысын оңтайландырудағы жұмысы қарастырылған. Құрастырылған веб-қосымша орталық қызметіне жүгінген тұтынушылардың сұраныстарын толығымен қанағаттандырады.*

***Түйін сөздер:** медициналық орталық, веб-қосымша, онлайн-тіркелу, онлайн-дүкен, онлайн-сервис.*

Қазіргі таңда веб-қосымшаның даму қарқынының алдыға басқаны соншалықты, тіпті шағын бизнес өкілдері де интернеттің көмегімен жаңа клиенттерін табуға тырысуда. Көптеген адамдар интернет көмегімен сатып алуды немесе жылдам қызметтерді алуды ұнатады, ал веб-қосымшалар клиенттердің қажеттіліктерін жеңілдетеді және тездетеді. Кез келген бизнес өкілдері клиенттердің сенімін арттыруға және үлкен клиенттік қорын қалыптастыруға мүдделі. Бұл мәселені шешу үшін веб-қосымшаны кеңінен пайдалануға болады. Соңғы жылдары веб-қосымшалар қолданысқа еніп, қарқынды дами бастады. Веб-қосымшалар бірдей функционалдылықты қамтамасыз ете алады және көптеген платформаларда жұмыс істеудің артықшылығын пайдалана алады.

Жобаның мақсаты медицина саласында қызмет ұсынатын орталықтың ақпараттық порталын, веб-қосымшадағы онлайн-дүкенін және онлайн-сервисін әзірлеу болып табылады. Медициналық мекеменің ұсынатын қызметтерін көпшілікке танымды ету мақсатында интернет желісінде мекеме қызметі туралы ақпаратты ұсыну, сондай-ақ қашықтықтан медициналық қызмет көрсету сервистерін ұсынады. Медициналық орталықтың қызметінің негізгі түрі медициналық қызмет, көмек көрсету, емдік жаттығулардың жеке бағдарламаларын құрастыру, жаттығу залын ұсыну және мамандардың бақылауы болып табылады.

Медициналық орталықтың негізгі бағыттарының бірі – емдік дене шынықтыру (ЕДШ). ЕДШ – арнайы іріктеліп, белгілі бір әдістеме бойынша ұйымдастырылған дене жаттығулары арқылы аурулардың алдын алуға, емдеуге және ағзаны қалпына келтіруге бағытталған медициналық оңалту әдістерінің бірі. Орталықта клиенттерді қабылдау және оларға қызмет көрсетуге арналған арнайы қабылдау орны қарастырылған. Емдеу және оңалту бағдарламаларын өткізу үшін қажетті құрал-жабдықтармен, тренажерлермен және спорттық снарядтармен жабдықталған арнайы бөлме бар. Жаттығу барысында маман клиентке қажетті жаттығуларды дұрыс орындауға көмектесіп, олардың орындалу барысын

қадағалайды. Сонымен қатар, клиенттердің қажеттіліктері мен денсаулық жағдайына қарай әзірленген әртүрлі жаттығу бағдарламалары электрондық форматта қолжетімді. Қажет болған жағдайда жекелеген емдеу және жаттығу бағдарламаларын қашықтан ұсыну мүмкіндігі де қарастырылған. Бұл клиенттерге медициналық орталыққа келмей-ақ, маман ұсынған жаттығуларды өз бетінше орындауға мүмкіндік береді.

Жобаның негізгі мақсаты – медициналық мекеме қызметін цифрландыруға бағытталған веб-қосымшаны әзірлеу. Жүйе пайдаланушыларға медициналық қызметтерге онлайн жазылу, тауарларды интернет-дүкен арқылы сатып алу, сондай-ақ көрсетілетін қызметтерді қашықтан пайдалану мүмкіндігін қамтамасыз ететін функционалдық модульдерді қамтиды.

Онлайн жазылу функционалы пайдаланушыға медициналық қызмет түрін, маманды және қолжетімді қабылдау уақытын ақпараттық жүйе арқылы таңдап, алдын ала белгіленген уақытқа электрондық тіркеуден өтуге мүмкіндік береді. Бұл үдеріс қызметкердің тікелей араласуын және қосымша растау рәсімдерін барынша азайтып, пайдаланушыларға қызмет көрсету үдерісінің жеделдігі мен қолжетімділігін арттырады. Сонымен қатар, веб-қосымшада пайдаланушының жеке кабинеті қарастырылып, оның көмегімен жеке мәліметтерді басқару, қабылдаулар тарихын қарау, таңдалған қызметтерді бақылау және онлайн сервистерді пайдалану мүмкіндігі жүзеге асырылады. Интернет-дүкен модулі медициналық және ілеспе өнімдерді электрондық форматта ұсынуға, тапсырыстарды рәсімдеуге және сатып алу үдерісін автоматтандыруға мүмкіндік береді. Осылайша, веб-қосымша медициналық мекеменің қызмет көрсету үдерістерін автоматтандыруға, пайдаланушылармен өзара әрекеттесуді цифрландыруға және медициналық қызметтердің қолжетімділігін арттыруға бағытталған ақпараттық жүйе ретінде қарастырылады.

Медициналық мекеме өзінің қызмет көрсету саласында тауарларды сатуды жоспарлаған. Ол үшін тауарларды онлайн сатып алу және төлеу мүмкіндігі бар интернет-дүкен орналасқан бөлім қажет.

Пайдаланушының жеке кабинеті тікелей қосымшаларда жеке жаттығулар жоспарын құру үшін қажет. Бұл науқастарға онлайн режимінде қызмет көрсетуге мүмкіндік береді. Жеке жаттығу жоспары науқастарға онлайн, қашықтықтан қызмет көрсету үшін жасалады және қолданушы жеке кабинетінде орналасады.

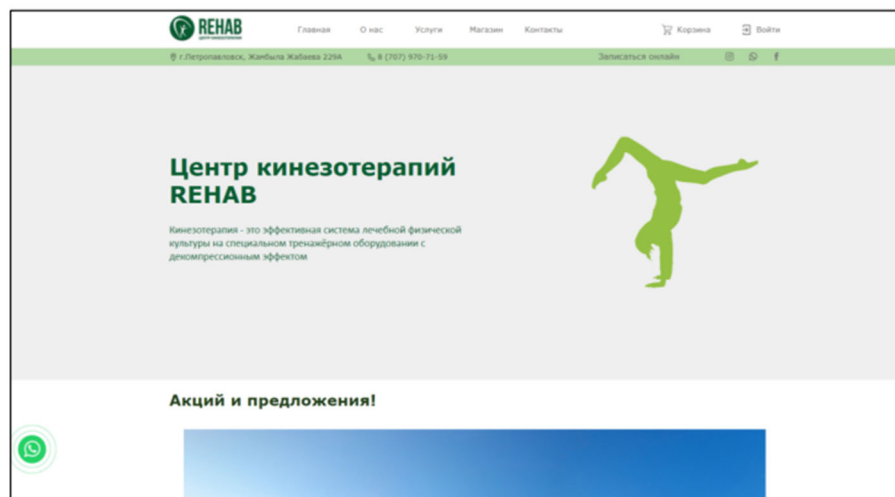
Медициналық орталықтың қызметі бойынша зерттеулер мен талдаулар жүргізіліп, жоба үшін негізгі міндеттер тізімі айқындалады. Жоба-дизайны заманауи безендірілген және көзге жағымды болуы қажет. Функционалдық жағынан келесі тізім айқындалған:

- қолданушылардың қосымшаға тіркелу мүмкіндігі;
- қабылдауға онлайн-тіркелу мүмкіндігі;
- интернет-дүкен және тауар-қоржыны;
- қолданушының жеке кабинеті;
- қолданушының пікір қалдыру мүмкіндігі;
- басқару-панелі;
- ұйым мамандары үшін, клиенттерге жеке жаттығу жоспарын құру мүмкіндігі;
- интернет-дүкенің басқару мүмкіндігін (тауарды қосу, жою және т.б.);
- қосымша мазмұнын басқару мүмкіндігі (мәтіндерді, суреттерді реттеу, жою);
- қосымшаны басқа құрылғыларда дұрыс ашылуын қамтамасыз ету;

Қойылған міндеттерді шешу үшін келесі технологиялар таңдалады: HTML, CSS, JavaScript, PHP 7.4.4, MySQL.

Веб-қосымшаның құрылымы пайдаланушының ыңғайлылығына маңызды рөл атқарады. Медициналық орталықтың веб-қосымшасының басты беті 1-суретте көрсетілген. Басты беттің жоғарғы бөлігінде пайдаланушының жүйе бөлімдері арасында навигация жасауын қамтамасыз ететін негізгі мәзір орналасқан. Сонымен қатар, интерфейс құрамында

медициналық орталықтың фирмалық логотипі, интернет-дүкендегі таңдалған тауарларға қол жеткізуге арналған «Қоржын» бөлімі және пайдаланушының жүйеде авторизациядан өтуі немесе жаңа есептік жазба құруы үшін арналған басқару элементтері қарастырылған. Аталған интерфейс элементтері веб-қосымшаның негізгі функционалдық бөлімдеріне жылдам әрі ыңғайлы қол жеткізуді қамтамасыз етеді.



Сурет 1. Басты бет

Навигациялық мәзір элементтері горизонталды түрде кезекпен орналасқан. Бұл парақшалар арасында жүруге ыңғай әкеледі. Медициналық орталықтың мекен-жайы, байланыс телефоны, онлайн-тіркелу бастырмасымен әлеуметтік желі сілтемелері орналасқан. Бұл қоладнушыларға ақпараттарды жедел табу үшін жасалған. Басты беттегі қосымша дизайнын безендіріп, қолданушылардың назарын аударуға мүмкіндік береді.

Науқастардың қалдырған пікірлер тізімі слайдер түрінде, екі блоктан тұрады. Клиенттердің пікірлерін көрсету жаңа клиенттердің сенімін арттыруға көмек көрсетеді. Веб-парақшаның астыңғы бөлігінде негізгі мәліметтер, байланыс ақпараттары орналасады.

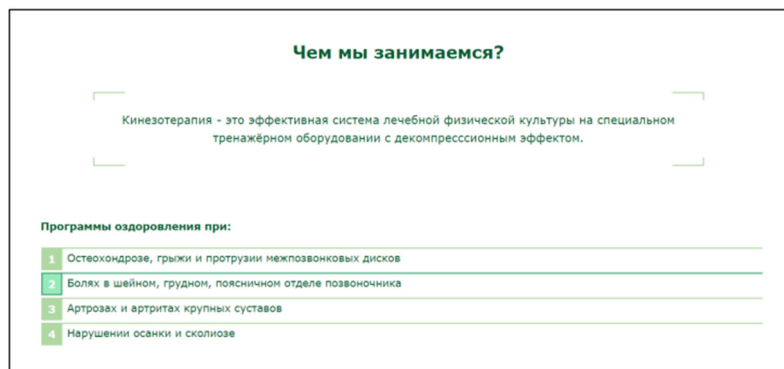


Сурет 2. Слайдер және футер.

Веб-қосымшаның «Біз туралы» бөлімінде медициналық орталықтың қызметі мен ұйымдастырушылық құрылымы туралы негізгі ақпарат ұсынылады. Аталған бөлімнің интерфейсінде орталық басшысы туралы мәліметтерді, көрсетілетін медициналық

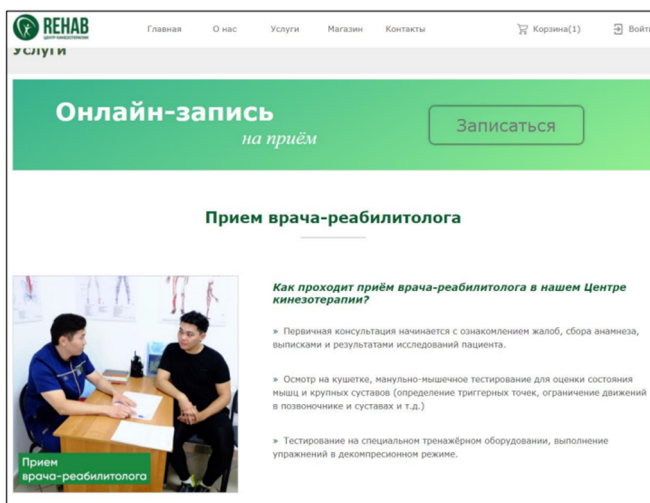
қызметтердің сипаттамасын, емдеу бағыттары мен медициналық көрсетілімдер тізімін, сондай-ақ орталық мамандары туралы ақпаратты қамтитын ақпараттық блоктар орналастырылған.

Орталықтың негізгі медициналық қызметіне қатысты ақпарат 3-суретте көрсетілген. Бұл бөлімде кинезотерапия ғылымының ғылыми сипаттамасы, оның емдік-оңалту мақсатындағы қолданылу ерекшеліктері және аталған әдіс қолданылатын аурулар мен патологиялық жағдайлардың тізімі берілген. Сонымен қатар, пайдаланушыларға медициналық қызметтің мазмұны, қолданылу саласы және негізгі емдеу бағыттары туралы толық ақпарат алу мүмкіндігі қарастырылған.



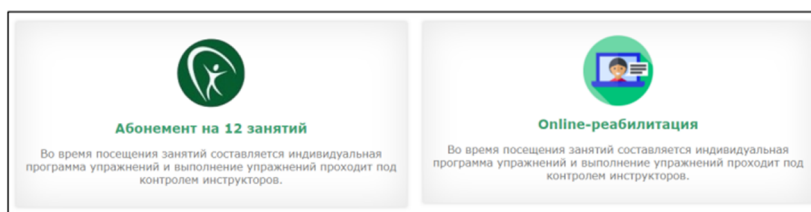
Сурет 3. «Біз немен айналысамыз» блогы

«Біздің мамандарымыз» блогында мамандар тізімі, фото-сурет, мамандардың аты-жөні, лауазымы көрсетілген. «Біз туралы» бөлімінде көрсетілетін қызметтер туралы ақпарат алуға болады.



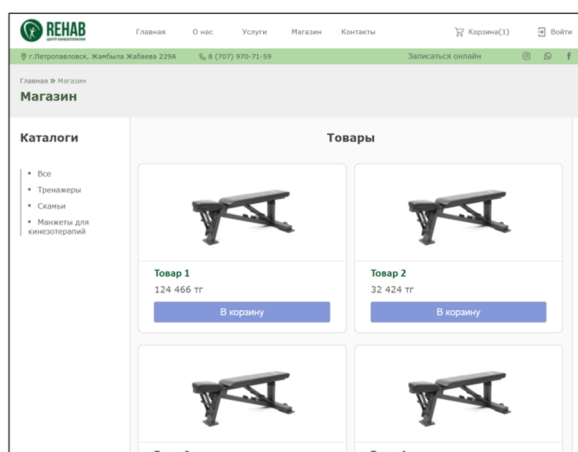
Сурет 4. «Біз туралы» бөлімі

Беттің жоғарғы бөлігінде онлайн-тіркеу бастырмасы орналасқан. Қызметтер бөлімінде 12 жаттығуға абонемент және веб-қосымшада жасалынған онлайн-оңалту туралы мәліметтер орналасқан. Блок келесі бөліктерден тұрады: сурет; қызмет атауы; сипаттамасы.



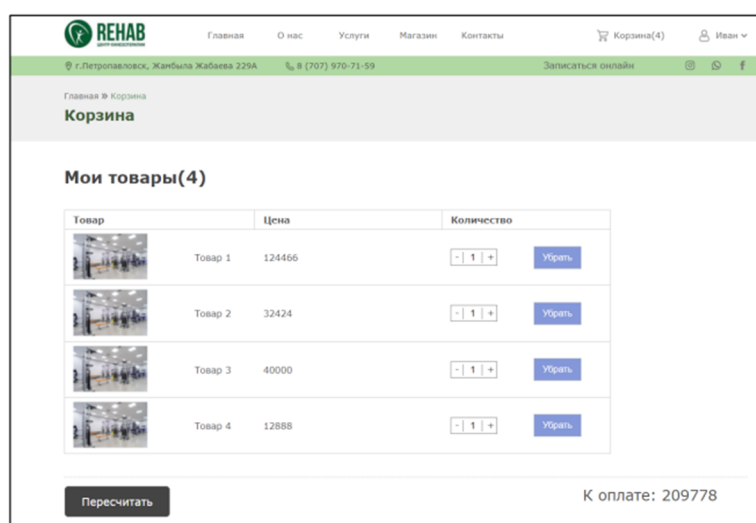
Сурет 5. Қызметтер туралы ақпарат

Веб-қосымшаның «Дүкен» бөлімінде орталық ұсынатын тауарлар онлайн-дүкені орналасқан. Парақшаның сол жағында дүкендегі тауарлардың атаулары, тауар туралы ақпарат орналасқан каталогтар бөлімі бар. Мұнда тауар суреті, тауар атауы, құны, қоржынға енгізу бастырмасы орнатылған.



Сурет 6. «Дүкен» бөлімі

Тауарлар тізімі бар қоржында тауар саны, тауарлар тізімі кесте түрінде беріледі. Астыңғы жағында тауар саның қайта санау үшін арнайы батырма мен тауарлардың жалпы саны көрсетілген жазба орналастырылған.



Сурет 7. Тауар кестесі элементі

Веб-қосымшаның «Байланыстар» бөлімінде орталықтың байланыстары, мекен-жайы, поштасы, сонымен қоса қабылдау күндері мен уақыты туралы ақпарат орналасқан. Веб-қосымша арқылы науқастар орталықтағы дәргерлерге онлайн-тіркелу мүмкіндігі бар. Формада науқастардың аты-жөні, байланыс телефоны, дәргерге жазылу күнін, келу уақытын таңдай алады. Осы форма арқылы қызметкерлер тапсырысты қабылдайды.

The image shows two parts of the online registration process. On the left is the registration form titled "Онлайн-запись". It contains fields for "Имя" (Name), "Фамилия" (Surname), and "Контактный телефон" (Contact phone number). There are also dropdown menus for "Выберите дату" (Select date) and "Выберите время" (Select time). Below these fields are buttons for "Отправить запрос" (Send request) and "Закрыть" (Close). On the right is a confirmation box titled "Заявка от пользователя(Online-запись)". It displays the submitted information: Имя: Алмаз, Фамилия: Домолаков, Телефон: +77778954367, Желаемая дата: 25-03-2022, and Желаемое время: 16:45.

Сурет 8. Онлайн-тіркелу туралы ақпарат

Науқас веб-қосымшаға тіркелу үшін ұсынылған нысанды толтыру керек. Тіркелу арқылы қолданушы ұйым клиенті ретінде жеке кабинет ашылады және оған кіре алады.

The image shows a screenshot of a web application interface for a rehabilitation center named "REHAB". The page is titled "Личный кабинет" (Personal cabinet). It displays user information under the heading "Общие данные" (General data): Имя: Иван, Фамилия: Иванов, Email: ggg@mail.ru, Телефон: 87774535345, Дата регистрации: 10.03.2022, and Диагноз: Диагноз ... Below this, there is a section titled "План упражнений" (Exercise plan) which contains a table with two exercises. Exercise 1 is "упражнение 1" with the description "Выполнять 3 раза в день, в течение недели" and a "Смотреть" (View) button. Exercise 2 is "упражнение 2" with the description "Выполнять каждый день, 1 раз" and a "Смотреть" (View) button.

Сурет 9. Науқастың жеке кабинеті

Жеке кабинетте науқастың аты, тегі, электронды пошта адресі, байланыс телефоны, тіркелген күні және диагнозы туралы ақпарат болады. Науқас жеке кабинетінде жеке жаттығу жоспары көрсетіледі.

План упражнений		
№1	Название Упражнение 1	Описание Выполнять 3 раза в день, в течение недели
№2	Название Упражнение 2	Описание Выполнять каждый день, 1 раз
№3	Название Упражнение 3	Описание Выполнять 1 раз в неделю, месяц
№4	Название Упражнение 4	Описание Выполнять каждый день 1 раз
№5	Название Упражнение 5	Описание Выполнять 3 раза в неделю

Сурет 10. Науқастың жеке жаттығу жоспары

Жаттығу орналасқан тізбек элементі келесі бөлімдерден тұрады: жаттығу нөмірі, жаттығу атауы, сипаттамасы, жаттығуды қарау бастырмасы. Тізбектегі қарау бастырмасын басқан кезде, сәйкес жаттығуға тиесілі бейне-жазба ашылады. Науқас қосымшадан шықпай сол жаттығуларды қарай алады. Жеке кабинетте орналасқан клиенттер пікірлерін қабылдайтын формасы негізгі жазба бөлімінен және жіберу бастырмасынан тұрады. Клиенттер қалдырған пікірлер, веб-қосымшаның бас парағында шығарылады.

Оставьте ваш отзыв!

Введите сообщение

Отправить

Сурет 11. Жеке кабинеттегі кері байланыс

Жобаның тәжірибелік маңыздылығы медициналық орталықтың негізгі қызмет көрсету үдерістерін цифрландыруға және автоматтандыруға бағытталған веб-қосымшаны әзірлеумен айқындалады. Ұсынылатын ақпараттық жүйе пайдаланушыларға медициналық қызметтерге қашықтан электрондық тіркелуге, жеке кабинет арқылы дербестендірілген емдеу және оңалту жоспарларына қол жеткізуге, сондай-ақ қажетті медициналық тауарларды электрондық сауда платформасы арқылы сатып алуға мүмкіндік береді.

Жеке кабинет функционалы пайдаланушының медициналық қызметтермен өзара әрекеттесуін жүйелеуге, жеке емдеу жоспарын ұсынуға және қажетті ақпаратқа жедел қол жеткізуді қамтамасыз етуге мүмкіндік береді. Интернет-дүкен модулін енгізу тауарларды онлайн режимде ұсыну және тапсырыстарды электрондық форматта рәсімдеу үдерісін автоматтандырады. Осылайша, мақалада қарастырылған веб-қосымша медициналық орталықтың қызмет көрсету үдерістерінің тиімділігін арттыруға, пайдаланушыларға көрсетілетін қызметтердің қолжетімділігі мен ыңғайлылығын қамтамасыз етуге, сондай-ақ ұйымның цифрлық инфрақұрылымын жетілдіруге мүмкіндік береді. Жобаның нәтижелері медициналық қызмет көрсету сапасын арттыруға және орталықтың ақпараттық үдерістерін оңтайландыруға бағытталған практикалық шешім ретінде сипатталады.

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Psychological Sciences

Theoretical foundations of the self-efficacy and psychological well-being relationship in industrial training

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Abstract: Depending on the changing conditions of universities, students' self-efficacy, life satisfaction, and related life goals vary. In today's conditions, one of the missions of universities is to cultivate individuals who think analytically, critically, objectively, creatively, and reflectively. The development of individuals with high levels of self-efficacy is largely directly proportional to these factors. Individuals' life goals change and differ in parallel with changing conditions. In particular, rapidly changing technology is reflected suddenly and quickly in individuals' living conditions, which affects their self-efficacy levels and causes them to change their life goals in line with the changing conditions.

This study aims to compare university students' life goals (desires) with their levels of general self-efficacy and life satisfaction. Based on this, the relationship between students' life goals and their levels of life satisfaction and general self-efficacy has been investigated.

In Psychological Counseling and Guidance, which, as a fundamental discipline, prioritizes the human being, aims to raise awareness, and enable self-actualization, special importance is given to life satisfaction. What makes life satisfaction so prominent is that individuals give meaning to their lives. The development of these multiple dimensions of the human being to the maximum extent parallels general self-efficacy and life satisfaction. Accordingly, it is known that individuals who achieve their life goals generally also have high levels of life satisfaction. Throughout history, many religions, philosophical beliefs, and mythologies have taught that individuals must have a purpose in life to make it meaningful. People with a purpose in life tend to be more strongly attached to life, better able to cope with challenges, find solutions, and biologically survive longer.

Keywords: self-efficiency, motivation, well-being, mental health, students

The concept of self-efficacy was first defined by Albert Bandura (Bandura 1989). Albert Bandura, who developed the social cognitive learning theory, named the concept of self-efficacy as "Self-Efficacy". Technically, self-efficacy is called "perceived self-efficacy". Bandura (1986) defines self-efficacy as an individual's own judgment about their capacity to organize and successfully perform the activities necessary to demonstrate a certain performance (Senemoğlu, 2002).

While Dale H. Schunk and Frank Pajares, Bandura's students who conducted many studies in the field of self-efficacy, expressed it as "Self-Efficacy", the concept of self-efficacy has been defined and used in different ways in the relevant literature in our country. Bandura (1999) defined self-efficacy as a fundamental concept of social cognitive theory, which he described as relating to people's beliefs about their ability to behave in a way that allows them to exert some control over events affecting their lives. Many researchers have defined self-efficacy in the literature. Pintrich and Linnenrink (2003) define self-efficacy belief as judgments about individuals' capacity to

organize and implement activities necessary to achieve defined performance patterns; authors define it as a judgment reached on a person's ability to organize and perform specific forms of performance, while personal success is a judgment reached on the outcomes of such performances; Schunk (1991) defines self-efficacy as essentially an individual's ability to control their emotional performance, which they acquire and use in difficult situations; and Çetin defines it as the result of the cognitive processing of various sources of competence knowledge revealed through interpretation, indirectly, socially, and physiologically (Çetin, 2007).

One of the most important processes in individuals' lives is personal development. Rogers described the developmental tendency, the drive for self-actualization, as a movement toward existence (Burger, 2006). According to humanistic psychology, life is not merely about meeting our basic needs. Humanistic theories state that humans are not happy when their basic needs are met. People are motivated to continue their development in a positive direction. If left to their own devices, and if they are not crushed under the burden of life, a person progresses towards a point of self-satisfaction. Carl Rogers called this point the person who fully utilizes their potential. The path to becoming a self-actualized individual is through 'becoming everything you can be'. This developmental process is assumed to be the natural form of human development. That is, unless certain problems prevent people from progressing, humankind progresses towards this satisfying state. When obstacles stop our personal development, humanistic psychology helps. However, the therapist does not bring the client back to this developmental process. Only the client themselves can do this. The therapist helps the client overcome their problems and grow; to continue their personal development. Rogers defines this never-ending process of self-discovery as the 'process of becoming'. Rogers said that 'a good life' is 'not a state, but a process. Not a destination, but a direction'. People who fully utilize their potential are open to new experiences. Instead of exhibiting similar, stereotypical behaviors, they want to see where life will take them. In connection with this, fully productive people try to appreciate every moment of life. The goal is not to brush past life, but to experience life fully. A person who fully utilizes their potential learns to trust their own feelings. If their feelings tell them that something is right, they are most likely to do it. They are not insensitive to the needs of others; however, they are not overly concerned with conforming to societal norms of behavior. Instead, they determine their own life goals; they consider their own interests, values, and needs when making important decisions such as career choice and lifestyle. Individuals who fully utilize their potential experience their emotions more deeply and intensely than others. This applies to both positive and negative emotions. Because of this sensitivity, individuals who fully utilize their potential experience greater richness in their lives (Burger, 2006).

A study was conducted by Massey, Gebhardt, and Garnefski in 2009, authors investigated individual differences in goal and goal-process evaluations among adolescents based on their socio-demographic characteristics, as well as the relationship between goal content, goal-process evaluation, and well-being. The findings revealed that girls and older students had more goals related to school, relationships, and physical appearance, while girls and ethnic minority adolescents experienced more disappointment in terms of personal goals. It also showed that good and positive outcomes in personal goals positively affected self-efficacy. Senecal et al., in their 2000 study on 638 diabetic patients, related the concepts of self-efficacy and self-regulation from social-cognitive theory to motivation, diet, commitment to self-care, and life satisfaction using a structural equation model. The results showed that self-efficacy and self-regulation were related to life satisfaction. According to the model, individuals with greater self-regulation, independence, and high self-efficacy showed increased dietary initiative, self-care, and life satisfaction. Lent et al. (2005), in their research integrating studies that used the core variables of social cognitive theory to predict general and specific life satisfaction individually, found that perceived self-efficacy, life

goals (personal growth), and environmental factors predicted life satisfaction in the specific life domain.

Conclusion: People with weak self-efficacy perceive the obstacles or actions they encounter in achieving their goals as more difficult than they seem, view everything from a narrow perspective, and find it very difficult or unsuccessful to find solutions to the problems they face. However, people with strong self-efficacy are more relaxed, calm, confident, and strong in difficult tasks, challenging goals, or difficult situations. When faced with failure, they try to overcome this problem by identifying it as a mistake made in achieving the goal and then putting more effort into achieving the goal again by correcting it (Bandura, 1998; Bandura, 1994). The sources of self-efficacy include an individual's previous experiences with the situation, learning from the experiences of others (modeling-representative experience), environmental support/verbal persuasion, and the individual's psychological and physiological state (Vera et.al, 2004). The processes influencing the development of self-efficacy perception are identified as cognitive processes, motivational processes, emotional processes, and choice processes.

The circumstances and psychological state of individuals are factors that influence their self-efficacy beliefs. Positive conditions and a positive psychological state increase self-efficacy, while negative physiological conditions or mood have a negative impact on self-efficacy beliefs. Bandura (1994) states that this area of influence on self-efficacy beliefs plays a particularly effective role in sports; in athletic and other physical activities. In this case, individuals can be enabled to reach positive judgments regarding their self-efficacy beliefs by changing their negative physiological and psychological conditions or their perceptions/beliefs in these conditions.

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Legal Sciences

RISK CRITERIA FOR FOREIGN INVESTMENT SCREENING: COMPARATIVE LESSONS FOR KAZAKHSTAN

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Abstract. Foreign investment screening has become an increasingly important instrument for reconciling investment openness with national security and economic resilience. This paper examines a specific question within this debate: which characteristics of an investment transaction justify enhanced security-related scrutiny. Using a qualitative comparative analysis of selected regulatory approaches in the United States, the European Union, India, and Kazakhstan, the study groups relevant risk variables into four categories: the sensitivity of the asset or sector, characteristics of the investor, characteristics of the transaction, and the potential consequences for national interests. The comparison shows that contemporary screening systems increasingly focus on targeted assessment of access to critical infrastructure, technologies, sensitive data, essential inputs, and strategic decision-making rights rather than on foreign capital as such. Kazakhstan already applies security-related controls to transactions involving strategic objects, including sectoral assessment, review of concentration of rights, consultation with national security authorities, and consideration of threats to national interests. These mechanisms, however, are not equivalent to a general cross-sectoral foreign investment screening regime. The paper argues that formalized risk criteria could provide a practical basis for a proportionate and transparent approach to identifying transactions that warrant enhanced review while preserving investment openness.

Keywords: foreign investment screening; economic security; strategic assets; national security; Kazakhstan

Introduction

Foreign direct investment (FDI) remains an important source of capital, technology, managerial expertise, and integration into global value chains. At the same time, states have become more attentive to the security implications of economic interdependence. The literature on economic statecraft explains how economic instruments can be used to pursue strategic objectives, while the concept of weaponized interdependence shows how control over central nodes in international networks can create asymmetric power and opportunities for coercion (Baldwin, 1985; Farrell & Newman, 2019). More recent research on the European Union likewise describes a broader geoeconomic turn in which trade and investment instruments are increasingly connected with security considerations (Bauerle Danzman & Meunier, 2024).

This shift does not mean that foreign capital is inherently risky. The policy problem is narrower: some transactions may provide access to assets, technologies, data, infrastructure, or decision-making mechanisms whose disruption, transfer, or external control can have consequences beyond the commercial interests of the parties. The OECD notes that investment screening has become the most common instrument used by OECD members to manage national-

security implications associated with certain foreign investments, while its guidance emphasizes non-discrimination, transparency, predictability, proportionality, and accountability (OECD, 2021, 2025).

For developing and investment-dependent economies, the regulatory dilemma is particularly pronounced. Excessively broad controls may increase transaction costs, weaken legal certainty, and discourage bona fide investors. Conversely, a regime that does not distinguish between ordinary commercial investment and transactions involving critical assets may leave strategically important sectors insufficiently protected. The central analytical task is therefore not to decide whether foreign investment should generally be restricted, but to identify the conditions under which a specific transaction justifies enhanced security review.

Existing studies have examined the political drivers and institutional evolution of investment screening, especially in the United States and the European Union. Research on the EU has shown both the historical fragmentation of national investment rules and the gradual emergence of coordination and common screening standards (Meunier, 2014; Chan & Meunier, 2022; Doppen, 2026). Less attention, however, has been paid to how the underlying risk variables can be translated into a compact analytical framework suitable for an investment-dependent state that does not yet operate a comprehensive cross-sectoral FDI screening regime.

The purpose of this paper is therefore to identify recurring security-related risk criteria in selected investment-control regimes and to assess their relevance for Kazakhstan. The research question is: which combinations of asset, investor, transaction, and consequence-related characteristics can provide a defensible basis for deciding when a foreign investment transaction requires enhanced review? The paper does not propose a complete institutional architecture for Kazakhstan. Instead, it focuses on the first analytical stage of screening: identifying which transactions require closer scrutiny and on what grounds.

Materials and Methods

The study uses a qualitative comparative-institutional approach. The primary materials consist of official legislation, regulations, and policy documents governing investment screening or security-related investment control in the United States, the European Union, India, and Kazakhstan. The analysis is supplemented by OECD guidance and peer-reviewed research on economic statecraft, geoeconomics, and the institutional development of FDI screening.

The jurisdictions were selected to capture different regulatory logics rather than to construct a representative global sample. The United States provides a mature cross-sectoral national-security review mechanism with jurisdiction over both control transactions and specified non-controlling investments. The European Union is relevant because its framework combines national decision-making with common risk factors and a cooperation mechanism; the Regulation adopted in 2026 additionally moves toward greater harmonization. India illustrates a narrower form of targeted government approval linked to investor origin and beneficial ownership under its revised 2026 FDI rules. Kazakhstan is the national case in which security-related controls already exist for strategic objects but do not amount to a general FDI screening regime.

The comparative procedure was conducted in three stages. First, official sources were reviewed to identify the legal triggers and substantive factors used to determine whether additional scrutiny is required. Second, these factors were coded into four analytical groups: (1) asset or sector characteristics; (2) investor characteristics; (3) transaction characteristics; and (4) potential consequences for security or national interests. Third, the resulting categories were compared with the criteria already embedded in Kazakhstan's regulation of strategic objects in order to distinguish existing domestic elements from additional criteria that would be needed for a broader risk-oriented approach.

The study does not attempt to rank the effectiveness of national regimes or estimate their impact on FDI flows. Such claims would require comparable administrative data on screened

transactions, outcomes, mitigation measures, and investment effects that are not consistently available across jurisdictions. Instead, the analysis is limited to institutional design and the legal logic of risk identification. This limitation is important because the same term — “screening” — can cover mechanisms with different scopes, thresholds, and decision-making powers.

Risk Criteria in Foreign Investment Screening

A risk-oriented approach shifts attention from the nationality of capital as such to the characteristics of the asset, investor, transaction, and possible consequences. A screening regime that treats all foreign investment as equally risky creates unnecessary administrative burdens and can blur the distinction between economic-security policy and protectionism. By contrast, transaction-specific criteria allow regulators to focus on cases in which an investment may create access to strategically important capabilities, information, infrastructure, or dependencies.

The first category concerns the asset or sector. Modern screening regimes commonly pay particular attention to critical infrastructure, critical and emerging technologies, energy and transport systems, sensitive data, essential inputs, and defense-related activities. Article 4 of Regulation (EU) 2019/452 lists critical infrastructure, critical technologies and dual-use items, critical inputs, sensitive information, and media freedom and pluralism among the factors that may be taken into account when assessing effects on security or public order (European Parliament & Council of the European Union, 2019). In the United States, the post-FIRRMA rules similarly distinguish businesses connected with critical technologies, covered investment critical infrastructure, and sensitive personal data (U.S. Department of the Treasury, 2020).

The second category concerns the investor. The ownership structure of an investor can alter the risk profile of the same transaction. Relevant factors may include direct or indirect control by a foreign government, state financing, beneficial ownership, prior involvement in transactions that raised security concerns, or other relationships capable of affecting commercial autonomy. The EU framework expressly permits consideration of whether a foreign investor is directly or indirectly controlled by a third-country government (European Parliament & Council of the European Union, 2019, Art. 4(2)). India provides a different example. Under Press Note No. 2 (2026 Series), an entity or citizen of a country sharing a land border with India remains subject to the Government route, while beneficial ownership in an investor entity registered elsewhere is assessed by reference to the Prevention of Money-laundering framework and specified ownership or control criteria (Government of India, 2026).

The third category concerns the structure of the transaction and the rights created by it. Security relevance cannot be inferred from ownership percentage alone. A non-controlling investment may still provide board representation, access to non-public technical information, participation in substantive decision-making, or other rights affecting sensitive operations. The U.S. rules are especially instructive because CFIUS jurisdiction extends to certain non-controlling investments in TID U.S. businesses when specified access, governance, or decision-making rights are present (U.S. Department of the Treasury, 2020). This illustrates why the legal analysis of a transaction should focus on effective access and influence rather than only on the nominal share acquired.

The fourth category is consequence-based. The relevant question is what could happen if the investment creates or deepens a vulnerability. Possible consequences include disruption of essential services, loss of access to critical technologies, excessive dependence on a foreign supplier, exposure of sensitive data, reduced resilience of critical infrastructure, or leverage over decisions that affect national security. The new Regulation (EU) 2026/1386 develops this logic further by requiring consideration of effects on critical technologies, critical entities and infrastructure, critical inputs, public health, food security, and sensitive military or public facilities, together with investor-related information (European Parliament & Council of the European Union, 2026, Art. 19).

These categories should not be treated as four independent checklists. In practice, risk generally arises from combinations of factors. State ownership of an investor may be unremarkable in a low-sensitivity activity but more consequential when combined with access to strategic data or critical infrastructure. Similarly, investment in a sensitive sector does not automatically imply an unacceptable risk if the transaction does not create control, access, dependency, or other adverse consequences. The analytical value of risk criteria therefore lies in their interaction: they provide a structured way to identify cases that require deeper assessment rather than a presumption that a listed characteristic alone justifies prohibition.

Comparative Approaches

In the United States, the Committee on Foreign Investment in the United States (CFIUS) operates a mature transaction-specific national-security review system. FIRRMA and the implementing rules preserved jurisdiction over transactions that may result in foreign control of a U.S. business and expanded review to certain non-controlling investments. The 2020 rule defines covered investment relationships with TID U.S. businesses and focuses on critical technologies, covered investment critical infrastructure, and sensitive personal data, while also examining the rights and access obtained by the foreign person (U.S. Department of the Treasury, 2020). The U.S. example therefore shows a relatively developed interaction between target sensitivity and transaction-specific access rights.

The European Union follows a different institutional structure because final screening decisions historically remained with the Member States, while Regulation (EU) 2019/452 created common factors and a cooperation mechanism. Academic research has emphasized that this arrangement emerged from previously fragmented national approaches and reflects a continuing effort to reconcile economic openness, national security, and European-level coordination (Meunier, 2014; Chan & Meunier, 2022). The 2026 reform marks a further step in this evolution. Regulation (EU) 2026/1386 entered into force on 16 July 2026, while most of its substantive framework will apply from 17 January 2028. It requires Member States to establish screening mechanisms, creates a common minimum scope for ex ante screening in specified sectors and activities, and expressly provides for risk-based screening decisions and mitigating measures (European Parliament & Council of the European Union, 2026, Arts. 3, 4, 19–20, 31).

This temporal distinction is important. As of September 2026, Regulation (EU) 2019/452 remains the principal operational framework for most screening activity, while Regulation (EU) 2026/1386 represents the legally adopted next stage of harmonization. The direction of reform nevertheless reinforces a central observation relevant to Kazakhstan: screening systems are moving toward more explicit definition of risk factors, clearer procedural requirements, and greater use of mitigation rather than a simple binary choice between unconditional approval and prohibition. This development is consistent with the broader geoeconomic shift identified in recent scholarship (Bauerle Danzman & Meunier, 2024; Doppen, 2026).

India illustrates a narrower regulatory logic. Press Note No. 2 (2026 Series), issued on 15 March 2026, revised the land-border-country rules originally introduced in 2020. Under the revised policy, an entity or citizen of a country sharing a land border with India is subject to the Government route. For an investor entity incorporated or registered in another country, the beneficial-ownership test is linked to the Prevention of Money-laundering framework and specified ownership or control criteria; investments with certain direct or indirect land-border-country ownership that do not require prior approval are subject to reporting requirements (Government of India, 2026). This regime should not be equated with the comprehensive cross-sectoral national-security screening systems found in the United States or increasingly institutionalized in the EU. Its relevance to the present comparison is more specific: it demonstrates how investor origin, beneficial ownership, and control can operate as formal regulatory triggers alongside sectoral FDI rules.

The comparison therefore reveals convergence at the level of analytical variables even where institutional forms remain different. The United States places strong emphasis on the interaction between sensitive businesses and the rights acquired by the investor. The EU combines common security factors with investor characteristics and is moving toward a harmonized minimum scope. India provides an example of a formal investor-origin and beneficial-ownership trigger. Taken together, these cases suggest that a defensible screening framework should not rely on a single proxy such as nationality, ownership percentage, or sector. It should instead identify combinations of characteristics that justify enhanced examination.

Table 1. Selected risk variables in investment-related security controls

Jurisdiction	Asset / sector factors	Investor factors	Transaction factors	Regulatory focus
United States	Critical technologies, critical infrastructure, sensitive personal data	Foreign-government interests and ownership/control profile	Control and certain non-controlling investments; access and governance rights	Transaction-specific national-security review
European Union	Critical infrastructure, technologies, inputs, sensitive information and other protected functions	Government control and other investor-related risk factors	Potential effects on security or public order; minimum ex ante scope under 2026 reform	Common risk factors and increasing harmonization
India	Sectoral FDI rules and prohibited/conditional activities	Land-border-country investor status; beneficial ownership and control under 2026 rules	Government-route approval in specified cases; reporting for certain other LBC-linked investments	Targeted entry and investor-related controls
Kazakhstan	Strategic objects and their socio-economic significance	Concentration of rights of the applicant and affiliates from one country	Encumbrance or alienation of a strategic object	Existing strategic-object control; not a general FDI screening regime

Discussion: From Broad Security Clauses to Structured Risk Assessment

The comparative material suggests that the key institutional problem is not the absence of broad security language. Most states can invoke national security or public order in some form. The more difficult question is how to translate these broad concepts into reviewable administrative criteria. OECD work on transparency, predictability, and accountability emphasizes that screening regimes become more predictable when governments define the interests protected, publish relevant factors or illustrative criteria, and provide procedures that constrain arbitrary decision-making (OECD, 2021). For an investment-dependent economy, this is especially important because uncertainty itself can become a regulatory cost even when very few transactions are ultimately restricted.

A structured risk assessment can also help separate the decision to screen from the final decision on the transaction. These are analytically different stages. The presence of a trigger should mean that a transaction deserves closer examination; it should not automatically mean that the investment is harmful or should be prohibited. This distinction is visible in the 2026 EU Regulation, which requires a risk-based analysis and allows authorization subject to mitigating measures when identified concerns can be adequately addressed (European Parliament & Council of the European Union, 2026, Art. 20). The same logic can be useful in designing a proportionate approach for Kazakhstan without importing the entire institutional architecture of another jurisdiction.

The comparison also indicates that risk criteria should be sufficiently stable to guide investors but sufficiently flexible to capture changing forms of vulnerability. Static lists of sectors are useful because they improve predictability, but they may become outdated as technologies, supply chains, and data-intensive business models change. A more resilient design combines a defined list of sensitive areas with functional criteria such as access to sensitive information, influence over strategic decisions, dependence on a single supplier, or the possibility of disruption of an essential service. Such functional criteria explain why screening systems increasingly examine the substance of access and control rather than only the formal legal category of the target company.

Finally, the cases demonstrate that institutional transfer must be selective. CFIUS reflects the legal and security institutions of the United States; the EU mechanism is shaped by the division of competences between the Union and Member States; and India's approval rules respond to a different regulatory context. For Kazakhstan, the comparative value of these systems lies less in copying an organizational model than in identifying transferable analytical principles: specificity of triggers, multi-factor assessment, differentiation between low- and high-risk transactions, and procedural safeguards that maintain openness for ordinary investment.

Implications for Kazakhstan

Kazakhstan does not begin from a regulatory vacuum, but its existing mechanisms should be described accurately. The Law of the Republic of Kazakhstan "On State Property" establishes a special regime for strategic objects owned by individuals and non-state legal entities. Encumbrance or alienation of such objects is possible on the basis of a Government decision, and the Government's decision is based on a sectoral opinion of the authorized body agreed with the national security authorities (Republic of Kazakhstan, 2011, Arts. 187–188). This is an important security-related control, but its object is the legally defined category of strategic assets rather than foreign investment as such.

The Rules approved by Government Resolution No. 1223 make the domestic analytical content more visible. The sectoral opinion evaluates the transaction with regard to the socio-economic significance of the strategic object, sectoral development priorities, concentration of rights of the applicant and its affiliated persons from one country in the same sector, and the presence or absence of threats to the national interests of the Republic of Kazakhstan. The current form of the sectoral opinion also includes assessment of expected effects and perceived risks connected with the transaction (Government of the Republic of Kazakhstan, 2011, as amended). These criteria show that Kazakhstan already uses concepts that are functionally comparable with parts of foreign screening practice.

At the same time, the existing regime has a narrower legal starting point. It is activated because the object has been designated as strategic and a specified transaction involving encumbrance or alienation is contemplated. By contrast, modern FDI screening mechanisms may also capture access to sensitive technologies, data, governance rights, beneficial ownership structures, or dependencies that do not necessarily involve an asset already designated as

strategic. This difference should not be interpreted as a defect in the strategic-object regime; it simply means that the regime solves a different regulatory problem.

For Kazakhstan, the most cautious next step would therefore be to formalize a transparent set of risk criteria for identifying foreign investment transactions that require enhanced assessment, while keeping the threshold for review narrower than ordinary investment regulation. The first block could concern the strategic character of the target: critical infrastructure, strategically important energy and transport assets, defense-related activities, critical minerals, telecommunications and data infrastructure, or technologies whose loss or transfer could create a significant security dependency. The second block could concern the investor, including beneficial ownership, foreign-government control, opaque ownership structures, or links that create a realistic possibility of non-commercial influence.

The third block could concern the rights created by the transaction: acquisition of control, board representation, veto rights, access to non-public technical information, access to sensitive datasets, or participation in decisions affecting continuity of essential operations. The fourth block could focus on consequences: concentration of control in a strategically significant sector, creation of a single-source dependency, potential disruption of essential supplies or infrastructure, transfer of critical capabilities, or other identifiable effects on national interests. Importantly, these criteria would operate as screening triggers and assessment factors rather than as automatic grounds for refusal.

Such an approach would build on, rather than displace, existing Kazakhstani law. The current strategic-object regime already demonstrates the use of sectoral expertise, national-security consultation, concentration analysis, and a national-interest test. A broader risk framework could preserve those domestic elements while adding criteria relevant to modern forms of access, control, and technological dependency. This evolutionary approach may be institutionally more realistic than direct transplantation of CFIUS or the future EU framework.

Proportionality should remain a central design principle. Low-risk transactions should remain subject to ordinary investment procedures, while enhanced scrutiny should be reserved for cases in which objective risk indicators are present. Clear criteria can improve both security and investment predictability: public authorities gain a structured basis for identifying sensitive transactions, while investors gain greater visibility regarding the circumstances in which additional review may be expected. This balance corresponds to the OECD principles of transparency, predictability, proportionality, and accountability (OECD, 2021, 2025).

Conclusion

The comparative analysis shows that foreign investment screening increasingly relies on combinations of risk variables rather than on foreign ownership alone. The most recurrent variables concern the strategic characteristics of the target asset, the investor's ownership and control profile, the rights and access created by the transaction, and the potential consequences for security and essential state or societal functions.

The United States provides the clearest example of transaction-specific analysis that combines sensitive business characteristics with access and governance rights. The European Union has developed common security factors and, through Regulation (EU) 2026/1386, is moving toward a more harmonized minimum screening framework. India demonstrates a narrower but relevant use of investor origin and beneficial ownership as formal approval triggers. These systems are institutionally different, but they converge in treating risk as a combination of factors rather than a single characteristic.

For Kazakhstan, the existing regulation of strategic objects provides a partial domestic foundation for this logic. It already includes sectoral assessment, Government authorization, involvement of national security authorities, analysis of concentration, and consideration of threats to national interests. These mechanisms should not, however, be described as a

comprehensive foreign investment screening regime. Their legal scope is tied to strategic objects and specified transactions involving those objects.

Formalizing transparent security-related risk criteria could provide an incremental way to develop a more systematic approach without imposing generalized restrictions on foreign capital. The immediate value of such criteria would be to determine when enhanced review is justified, not to predetermine the final decision. Further research should examine how these criteria can be translated into legal thresholds, procedural safeguards, interagency assessment rules, and reviewable decision-making standards in the institutional context of Kazakhstan.

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