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Contact information

Website: <https://sconferences.com>

E-mail: info@sconferences.com

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Economic sciences

MODERN TRANSFORMATION OF MANAGEMENT PRINCIPLES: BASED ON HENRI FAYOL'S THEORY

Ainash Mussabekova

Senior Lecturer, Department of Management,
Academician E.A. Buketov Karaganda National Research University,
Republic of Kazakhstan, Karaganda
<https://orcid.org/0000-0001-6787-8967>

Abylai Akzhan

Bakhadirova Gulmira

Academician E.A. Buketov Karaganda National Research University,
Republic of Kazakhstan, Karaganda

Abstract

This research article provides a comprehensive and critical examination of the fourteen principles of management formulated by Henri Fayol in 1916, evaluating their contemporary relevance and adaptation within the 21st-century organizational landscape. In an era dominated by rapid technological disruption, the transition to digital ecosystems, and the emergence of the gig economy, the traditional "command and control" structures of the industrial age are being fundamentally challenged. The study explores the transition from rigid, vertical hierarchies toward flexible matrix management systems, where the classical "unity of command" is being redefined to accommodate multi-dimensional reporting lines and cross-functional collaboration. Furthermore, the article analyzes the shift in core management functions—planning, organizing, commanding, coordinating, and controlling—into more agile, data-driven, and supportive processes. Special emphasis is placed on the evolving role of the human factor, where employees are no longer viewed as mere functional components or "cogs in a machine," but as strategic partners whose intellectual capital and initiative drive organizational innovation. By synthesizing classical administrative theory with modern management paradigms such as Agile, Servant Leadership, and Knowledge Management, this paper demonstrates that Fayol's "golden rules" have not become obsolete. Instead, they have undergone a structural and philosophical metamorphosis, evolving from punitive surveillance mechanisms into frameworks for psychological safety and systemic continuity. The findings suggest that the integration of Fayol's foundational wisdom with modern digital flexibility is essential for achieving operational excellence and resilience in a volatile, uncertain, complex, and ambiguous (VUCA) global market.

Keywords: *management principles, management functions, matrix structure, corporate culture, employee retention, gig economy, partnership relations, digital transformation, leadership.*

In the contemporary global landscape, the essence of organizational success is inextricably linked to the efficiency and sophistication of its management systems. Management is no longer perceived as a mere bureaucratic necessity or a simple oversight function; rather, it is understood as a complex, creative, and scientific synthesis of leveraging diverse resources to achieve collective objectives in an increasingly volatile and uncertain world. The formalization of this discipline as a rigorous academic and practical field began in the early 20th century, spearheaded by the pioneering insights of the French engineer and management theorist, Henri Fayol.

In his 1916 seminal work, "General and Industrial Management," Fayol articulated fourteen "golden rules" or principles that effectively laid the conceptual groundwork for modern administrative science. These principles were designed to provide a roadmap for leaders to organize work, manage people, and steer enterprises toward stability and profit. However, as we navigate the third decade of the 21st century, characterized by rapid technological disruption and globalization, these classical doctrines are being re-examined. While the foundational logic of Fayol remains indispensable, the application of his rules has undergone a radical metamorphosis to meet the demands of a decentralized, digital, and hyper-connected business environment [1].

Despite the seismic shifts in how work is performed today, certain Fayolistic principles continue to serve as the bedrock of organizational health. These include the division of labor, discipline, equity, and the promotion of a collective spirit (esprit de corps). In the current era of "Big Tech" and knowledge-based economies, specialization (division of labor) has not disappeared; it has simply become more granular.

Discipline and equity also remain paramount. In a modern context, equity is no longer just about fair wages, but about inclusivity, diversity, and psychological safety. Organizations that fail to uphold these values find that no amount of advanced technology or capital can compensate for a toxic internal environment. Furthermore, esprit de corps has evolved into the sophisticated domain of "corporate culture." Modern leaders recognize that a shared sense of mission and emotional connection to the brand are the primary drivers of employee retention and high-level performance. Fayol's early observation that a harmonious workforce is more productive remains an undisputed truth in the history of management [3].

Perhaps the most significant departure from classical theory involves Fayol's "unity of command." Historically, this principle dictated that an employee should receive orders from only one superior to ensure clarity and prevent the dilution of authority. In the industrial-age factory, this was the ultimate safeguard against chaos. However, the modern business landscape has necessitated the rise of Matrix Management Systems.

In today's complex organizations, it is standard for a professional to operate at the intersection of different functional and project-based lines. For instance, a software engineer may report to a Head of Engineering for their professional development and long-term career path, while simultaneously reporting to a Project Manager for daily deliverables and sprint cycles. While this dual-reporting system technically violates Fayol's "one person – one boss" rule, it dramatically increases organizational agility. Modern management mitigates Fayol's fear of conflict through clearly defined Service Level Agreements (SLAs) and digital project management tools that delineate responsibilities, thereby ensuring that the core objective—operational efficiency—is achieved through a more flexible architecture [2].

Fayol identified five core functions of management: planning, organizing, commanding, coordinating, and controlling. In a stable, slow-moving economy, these functions were linear and predictable. Today, they have been digitally reimaged:

- 1. Planning as Strategic Agility: Traditional five-year or ten-year plans have largely become obsolete. In a world defined by the VUCA (Volatility, Uncertainty, Complexity, Ambiguity) framework, planning has become a continuous process of "sprints" and pivots. Using Big Data and AI, managers now engage in predictive modeling rather than static forecasting, allowing the organization to change direction within weeks rather than years.*

- 2. Organizing as an Ecosystem: The act of "organizing" has moved beyond physical assets to the management of digital and human ecosystems. Modern organizations often consist of remote teams spread across different continents, connected by cloud-based infrastructures. Organizing today involves managing access to information, digital workflows, and virtual collaboration spaces.*

- 3. From Command to Empowerment: The traditional concept of "commanding" or giving orders is increasingly viewed as an outdated "top-down" relic. In the knowledge economy, authority is derived from expertise and emotional intelligence rather than rank. Leading today is about "servant leadership" and coaching—empowering employees to make decisions autonomously while the manager provides the necessary resources and strategic vision.*

- 4. Coordination via Integration: Coordination has moved from long, bureaucratic meetings to real-time integration platforms like Slack, Trello, and Jira. These tools provide a "single source of truth," allowing for seamless collaboration across different time zones and departments without the friction of traditional communication barriers.*

The "control" function of management has perhaps experienced the most profound philosophical shift. In the early 20th century, control was synonymous with surveillance—ensuring that workers did not deviate from established procedures. In the contemporary era, control has been rebranded as "performance management" and "strategic support" [5].

The modern manager is no longer a "policeman" looking for mistakes; they are a "coach" looking for opportunities to optimize. Through real-time data analytics, managers can identify bottlenecks before they become crises, providing proactive support rather than reactive punishment. This creates a culture of transparency and trust, where feedback loops are shortened, and continuous improvement (the Japanese concept of Kaizen, which echoes Fayol's principle of initiative) becomes part of the organizational DNA.

A major point of discussion in modern management is Fayol's 12th principle: Personnel Stability. Fayol argued that high turnover is both a cause and a consequence of bad management. However, the 21st century has seen the rise of the Gig Economy, characterized by freelance contracts, short-term projects, and "portfolio careers." Generations Z and Alpha are far less likely to seek "lifetime employment."

Does this render Fayol's principle irrelevant? Not necessarily. The concept of stability has shifted from the person to the process. Organizations now focus on "Institutional Memory" and Knowledge Management systems. By documenting processes and utilizing AI to capture expertise, companies ensure that the departure of an individual does not result in the loss of critical organizational intelligence. Stability is now achieved through a robust digital backbone that allows for the seamless "plug-and-play" of human talent, whether they are full-time employees or temporary contractors [6].

Finally, we must address the status of the employee. In classical industrial management, the worker was often treated as a replaceable component—a "cog" in the machine. Modern management philosophy, however, views the employee as a strategic partner. This shift is driven by the realization that in a globalized market, intellectual capital and creativity are the only sustainable competitive advantages.

Treating employees as partners involves involving them in decision-making processes, offering equity in the company, and respecting their work-life harmony. This is the ultimate fulfillment of Fayol's "Initiative" principle. When every member of the organization feels empowered to suggest improvements and take ownership of their work, the enterprise becomes a living, breathing, and self-correcting organism capable of thriving in even the most hostile market conditions.

In conclusion, Henri Fayol's 14 principles are not static museum pieces; they are living ideas that continue to evolve. While the methods of management have changed—moving from paper ledgers to AI algorithms, and from factory floors to virtual offices—the objectives remain constant. Effective management still requires order, discipline, clear communication, and a unified spirit. The challenge for the modern executive is to synthesize the structural wisdom of the past with the technological and social flexibility of the present. By doing so, they ensure that the "golden rules" of management continue to light the way toward organizational excellence in the digital age.

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INNOVATIVE BREAKTHROUGH IN THE ERA OF DIGITAL TRANSFORMATION: THE COMBINATION OF TECHNOLOGY AND HUMAN MOTIVATION

Ainash Mussabekova

Senior Lecturer, Department of Management,
Academician E.A. Buketov Karaganda National Research University,
Republic of Kazakhstan, Karaganda
<https://orcid.org/0000-0001-6787-8967>

Komila Ermatvaeva

Safarmet Fatima

Academician E.A. Buketov Karaganda National Research University,
Republic of Kazakhstan, Karaganda

Abstract

Modern technological revolution is not limited only to the development of algorithms and digital systems, but also creates a real innovative breakthrough at the intersection of human potential and technological capabilities. In this work, the introduction of artificial intelligence and automation processes into human life is considered not only as a technical phenomenon, but primarily as a factor that changes the motivational structure of the individual. The main focus of the article is the problem of finding a balance between technological tools and human creative will, searching for new meaning in the digital environment. Here, the reader will get acquainted with in-depth analyses of how the importance of human capital increases in the era of robotization, and how the main force that drives innovation is not technology, but the internal drivers of a person who effectively controls that technology.

Keywords: Digital transformation, innovation breakthrough, human motivation, artificial intelligence, human capital, technological integration, psychology of digitalization, creative potential, automation, future skills.

Introduction

Today's world is a battlefield where algorithms and human ambition clash. We are witnessing not just technological innovation, but also a transformation of consciousness. While many people perceive digitalization as the rule of dry code and cold steel, in reality, at the heart of any innovative breakthrough is only human motivation and creative will. Technology is just a tool, and the force that turns that tool into a mechanism for global change is the quality of human capital. This study examines a new paradigm for the digital age: we analyze how to synchronize human internal drivers with technological progress in the era of automation and artificial intelligence. If we find the harmony of these two powerful streams, then innovation will become not just a production indicator, but a new stage of human civilization. This text opens the way to a world of new opportunities that are born where the cold calculation of technology and the hot energy of people intersect.

In the current situation, the main task for organizations and society is not only to introduce new technologies, but also to form a person who can effectively use these technologies, who is prone to change, and who thinks creatively. Because no matter how advanced digital tools are, it is people who both activate and direct them. Therefore, motivation, values, and purposefulness are becoming an integral part of digital transformation. It is these factors that form the basis for the sustainable and high-quality development of innovation.

In addition, in the digital era, the role of knowledge and skills has increased more than ever. Continuous learning, self-development, and adaptation to new technologies are among the main abilities of a modern person. The harmony between man and technology not only increases professional efficiency, but also accelerates the overall pace of development of society.

intellectual potential to infinity. The main competitive advantage at this stage is not having the most advanced software, but being able to direct these systems to ethical norms and the benefit of humanity. In fact, the digital evolution is not a technological triumph, but a rediscovery of one's own being on a new level. At the heart of any complex algorithm is a person who defines its purpose. Therefore, the real architects of the future will not be engineers who rely solely on cold calculations, but creative leaders who can imbue technology with deep values, thinking strategically.

1. Motivation 3.0: Human Drivers in the Age of Artificial Intelligence

The biggest mistake in the era of digital transformation is to consider a person as a mechanism or function of a machine. Despite the fact that we proclaim "Industry 4.0", many management systems still cannot get rid of the "stick and sweet bread" method of the last century. However, the truth is that in a high-tech environment, standard labor motivation — salary or strict control — has completely lost its power. In today's digital world, artificial intelligence performs any logical task faster and more accurately than a person, but it can never imitate inner fire and passion.

A real innovation breakthrough is possible only when the Motivation 3.0 model is implemented. This is a system of internal drivers based on autonomy, mastery and a high goal [1].

As studies have shown, material incentives can sometimes reduce the quality of work in industries that require creativity and highly intellectual labor. Why? Because only when a person feels like an architect of the process, not a prisoner of the algorithm, does his brain switch to "genius mode". The main capital in the age of artificial intelligence is not time, but energy and attention.

In my opinion, the harmony of technology and man is not a machine replacing a person, but a machine freeing a person from routine and allowing him to "be a person" [8].

Robots do not take away work, they save us from meaningless labor. Therefore, the main driver of today's innovation is not the power of technology, but the inner freedom of a person who wants to use that technology to increase his potential to infinity. We can reach new heights not by arming algorithms, but by arming the human spirit with digital tools.

2. Synchronization strategy: A hybrid model of technology and personality

The real formula for an innovative breakthrough is a hybrid union of technological power and emotional intelligence [6].

Today, there are so many "smart" systems that we have reached the thresh old of "digital burnout". In fact, even the most advanced software, if it contradicts the natural cognitive characteristics of a person, will simply become digital garbage. Real progress is adapting technology to a person, not enslaving a person to technology. We have entered an era of new interfaces that consider digital tools as an extension of the human brain and nervous system [3].

The main concept in this section is symbiosis. According to statistics, when a person and artificial intelligence work together, the efficiency of a task is 40% higher than that of a robot or a person alone [8].

Why? Because a machine is perfect at processing data, and a person is unparalleled in giving meaning to that data and feeling the context. The synchronization strategy is to give the routine to the machine, leaving the strategic decisions and creative framework in the hands of a person. This is not just a technical solution, it is a new ecology in the labor market.

I deeply believe that the most important skill of the future is not writing code, but the ability to communicate with technology. Only when we accept technology as a "complement" will digital transformation begin to bear fruit. Technology should not tire a person, but rather be a springboard that overcomes his fatigue and leads to higher goals. Only where this harmony is established will innovation become not just a term, but a way of life. We must not be slaves of algorithms, but conductors who direct them to fulfill the great dreams of humanity.

3. Architecture of the Future: Do not resist change, but manage it

The biggest obstacle to an innovative breakthrough is not a lack of technology, but the fear of uncertainty in the human mind. In fact, any transformation is the collapse of the old system and the emergence of a new, unknown space. However, as history has proven, only those who are the first to harness the wave of progress, not those who resist progress, will win. The architecture of the future is not just about updating infrastructure, it is a combination of a "growth mindset" and digital foresight.

Today, the main priority is not to become a specialist who has mastered technology, but to form a "digital leader" who can constantly evolve with technology. According to data, 70% of digital transformation projects fail not because of technical flaws, but because of organizational culture and people's psychological unpreparedness. Therefore, to lay the foundation for the future, we must first develop "digital intelligence" (DQ) on a par with emotional intelligence (EQ) [7].

In our opinion, we are not just living in an era of change, but in an "explosion of opportunities". Managing the future means not letting algorithms control us, but turning them into strategic partners aimed at solving the most pressing problems of humanity [4].

An innovative breakthrough is not an end point, but an endless movement. Therefore, we should not be afraid of technology, but accept it as the most powerful tool for transforming our being, knowledge and the world. We are not consumers of the future, but its creators

4. A Practical Model of Digital Transformation: D. Rogers's Perspective

Considering digital transformation solely as a technological upgrade is one of the biggest strategic mistakes of modern organizations. In his work, David Rogers describes this process as a fundamental restructuring of business models. According to him, in the digital era, competitive advantage lies not in the company's resources, but in the quality of the relationship it establishes with the customer.

The model proposed by Rogers is based on five main areas: customers, competition, data, innovation, and value. These elements, working in close conjunction with each other, form the entire digital ecosystem of the organization. The role of data is especially important - today, data is not just a source of information, but a strategic asset.

Digital transformation is not just the introduction of new technologies, it is a complete change in the rules of the game. Today, those who win are not those with the strongest resources, but those who adapt the fastest. The market is no longer a static structure, but a constantly changing system. That is why organizations should not limit themselves to producing products, but should become living organisms that continuously communicate with consumers and anticipate their needs. Competition has also shifted from the question of "who is stronger" to "who learns faster" [5].

In this new reality, data is not just information, it is the main weapon for decision-making. Whoever understands data correctly controls the future. But the most important thing is not the technology, but how we think about that technology. Innovation is no longer a rare phenomenon, it is a constant process, and mistakes are not a weakness, but the fuel of development. Therefore, the core of digital transformation is not changing the system, but changing thinking. And only where thinking changes, real breakthroughs begin [2].

This approach allows us to understand the essence of digital transformation more deeply: the problem is not in technology, but in the mindset that accepts it. If organizations can see change not as external pressure, but as an internal opportunity, they will not only adapt, but also begin to create new rules themselves. In today's world, the concept of sustainable advantage has disappeared, replaced by the ability to continuously develop. Therefore, the future lies not in the smartest systems, but in the hands of people and organizations that can grow with them and use them in a meaningful way. The digital era requires organizations not only speed, but also depth. That is, not superficial changes, but the transformation of the internal structure and culture is important. If technology remains only on the surface, it will not have long-term results. Real change will only occur when people change their way of thinking, the logic of decision-making, and their attitude to risk. Therefore, digital transformation is not about mastering tools, but about forming a philosophy of living in a new reality.

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Mathematical sciences

CHANCE IN ACTION: HOW PROBABILITY THEORY SHAPES EVERYDAY DECISIONS AND MODERN LIFE

Abdullayeva Camila

Associate Professor

Azerbaijan State Pedagogical University,

Department of Mathematics and its Teaching Technology

Abstract

Probability theory plays a fundamental role in understanding uncertainty and guiding decision-making in everyday life. Although often associated with mathematics and statistics, its applications extend far beyond academic settings into practical domains such as healthcare, finance, education, technology, and social behavior. This article explores how probabilistic thinking influences daily choices, risk assessment, and predictive modeling in modern society. By examining real-life examples—including weather forecasting, medical diagnosis, investment strategies, insurance systems, and digital recommendation algorithms—the paper demonstrates how probability helps individuals and institutions make informed decisions under uncertainty. Furthermore, the study highlights the importance of probabilistic literacy in improving critical thinking skills and reducing cognitive biases. The integration of probability theory into technological advancements, such as machine learning and data analytics, has further strengthened its relevance in contemporary life. Ultimately, understanding probability theory empowers individuals to interpret information more accurately, evaluate risks rationally, and navigate complex environments effectively. The discussion emphasizes that probability is not merely a theoretical construct but a practical tool that shapes everyday experiences and supports evidence-based decision-making in a rapidly evolving world.

Keywords: *Probability theory; uncertainty; decision-making; risk assessment; Bayesian reasoning; everyday life applications; statistical thinking; predictive modeling; behavioral economics; machine learning; data analysis*

Introduction

In an increasingly complex and data-driven world, uncertainty has become an unavoidable component of everyday decision-making. Probability theory provides a systematic framework for quantifying uncertainty and guiding rational choices in situations where outcomes cannot be predicted with certainty. Over the past few decades, the practical significance of probabilistic reasoning has expanded rapidly, particularly with the growth of data analytics, artificial intelligence, and predictive modeling. Recent research emphasizes that probability theory is no longer confined to theoretical mathematics; instead, it serves as a foundational tool across disciplines including economics, healthcare, education, and social sciences (Hanea, McBride, & Bedford, 2021). As individuals encounter uncertain situations daily—such as interpreting risk, evaluating information, or planning for the future—probabilistic literacy becomes increasingly essential.

The growing reliance on statistical and probabilistic information in public communication further underscores this importance. For instance, during global health crises, governments and health organizations frequently present probabilities related to infection rates, vaccine effectiveness, and risk reduction. Studies conducted in the last five years indicate that individuals with stronger probabilistic understanding are better equipped to interpret such information and make informed decisions (van der Bles et al., 2020; McDowell & Jacobs, 2022). These findings highlight the societal relevance of probability theory and its direct impact on everyday behavior. Moreover, probability-based reasoning supports critical evaluation of media reports, reducing susceptibility to misinformation and exaggerated risk perceptions.

Technological advancements have also accelerated the integration of probability theory into daily life. Machine learning algorithms, recommendation systems, and predictive analytics depend heavily on probabilistic models to analyze patterns and forecast outcomes. According to research by Jordan and Mitchell (2022), probabilistic approaches remain central to artificial intelligence systems, enabling them to handle uncertainty and incomplete data effectively. From navigation applications predicting travel time to online platforms recommending products, these probabilistic systems operate continuously in the background, shaping user experiences. Consequently, probability theory has transitioned from a specialized academic discipline into a practical instrument embedded in digital infrastructure.

In addition to technological applications, probability theory influences human judgment and decision-making processes. Behavioral studies demonstrate that individuals often rely on intuitive assessments of likelihood, which may diverge from statistical reality. Recent work by Pennycook and Rand (2021) suggests that improving probabilistic reasoning skills can enhance analytical thinking and reduce cognitive biases. Such findings reinforce the argument that understanding probability is crucial not only for professionals but also for the general population. As modern society increasingly depends on data interpretation and risk evaluation, probability theory becomes an essential component of everyday reasoning and informed decision-making.

Probability Theory in Everyday Decision-Making

Probability theory plays a central role in everyday decision-making, particularly when individuals must choose among alternatives with uncertain outcomes. Daily life is filled with such situations, ranging from simple personal choices to complex social and economic decisions. Whether deciding when to travel, evaluating job opportunities, or assessing health risks, individuals implicitly rely on probabilistic reasoning. Recent studies indicate that people who consciously apply probability-based thinking tend to make more consistent and rational decisions, especially in environments characterized by uncertainty (Meder & Nelson, 2021). This demonstrates that probability theory functions not only as a mathematical framework but also as a cognitive tool for structured reasoning.

One of the most visible applications of probability in everyday life is weather forecasting. Individuals routinely use probability estimates—such as a 60% chance of rain—to plan daily activities. These forecasts are generated through probabilistic models that combine historical data, atmospheric simulations, and real-time observations. Research shows that probabilistic weather communication improves public preparedness and reduces decision-making errors compared to deterministic forecasts (Joslyn & LeClerc, 2021). For example, a farmer deciding whether to irrigate crops or an individual planning outdoor events relies on such probabilistic predictions to minimize potential losses. The widespread use of weather probabilities highlights how mathematical concepts directly influence practical decisions.

Healthcare decisions represent another critical domain where probability theory guides everyday actions. Individuals must often evaluate risks related to lifestyle, medical treatments, and preventive measures. For instance, understanding the probability of developing certain diseases based on age, genetics, or habits can motivate behavioral changes. Recent literature emphasizes that presenting health information in probabilistic terms enhances patient comprehension and supports shared decision-making between doctors and patients (Zipkin et al., 2020; Trevena et al., 2022). When individuals understand risk percentages—such as the probability of side effects from medication—they are better equipped to weigh benefits against potential harms. This probabilistic approach leads to more informed and personalized healthcare decisions.

Financial planning also depends heavily on probability-based reasoning. Individuals saving for retirement, investing in stocks, or purchasing insurance must consider uncertain future events. Probability models help estimate potential gains, losses, and risks associated with different options. For example, investment diversification is based on the idea that spreading resources across multiple assets reduces overall risk. Empirical studies conducted in recent years confirm that individuals who understand probability and risk variability are more likely to adopt diversified portfolios and avoid impulsive financial decisions (Bucher-Koenen et al., 2021). Thus, probability theory contributes to financial stability and long-term economic well-being.

Transportation and mobility decisions further illustrate the role of probability in daily life. Navigation applications estimate travel time by calculating the likelihood of congestion, accidents, or delays. These probabilistic predictions rely on historical traffic data and real-time updates. Research shows that probabilistic routing improves travel efficiency and reduces uncertainty for commuters (Zhang & Fan, 2023). When drivers choose between alternative routes, they implicitly rely on probability estimates to minimize travel time. This integration of probabilistic models into digital tools demonstrates how probability theory enhances everyday convenience and efficiency.

In addition to structured decisions, probability influences social and psychological judgments. People frequently assess the likelihood of outcomes in interpersonal interactions, such as predicting responses, evaluating trustworthiness, or estimating success in opportunities. However, these judgments are often affected by cognitive biases. Recent studies indicate that improving probabilistic literacy reduces overconfidence and enhances critical thinking skills (Sirota, Juanchich, & Hagmayer, 2021). By understanding how probabilities operate, individuals become more cautious in their assumptions and more analytical in their reasoning.

Overall, probability theory provides a practical framework for navigating uncertainty in multiple aspects of daily life. From weather forecasts and healthcare decisions to financial planning and transportation choices, probabilistic thinking enables individuals to evaluate risks and make informed decisions. As access to data-driven tools continues to expand, the importance of understanding probability in everyday contexts will only increase.

Probability Theory in Risk Assessment and Financial Planning

Risk assessment is one of the most important areas where probability theory directly influences everyday life. Individuals constantly evaluate uncertain outcomes when making financial decisions, such as saving money, investing, purchasing insurance, or planning long-term expenditures. Probability theory provides a structured way to estimate potential gains and losses, allowing individuals to make rational choices under uncertainty. Recent studies emphasize that probabilistic reasoning improves individuals' ability to assess financial risks and avoid impulsive decisions, particularly in volatile economic environments (Batsaikhan & Demertzis, 2021). As modern financial systems become more complex, understanding probability becomes essential for personal financial stability.

Investment decisions are particularly dependent on probabilistic thinking. When individuals invest in stocks, bonds, or other assets, they cannot predict future returns with certainty. Instead, they rely on probability distributions of expected performance. The concept of diversification, which involves spreading investments across multiple assets, is based on probabilistic risk reduction. By combining assets with different risk profiles, investors decrease the probability of large losses. Empirical research shows that individuals with higher financial literacy, including knowledge of probability, are more likely to diversify their portfolios and achieve better long-term outcomes (Klapper & Lusardi, 2020; Bucher-Koenen et al., 2021). These findings highlight the practical value of probabilistic reasoning in improving financial decision-making.

Insurance systems also rely heavily on probability theory. Companies calculate premiums by estimating the likelihood of events such as accidents, illness, or property damage. These calculations are based on large datasets and statistical modeling. Individuals, in turn, decide whether purchasing insurance is worthwhile by weighing the probability of loss against the cost of coverage. For example, a person living in an area prone to floods may consider the probability of such events when deciding to buy insurance. Recent research indicates that communicating risks using probability-based information improves consumer understanding and leads to more informed insurance decisions (Schwarcz & Siegelman, 2021). This demonstrates how probability theory facilitates both institutional planning and individual protection against uncertainty.

Another everyday financial application of probability theory is budgeting and long-term planning. Individuals often face uncertainty regarding future income, expenses, and unexpected events. Probabilistic thinking allows them to estimate possible scenarios and prepare accordingly. For instance, emergency savings are recommended because unexpected events—such as job loss or medical expenses—have a non-zero probability. Studies conducted in the last few years confirm that individuals who consider probabilistic scenarios are more likely to maintain savings and demonstrate financial resilience during economic disruptions (Farrell, Wheat, & Mac, 2020). This highlights how probability theory supports responsible financial behavior and risk management.

Probability also influences consumer decision-making in markets. When evaluating discounts, warranties, or product reliability, individuals implicitly assess probabilities. For example, purchasing an extended warranty involves estimating the likelihood that a product will fail. Research shows that many consumers overestimate small probabilities, leading to decisions that may not be economically optimal (Bhargava, Loewenstein, & Sydnor, 2021). Understanding probability theory helps individuals avoid such biases and make more rational choices based on realistic risk assessment.

Overall, probability theory plays a crucial role in financial planning and risk management. By enabling individuals to estimate uncertain outcomes, diversify investments, evaluate insurance options, and plan for unexpected events, probabilistic reasoning contributes to economic stability and informed decision-making. As financial systems continue to evolve and uncertainty remains a constant factor, the importance of probability-based risk assessment in everyday life will continue to grow.

Conclusion

Probability theory has evolved from a purely mathematical discipline into an essential framework for understanding uncertainty in everyday life. This article has demonstrated that probabilistic reasoning plays a significant role in multiple domains, including daily decision-making, healthcare, financial planning, risk assessment, and technological systems. In modern society, individuals constantly encounter uncertain situations, and probability theory provides the tools needed to evaluate risks, interpret

information, and choose among alternatives. Recent research confirms that improved probabilistic literacy enhances critical thinking, supports rational judgment, and reduces susceptibility to misinformation (Pennycook & Rand, 2021; McDowell & Jacobs, 2022). These findings emphasize that understanding probability is not limited to academic contexts but is crucial for practical life skills.

One of the key insights highlighted throughout this discussion is that probability theory supports evidence-based decision-making. Whether individuals are interpreting weather forecasts, evaluating medical risks, or planning financial investments, probabilistic thinking allows them to weigh potential outcomes logically. Studies show that individuals who apply probability-based reasoning are more likely to make balanced decisions and avoid extreme risk-taking or overly cautious behavior (Meder & Nelson, 2021). This balanced approach is particularly important in a world characterized by rapid technological change and increasing access to complex data.

Furthermore, probability theory plays a central role in modern technological developments. Artificial intelligence, machine learning, and predictive analytics rely heavily on probabilistic models to analyze large datasets and generate predictions. These technologies influence everyday experiences, from personalized recommendations to traffic navigation systems. As such systems become more integrated into daily life, the importance of understanding the probabilistic nature of their outputs increases. Research indicates that individuals who understand probability are better equipped to interpret algorithmic predictions and use them effectively (Jordan & Mitchell, 2022). This highlights the growing intersection between probabilistic thinking and digital literacy.

Another important conclusion is that probability theory enhances risk management and financial stability. By understanding uncertainty, individuals can make informed choices about investments, insurance, and long-term planning. Probabilistic reasoning encourages diversification, savings, and preparation for unexpected events, all of which contribute to economic resilience. Recent studies emphasize that financial decisions grounded in probability-based assessments lead to improved long-term outcomes and reduced vulnerability to economic shocks (Bucher-Koenen et al., 2021). Thus, probability theory serves as a practical tool for achieving both personal and societal stability.

In addition, probability theory helps individuals recognize cognitive biases and improve judgment. People often rely on intuition when estimating likelihoods, which can lead to systematic errors. Learning probabilistic concepts enables individuals to question assumptions, evaluate information critically, and avoid misinterpretation of data. This skill is particularly valuable in the modern information environment, where individuals are frequently exposed to statistics, polls, and risk-related claims. By applying probability theory, individuals can distinguish between realistic and exaggerated risks, leading to more informed and rational decisions.

In conclusion, probability theory is deeply embedded in everyday life, shaping how individuals interpret uncertainty and make decisions. Its applications span diverse areas such as healthcare, finance, education, and technology, demonstrating its broad relevance and practical value. As society becomes increasingly data-driven, the need for probabilistic literacy will continue to grow. Understanding probability empowers individuals to navigate uncertainty, evaluate risks effectively, and make informed choices in both personal and professional contexts. Therefore, promoting probabilistic thinking is essential for improving decision-making and enhancing overall societal well-being in the modern world.

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ANALYTICAL SOLUTIONS OF THE TWO-DIMENSIONAL NAVIER-STOKES EQUATIONS

*Rustemova Karashash Zhorabekovna**candidate of physical and mathematical sciences, assistant professor**Abdimanapova Perizat Bakhytovna**PhD, assistant professor**Mazhit Zhamilya Batytkyzy**Master of Mathematics**Tattibekov Konysbek Satievich**candidate of physical and mathematical sciences, associate Professor,**Almaty Technological University, Almaty, Republic of Kazakhstan*

АНАЛИТИЧЕСКИЕ РЕШЕНИЯ ДВУМЕРНЫХ УРАВНЕНИЙ НАВЬЕ–СТОКСА

*Рустемова Карашаш Жорабековна**к.ф.-м.н., ассистент профессор**Абдимананова Перизат Бахытовна**PhD, ассистент профессор**Мажит Жамила Батыккызы**Магистр математики**Таттибеков Конысбек Сатиевич**к.ф.-м.н., доцент,**Алматинский технологический университет, г. Алматы, Республика Казахстан***Abstract**

The article considers particular analytical solutions of the Navier–Stokes equations describing laminar flows of a viscous incompressible fluid. Despite the overall complexity and nonlinear nature of these equations, exact solutions can be obtained in a number of cases that are of significant theoretical and practical importance. Special attention is given to flows between non-parallel planes, which lead to a two-dimensional formulation of the problem and make it possible to reveal the features of the flow behavior in converging and diverging configurations of boundaries.

In addition, the axisymmetric Couette flow arising between two coaxial rotating cylinders is examined in detail. For this problem, the main differential equations of motion, the corresponding boundary conditions, and their analytical solutions for the distribution of tangential velocity and pressure in the fluid are presented. It is shown that the flow structure is determined by the geometric parameters of the system and the angular velocities of the cylinders.

The obtained results provide a deeper understanding of the physical mechanisms of laminar flow and serve as a foundation for the analysis of more complex hydrodynamic problems, including flows at high Reynolds numbers and problems of boundary layer theory.

Аннотация

В статье рассматриваются частные аналитические решения уравнений Навье–Стокса, описывающих ламинарные течения вязкой несжимаемой жидкости. Несмотря на общую сложность и нелинейный характер этих уравнений, в ряде случаев удаётся получить точные решения, имеющие важное теоретическое и прикладное значение. Особое внимание в исследовании уделяется течениям между непараллельными плоскостями, которые приводят к двумерной постановке задачи и позволяют выявить особенности поведения потока при сходящихся и расходящихся конфигурациях границ.

Кроме того, подробно рассматривается осесимметричное течение Куэтта, возникающее между двумя коаксиальными вращающимися цилиндрами. Для данной задачи приводятся основные дифференциальные уравнения движения, соответствующие граничные условия, а также их аналитические решения для распределения тангенциальной скорости и давления в жидкости. Показано, что структура потока определяется геометрическими параметрами системы и угловыми скоростями цилиндров.

Полученные результаты позволяют глубже понять физические механизмы ламинарного течения и служат основой для анализа более сложных гидродинамических задач, включая течения при больших числах Рейнольдса и задачи теории пограничного слоя.

Keywords: Navier–Stokes equations, laminar flow, viscous incompressible fluid, analytical solutions, two-dimensional problem, Couette flow.

Ключевые слова: Уравнения Навье–Стокса, ламинарное течение, вязкая несжимаемая жидкость, аналитические решения, двумерная задача, течение Куэтта.

Введение. В общем случае нахождение точных решений нелинейных уравнений Навье–Стокса представляет значительные трудности. Известны решения лишь для ограниченного числа нетривиальных частных случаев. Например, при рассмотрении течения в трубе нелинейные члены уравнений обращаются в нуль. При больших значениях числа Рейнольдса течение жидкости вокруг тела до настоящего времени полностью не изучено.

Следует отметить, что все известные точные решения согласуются с предположениями теории пограничного слоя и широко используются при больших числах Рейнольдса, а также при построении асимптотических решений.

Основная часть. Течение между непараллельными плоскостями сводится к двумерной задаче. Линии тока представляют собой прямые, сходящиеся в точке пересечения плоскостей.

Для сходящихся ламинарных течений между непараллельными пластинами различия в структуре потока отсутствуют. В случае расходящихся течений наблюдается отличие: угол между плоскостями превышает критическое значение, зависящее от числа Рейнольдса.

Точное решение для осесимметричного течения в коническом канале неизвестно. Однако ряд классических задач имеет аналитические решения. Например, течение, вызванное вращением диска в полупространстве, формируется под действием центробежных сил.

Двумерная задача течения вдоль плоской поверхности была решена Блазиусом и Хименцем. Эти решения играют важную роль в теории пограничного слоя.

Ламинарное вращательное течение несжимаемой жидкости между двумя цилиндрами известно как течение Куэтта. Линии тока имеют вид концентрических окружностей.

Рассмотрим стационарное течение в цилиндрических координатах (r, φ, x) . Единственной ненулевой компонентой скорости является тангенциальная компонента $v_\varphi(r)$. В этом случае уравнение неразрывности выполняется автоматически, а система Навье–Стокса сводится к:

$$\frac{1}{r} \frac{d}{dr} \left(r \frac{dv_\varphi}{dr} \right) - \frac{v_\varphi}{r^2} = 0 \quad (1a)$$

и

$$\frac{d\rho}{dr} = \rho \frac{v_\varphi^2}{r} \quad (16)$$

Общее решение уравнения (1a) имеет вид:

$$v_\varphi = C_1 r + \frac{C_2}{r}, \quad (2)$$

Константы определяются из граничных условий:

$$v_\varphi = \omega_i r_i, \quad r = r_i,$$

$$v_\varphi = \omega_0, \quad r = r_0$$

Откуда

$$C_1 = \frac{\omega_0 r_0^2 - \omega_i r_i^2}{r_0^2 - r_i^2}, \quad (3)$$

$$C_2 = \frac{(\omega_0 - \omega_i) r_0^2 r_i^2}{r_0^2 - r_i^2}$$

Подставляя выражение скорости в уравнение (1b), получаем распределение давления:

$$p = p_i + \frac{p}{(r_0^2 - r_i^2)} \left[(\omega_0 r_0^2 - \omega_i r_i^2) \frac{1}{2} (r^2 - r_i^2) - 2 r_i^2 r_0^2 (\omega_0 - \omega_i) (\omega_0 r_0^2 - \omega_i r_i^2) \ln \frac{r}{r_i} - r_i^4 r_0^4 (\omega_0 - \omega_i) \left(\frac{1}{r_i^2} - \frac{1}{r^2} \right) \right] \quad (4)$$

где p_i — давление на поверхности внутреннего цилиндра.

Рассмотрим частный случай. Если цилиндры вращаются с одинаковой угловой скоростью ω , т.е. $\omega_0 = \omega_i = \omega$, то:

$$v_\varphi = \omega r \quad \text{и} \quad p = p_i + \frac{1}{2} \rho \omega^2 (r^2 - r_i^2)$$

Чтобы найти момент сил, действующий на цилиндры, учитываем, что ненулевая только тангенциальная компонента тензора напряжений:

$$\Pi_{r\varphi} = \mu r \frac{\partial}{\partial r} \left(\frac{v_\varphi}{r} \right) \quad (5)$$

Умножая на r , получаем момент сил. В итоге для момента на единицу длины получаем формулу осесимметричного течения Куэтта:

$$M = \frac{4\pi\mu|\omega_0 - \omega_i|}{\left(\frac{1}{r_i^2}\right) - \left(\frac{1}{r_0^2}\right)} \quad (6)$$

Заключение. Таким образом, несмотря на общую сложность уравнений Навье–Стокса, для ряда важных физических задач удаётся получить точные аналитические решения. Эти решения играют ключевую роль в понимании структуры ламинарных течений и служат основой для более сложных приближённых методов.

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SOME FEATURES OF THE NAVIER–STOKES EQUATIONS AND THEIR SOLUTIONS**Rustemova Karashash Zhorabekovna***candidate of physical and mathematical sciences, assistant-professor***Abdimanapova Perizat Bakhytovna***PhD, assistant-professor***Shinikulova Gulnur Nurbekovna***Master of Physics***Mazhit Zhamilya Batytkyzy***Master of Mathematics,**Almaty Technological University, Almaty, Republic of Kazakhstan***НЕКОТОРЫЕ ОСОБЕННОСТИ УРАВНЕНИЙ НАВЬЕ–СТОКСА И ИХ РЕШЕНИЙ****Рустемова Карашаш Жорабековна***к.ф.-м.н., ассистент-профессор***Абдимананова Перизат Бахытовна***PhD, ассистент-профессор***Шиникулова Гульнур Нурбековна***Магистр физики***Мажит Жамила Батыккызы***Магистр математики,**Алматинский технологический университет, г. Алматы, Республика Казахстан***Abstract**

В статье рассматриваются уравнения Навье–Стокса для вязкой несжимаемой жидкости, их приближённые и частные аналитические решения, а также особенности постановки начально-краевых задач. Данная система уравнений является фундаментальной в механике сплошных сред и широко применяется для описания различных гидродинамических процессов как в теоретических исследованиях, так и в инженерной практике.

Особое внимание уделяется физической интерпретации уравнений, позволяющей установить связь между инерционными, вязкими и внешними силами, действующими в потоке. Рассматриваются различные типы граничных условий, включая условия прилипания на твёрдых стенках, асимптотические условия на бесконечности, а также периодические и симметричные условия, используемые при моделировании сложных течений.

В работе также анализируются основные подходы к численному решению уравнений Навье–Стокса. Обсуждаются требования к вычислительным методам, такие как устойчивость, точность и экономичность, а также особенности их применения при различных значениях числа Рейнольдса. Отмечается, что при больших значениях этого параметра возникают сложные нестационарные и турбулентные режимы течения, требующие использования специальных численных моделей.

Полученные результаты и представленные подходы могут быть использованы для анализа широкого круга задач гидродинамики и служат основой для дальнейших исследований в области вычислительной механики жидкости.

Аннотация

The article considers the Navier–Stokes equations for a viscous incompressible fluid, their approximate and particular analytical solutions, as well as the features of formulating initial and boundary value problems. This system of equations is fundamental in continuum mechanics and is widely used to describe various hydrodynamic processes in both theoretical research and engineering practice.

Special attention is given to the physical interpretation of the equations, which makes it possible to establish the relationship between inertial, viscous, and external forces acting in the flow. Various types of boundary conditions are considered, including no-slip conditions on solid walls, asymptotic conditions at infinity, as well as periodic and symmetry conditions used in modeling complex flows.

The paper also analyzes the main approaches to the numerical solution of the Navier–Stokes equations. The requirements for computational methods, such as stability, accuracy, and efficiency, are discussed, along with the specifics of their application at different Reynolds numbers. It is noted that at high

values of this parameter, complex unsteady and turbulent flow regimes arise, requiring the use of specialized numerical models.

The obtained results and presented approaches can be used to analyze a wide range of hydrodynamic problems and serve as a basis for further research in the field of computational fluid dynamics.

Keywords: Navier–Stokes equations, laminar flow, viscous incompressible fluid, analytical solutions, two-dimensional problem, Couette flow.

Ключевые слова: Уравнения Навье–Стокса, ламинарное течение, вязкая несжимаемая жидкость, аналитические решения, двумерная задача, течение Куэтта.

Введение. Уравнения Навье–Стокса описывают движение вязкой жидкости и являются фундаментальной системой уравнений гидродинамики. Несмотря на их широкое применение, аналитическое решение возможно лишь в ограниченном числе частных случаев.

Течение вязкой жидкости при малой вязкости часто описывается уравнениями пограничного слоя, тогда как при более вязких режимах используются уравнения Стокса и полная система Навье–Стокса. Эти уравнения могут быть выведены как на основе феноменологического подхода (постулаты Стокса), так и на основе молекулярно-кинетической теории.

Основная часть. Течение вязкой жидкости при малой вязкости в соответствии с законом трения Ньютона описывается уравнениями пограничного слоя, тогда как при больших значениях вязкости используются приближения Стокса и общие уравнения Навье–Стокса. Уравнения Навье–Стокса могут быть получены как феноменологическим путём на основе постулатов Стокса, так и на основе молекулярно-кинетической теории.

Для однородной несжимаемой жидкости система Навье–Стокса записывается в виде:

$$\frac{\partial \mathbf{V}}{\partial t} + (\mathbf{V} \nabla) \mathbf{V} = -\frac{1}{\rho} \text{grad } p + \nu \Delta \mathbf{V} + \mathbf{f} \cdot \mathbf{n} \quad (1)$$

$$\text{div } \mathbf{V} = 0$$

где неизвестными являются вектор скорости \mathbf{V} и давление p , зависящие от пространственных координат и времени t . Плотность ρ и кинематическая вязкость $\nu = \mu/\rho$ считаются заданными параметрами, \mathbf{f} — массовая сила.

Первое уравнение системы представляет закон сохранения импульса (уравнение движения), второе — уравнение неразрывности:

$$\frac{\partial \rho}{\partial t} + \text{div } \rho \mathbf{V} = 0 \quad (1.2)$$

Такое представление приводит к важному свойству системы: давление определяется с точностью до произвольной постоянной p_0 .

Система (1) при заданных начальных условиях в момент времени t_0 и соответствующих граничных условиях позволяет определить поле скорости и давления в момент $t_0 + \Delta t$, где $\Delta t > 0$. Движение жидкости может быть вызвано как массовыми силами, так и внешними воздействиями, приводящими к перепаду давления Δp .

Значит, одним из ключевых свойств системы является определение давления с точностью до произвольной константы.

Рассмотрим граничные условия более подробно для частного случая уравнений

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = -\frac{1}{\rho} \frac{\partial p}{\partial x} + \nu \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) + f_x \quad (3)$$

$$\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} = -\frac{1}{\rho} \frac{\partial p}{\partial y} + \nu \left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right) + f_y \quad (4)$$

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0, \quad (5)$$

где u, v — компоненты скорости, p — давление, x, y — координаты прямоугольной системы. Кинематический коэффициент вязкости обозначен ν .

Строгий вывод этих уравнений приводится в курсах механики жидкости и газа. Их физический смысл заключается в том, что они являются проекциями второго закона Ньютона $F=ma$, а вязкие силы подчиняются закону Ньютона для касательных напряжений, связывающему их со скоростью деформации. Уравнение (5) описывает условие непрерывности в двумерной области.

В механике жидкости используются два подхода: эйлеров и лагранжев. В эйлеровой системе координат жидкость движется относительно фиксированной системы отсчёта, тогда как в лагранжевой системе координаты движутся вместе с жидкостью.

Уравнения (3)–(5) являются уравнениями математической физики в частных производных и описывают широкий класс задач. Различия между ними определяются начальными и граничными условиями.

Для скорости обычно используется условие прилипания на твёрдой стенке $u=0, v=0$, тогда как для давления граничные условия задать сложнее. Оно может быть восстановлено из уравнений движения.

Вводя завихрённость:

$$\omega = \frac{\partial u}{\partial y} - \frac{\partial v}{\partial x}$$

получаем уравнение переноса завихрённости:

$$\frac{\partial \omega}{\partial t} = -u \frac{\partial \omega}{\partial x} - v \frac{\partial \omega}{\partial y} + \nu \left(\frac{\partial^2 \omega}{\partial x^2} + \frac{\partial^2 \omega}{\partial y^2} \right)$$

Граничные условия играют определяющую роль и могут существенно влиять на характер решения. Классификация граничных условий:

1 Условие прилипания. На твёрдой неподвижной поверхности выполняется условие отсутствия скольжения:

$$V \Big|_{\infty} = V_c, \quad (6)$$

при $V_c=0$ поверхность считается неподвижной.

2 Асимптотические условия. На бесконечности или вдали от тела задаются условия вида:

$$V \rightarrow V_c, \quad r \rightarrow \infty \quad (7)$$

3 Периодические условия. В ряде задач используются периодические граничные условия:

$$V_1 \rightarrow V_2 \quad (8)$$

4 Условия симметрии. Для симметричных течений используются условия:

$$v = 0, \quad \frac{\partial u}{\partial n} = 0 \quad (9)$$

В определённом диапазоне режимных параметров (прежде всего при малых значениях числа Рейнольдса) эти условия могут соответствовать реально наблюдаемым течениям. Однако во многих случаях их задание, подобно условию (8), расширяет класс возможных движений.

Граничные условия (5) на границе раздела двух сред, если эта поверхность неподвижна и можно пренебречь трением в одной из сред (например, на границе жидкости и газа), принимают вид, аналогичный условию симметрии (9):

$$v_n = 0, \quad \frac{\partial u}{\partial n} = 0 \quad (10)$$

Отличие условия (10) от условия прилипания (6) заключается в том, что оно учитывает движение жидкости вдоль поверхности и, в сочетании с решениями системы уравнений (3)–(5), позволяет определить скорость этого движения.

При строгой математической постановке задачи, если начальные данные заданы в виде системы (3)–(5), в рассмотренных выше случаях задание граничных условий для давления не требуется.

$$u^0 = u(x, y, 0), \quad v^0 = v(x, y, 0), \quad p^0 = p(x, y, 0)$$

Система уравнений (3)–(5), заданная с начальными и соответствующими граничными условиями, является замкнутой и позволяет определить поля скорости и давления однородной несжимаемой вязкой жидкости, а также их изменение во времени.

Однако система уравнений (3)–(5) в форме уравнения неразрывности (5) не всегда удобна для проведения вычислений, в связи с чем её можно заменить эквивалентной системой. Для

этого, например, уравнение (3) дифференцируют по переменной y , а уравнение (4) — по переменной x , затем складывают полученные результаты и используют преобразования, связанные с уравнением (5). В результате получаем:

$$\frac{\partial^2 p}{\partial x^2} + u \frac{\partial^2 p}{\partial y^2} = -\rho \left[\left(\frac{\partial u}{\partial x} \right)^2 + \frac{\partial u}{\partial y} \frac{\partial v}{\partial x} + \frac{\partial v}{\partial y} \frac{\partial u}{\partial x} + \left(\frac{\partial v}{\partial y} \right)^2 \right] + \frac{\partial f_x}{\partial x} + \frac{\partial f_y}{\partial y} \quad (11)$$

Система уравнений (3), (4), (11) является одной из наиболее часто используемых форм уравнений Навье–Стокса в переменных «скорость–давление» в вычислительной практике. В этом случае граничные условия для давления могут быть получены из уравнений движения (3) и (4).

Например, для неподвижной твёрдой стенки при $y=0$ граничное условие для давления имеет следующий вид:

$$\frac{\partial p}{\partial x} = \mu \frac{\partial^2 u}{\partial y^2} + \rho f_x \quad (12)$$

При проведении вычислений, как правило, используется безразмерная форма записи уравнений, а также начальных и граничных условий. Введём безразмерные величины, где характерный масштаб обозначим через c_1 . Переход к безразмерной форме осуществляется заменой размерной величины на её нормированное значение.

Выбор масштабов определяется конкретными условиями задачи. Пусть заданы характерная скорость V_1 и характерный размер области L . Течение, заданное через характерную скорость или перепад давления, называется вынужденной конвекцией. В качестве масштабов скорости и длины принимаются соответственно V_1 и L , а параметры ρ , ν , f_1 задаются условиями задачи.

Выполнив указанные преобразования, можно получить следующую безразмерную форму исходной системы уравнений:

$$\frac{\partial \bar{V}}{\partial \bar{t}} + (\bar{V} \nabla) \bar{V} = - \text{grad } \bar{p} \frac{1}{\text{Re}} \Delta \bar{V} + F \cdot n \quad (13)$$

$$\text{div } \bar{V} = 0 \quad (14)$$

В данной системе присутствуют два безразмерных параметра, построенных на основе выбранных масштабов: $\text{Re} = \frac{V_1 L}{\nu}$ — число Рейнольдса, которое характеризует отношение инерционных сил к вязким и определяет интенсивность вынужденной конвекции; а также критерий подобия $F_0 = (\text{Fr})^{1/2}$, отражающий отношение массовых сил $F = F_0 \bar{f}$, $F_0 = f_1 L / V_1^2$ к инерционным, где $\text{Fr} = V_1 / (f_1 L)^{1/2}$ — число Фруда.

Как видно, для времени и давления в системе (13), (14) используются соответствующие масштабные величины и их безразмерные аналоги.

Использование безразмерной формы уравнений преследует две основные цели: приведение вычисляемых величин к удобным масштабам и представление результатов в обобщённой критериальной форме с минимальным числом параметров. Достижение этих целей обеспечивается правильным выбором характерных масштабов.

Особенности уравнений Навье–Стокса. Уравнения Навье–Стокса, независимо от формы их записи, обладают рядом специфических особенностей, проявляющихся при численных расчётах. Одной из характерных особенностей является пространственно-эллиптический характер уравнений, обусловленный влиянием вязкости во всём поле течения. В связи с этим при их решении необходимо использовать методы, применяемые для эллиптических уравнений. В отличие от уравнений пограничного слоя, при решении задач Навье–Стокса требуется задание граничных условий на всех границах рассматриваемой области, которая в реальных условиях может быть бесконечной, но в вычислениях должна быть ограничена. Это приводит к проблеме «замыкания» в ряде внешних задач, требующей использования асимптотических приближений.

В системе уравнений Навье–Стокса присутствует малый параметр $\varepsilon = 1/\text{Re}$ при старших производных, изменение которого существенно влияет на характер решения. С увеличением числа Рейнольдса формируется пограничный слой у стенок.

Система уравнений Навье–Стокса является нелинейной, что характерно для большинства гидродинамических задач. Нелинейность в сочетании с указанными особенностями

приводит к возникновению сложных пространственно-временных структур при больших числах Рейнольдса.

Во многих случаях для каждого типа течения в определённом диапазоне значений Re существует единственное устойчивое стационарное решение. Для его получения часто используют нестационарные уравнения, рассматривая стационарное решение как предел при $t \rightarrow \infty$. Однако с увеличением числа Рейнольдса стационарное решение может перестать быть единственным и начинает зависеть от начальных условий. При дальнейшем росте Re реализуются только нестационарные режимы.

В этих условиях решения приобретают сложный не только временной, но и пространственный характер: пограничный слой теряет устойчивость, происходит его разрушение, возникают вторичные течения и другие эффекты. Для описания таких режимов одних уравнений Навье–Стокса недостаточно. При больших значениях Re наблюдается турбулентность — хаотическое, неупорядоченное движение жидкости. Например, переход от ламинарного к турбулентному течению в круглой трубе происходит при $Re \sim 2 \cdot 10^3$.

В инженерных и природных условиях числа Рейнольдса часто принимают очень большие значения $10^6 \div 10^9$, поэтому турбулентные режимы широко распространены. До недавнего времени численные методы при больших Re в основном основывались на линеаризованных уравнениях и применялись для анализа малых возмущений. В настоящее время активно развиваются методы прямого численного моделирования нестационарных и турбулентных течений на основе полной системы уравнений Навье–Стокса.

Таким образом, методы решения уравнений Навье–Стокса существенно различаются в зависимости от диапазона чисел Рейнольдса и целей численного моделирования.

Можно выделить следующие требования к численным методам решения уравнений Навье–Стокса:

- устойчивость вычислительной схемы;
- высокая точность аппроксимации;
- экономичность по памяти и времени вычислений.

Эти требования часто противоречат друг другу, что приводит к необходимости использования компромиссных численных методов.

Особую сложность представляет моделирование течений при высоких числах Рейнольдса, где наблюдаются турбулентные режимы.

Заключение. Уравнения Навье–Стокса представляют собой фундаментальную, но математически сложную систему. Несмотря на ограниченное число аналитических решений, они остаются основой современной гидродинамики и численного моделирования течений вязких жидкостей.

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Medical sciences

MODERN APPROACHES TO MEDICAL REHABILITATION: PRINCIPLES OF COMPREHENSIVE AND INDIVIDUALIZED RECOVERY IN CONTEMPORARY CLINICAL PRACTICE

Harets Vira Ivanivna

*Doctor of Medical Sciences, Professor,
Professor of the Department of Social, Humanitarian and Biomedical Disciplines
Private Higher Education Institution "Dnipro Institute of Medicine and Public Health"*

Mirzebasov Maksym Abdulakhovich

*Candidate of Medical Sciences, Associate Professor,
Associate Professor of the Department of Clinical Disciplines
Private Higher Education Institution "Dnipro Institute of Medicine and Public Health"*

Yanchevskyi Oleksandr Valeriiovich

*Doctor of Philosophy in Medicine, Associate Professor,
Associate Professor of the Department of Clinical Disciplines
Private Higher Education Institution "Dnipro Institute of Medicine and Public Health"*

СУЧАСНІ ПІДХОДИ ДО МЕДИЧНОЇ РЕАБІЛІТАЦІЇ: ПРИНЦИПИ КОМПЛЕКСНОГО ТА ІНДИВІДУАЛЬНОГО ВІДНОВЛЕННЯ У СУЧАСНІЙ КЛІНІЧНІЙ ПРАКТИЦІ

Гарець Віра Іванівна

*д. мед. наук, професор, професор кафедри соціально-гуманітарних та біомедичних дисциплін
Приватний заклад вищої освіти*

«Дніпровський інститут медицини та громадського здоров'я»

Мірзебасов Максим Абдулахович

*к. мед. наук, доцент, доцент кафедри клінічних дисциплін
Приватний заклад вищої освіти*

«Дніпровський інститут медицини та громадського здоров'я»

Янчевський Олександр Валерійович

*доктор філософії (медицина), доцент, доцент кафедри клінічних дисциплін
Приватний заклад вищої освіти*

«Дніпровський інститут медицини та громадського здоров'я»

Abstract

The thesis highlights modern approaches to medical rehabilitation as an integral component of clinical practice and medical education. Emphasis is placed on the principles of early initiation, comprehensiveness, individualization, staged implementation, and continuity of the rehabilitation process. The importance of kinesiotherapy, physiotherapeutic methods, massage, and the educational training of future physicians in developing a holistic approach to restoring the patient's functional status is demonstrated. Particular attention is paid to the special relevance of rehabilitation care development in Ukraine under conditions of a growing number of patients with long-term functional limitations.

Анотація

У даній праці висвітлено сучасні підходи до медичної реабілітації як невід'ємної складової клінічної практики та медичної освіти. Акцентовано увагу на принципах раннього початку, комплексності, індивідуалізації, етапності та безперервності реабілітаційного процесу. Показано значення кінезотерапії, фізіотерапевтичних методів, масажу та освітньої підготовки майбутніх лікарів у формуванні цілісного підходу до відновлення функціонального стану пацієнта. Особливо підкреслено актуальність розвитку реабілітаційної допомоги в Україні в умовах зростання кількості пацієнтів із довготривалими функціональними обмеженнями. Навчання реабілітації в медичному інституті розглядається як важливий елемент підготовки лікаря, здатного оцінювати не лише захворювання, а й рівень функціонування, адаптації та якості життя пацієнта.

Keywords: *medical rehabilitation; kinesiotherapy; physiotherapy; functional recovery; medical education; individualized approach.*

Ключові слова: медична реабілітація; кінезотерапія; фізіотерапія; функціональне відновлення; медична освіта; індивідуалізований підхід.

Медична реабілітація є невід'ємною складовою сучасної системи охорони здоров'я, оскільки спрямована не лише на лікування наслідків захворювання чи травми, а й на відновлення функціональної незалежності, повсякденної активності, працездатності та соціальної участі пацієнта. У сучасному розумінні реабілітація охоплює сукупність втручань, спрямованих на оптимізацію функціонування людини та зменшення обмежень життєдіяльності у взаємодії з навколишнім середовищем. Саме тому її слід розглядати не як другорядний етап після завершення лікування, а як повноцінний клінічний напрям, інтегрований у систему медичної допомоги.

Для України ця тема має особливу актуальність. Умови повномасштабної війни зумовили різке зростання потреби в реабілітаційній допомозі серед цивільного населення та військовослужбовців, зокрема у пацієнтів із травмами, наслідками поранень, ампутаціями, неврологічними порушеннями, хронічним боєм, психоемоційними розладами та довготривалими функціональними обмеженнями. ВООЗ наголошує, що для України реабілітація є одним із пріоритетів реагування в умовах війни, а Уряд України окремо визначає розвиток реабілітаційних послуг як напрям, у якому попит невпинно зростає. За даними Міністерства соціальної політики, лише у першому півріччі 2025 року понад 56 тисяч українців отримали понад 208 тисяч засобів реабілітації в межах державної програми.

У цьому контексті реабілітація набуває не лише клінічного, але й виразного освітнього значення. Підготовка здобувачів медичної освіти повинна формувати вміння оцінювати не тільки нозологічний діагноз, а й функціональний статус пацієнта, рівень обмеження активності, реабілітаційний потенціал, показання та протипоказання до відновних втручань, а також здатність будувати індивідуалізовану програму допомоги. Для медичного інституту розділ реабілітації є важливим не тому, що це "модно", а тому, що без нього випускник ризикує бачити хворобу, але не бачити людину після неї.

Метою медичної реабілітації є максимально можливе відновлення або компенсація порушених функцій, профілактика ускладнень і рецидивів, зниження рівня інвалідизації та повернення пацієнта до активного життя. У практичному вимірі це означає поєднання клінічної оцінки, функціонального тестування, динамічного спостереження та індивідуального добору засобів відновлення. В освітньому процесі це вимагає навчання на клінічних сценаріях, де відновлення функції є не додатком до лікування, а одним із його головних результатів.

До ключових принципів медичної реабілітації належать ранній початок, комплексність, індивідуалізація, етапність, безперервність та контроль ефективності. Раннє включення реабілітаційних заходів дозволяє зменшити ризик формування стійких функціональних дефіцитів і підвищує шанси на краще відновлення. Етапність забезпечує логічний перехід від гострого стаціонарного етапу до амбулаторного, санаторного або домашнього спостереження. Безперервність означає, що реабілітація повинна тривати стільки, скільки цього потребує функціональний стан пацієнта, а не стільки, скільки красиво поміщається у випуску.

Комплексний підхід передбачає поєднання лікувального рухового режиму, терапевтичних вправ, фізіотерапії, масажу, психоемоційної підтримки, освітньої роботи з пацієнтом, а за потреби — професійної та соціальної адаптації. Такий формат є особливо цінним для пацієнтів із наслідками бойової травми, політравми, ураженнями нервової системи, захворюваннями опорно-рухового апарату, серцево-судинною та пульмонологічною патологією. В умовах України цей підхід має ще й системне значення, оскільки реабілітація повинна бути інтегрована в різні рівні медичної допомоги — від стаціонару до первинної ланки та громади. ВООЗ окремо підкреслює важливість розвитку реабілітації на різних рівнях системи охорони здоров'я, включно з первинною допомогою.

Особливе місце у структурі реабілітаційної допомоги займає кінезотерапія. Терапевтичні вправи є одним із найбільш фізіологічних і клінічно значущих методів відновлення, оскільки сприяють покращенню сили, витривалості, координації, мобільності, толерантності до навантаження та загального функціонального стану. Їх призначення має бути дозованим, цілеспрямованим і адаптованим до конкретної клінічної ситуації. У викладанні реабілітації саме кінезотерапія дає змогу найнаочніше показати зв'язок між патофізіологією захворювання, функціональним дефіцитом та інструментами його корекції.

Фізіотерапевтичні методи та масаж доцільно розглядати як складові комплексної програми реабілітації, особливо коли необхідно зменшити біль, покращити трофіку тканин, знизити м'язовий спазм або підготувати пацієнта до активної рухової терапії. Водночас їх застосування потребує чіткого дотримання принципів безпеки, оцінки загального стану, супутньої патології та можливих протипоказань. У клінічному навчанні важливо акцентувати не лише на потенційній користі фізичних чинників, а й на вмінні своєчасно обмежити або відкласти їх застосування, коли ризик перевищує очікуваний ефект.

Отже, медична реабілітація як навчальна дисципліна повинна формувати у здобувачів освіти цілісне уявлення про відновний процес — від клінічної оцінки та визначення функціональних порушень до побудови індивідуалізованої програми допомоги. Для сучасної України це має особливе значення, оскільки потреба у якісній реабілітації зростає не лише в межах окремих клінічних випадків, а й на рівні всієї системи охорони здоров'я та соціальної підтримки. Саме тому реабілітація сьогодні є не периферійною темою медичної освіти, а одним із ключових напрямів підготовки лікаря, здатного працювати з пацієнтом не лише в гострому періоді, а й на шляху до відновлення функції, автономії та якості життя.

Перспективи.

Перспективним є подальше вдосконалення викладання реабілітації у медичних інститутах із посиленням клінічної орієнтації та міждисциплінарного підходу. В умовах України особливого значення набуває підготовка фахівців, здатних працювати з пацієнтами, які мають тривалі функціональні обмеження внаслідок травм, захворювань і наслідків бойових дій. Подальший розвиток цього напрямку пов'язаний із впровадженням сучасних реабілітаційних програм, стандартизацією навчання та підвищенням якості відновної допомоги.

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IMPROVING THE PROFESSIONAL PERFORMANCE OF MEDICAL STAFF IN OUTPATIENT AND POLY-CLINIC SETTINGS**Moldagaliyeva A.A.**2nd year Master's student
Al-Farabi Kazakh National University
Almaty, Kazakhstan**СОВЕРШЕНСТВОВАНИЕ ПРОФЕССИОНАЛЬНОЙ ДЕЯТЕЛЬНОСТИ МЕДИЦИНСКИХ РАБОТНИКОВ АМБУЛАТОРНО-ПОЛИКЛИНИЧЕСКОГО ЗВЕНА****Молдагалиева А.А.**магистрант 2 курса
Казахский национальный
университет имени аль-Фараби
Алматы, Казахстан**Abstract**

Currently, healthcare system reforms are aimed not only at improving material and technical resources but also at enhancing the quality of medical services and human resource capacity. The purpose of this study is to assess the professional performance of medical staff in outpatient and polyclinic settings and to identify ways for its improvement.

A total of 386 medical workers participated in the study. Data were collected using a specially designed questionnaire. The results obtained made it possible to identify key factors affecting the quality of professional performance and the provision of medical care. The study revealed the need for systemic changes to improve the efficiency of outpatient care.

Аннотация

В настоящее время реформы в системе здравоохранения направлены не только на развитие материально-технической базы, но и на повышение качества медицинских услуг и кадрового потенциала. Целью данного исследования является оценка профессиональной деятельности медицинских работников амбулаторно-поликлинического звена и определение путей её совершенствования. В исследовании приняли участие 386 медицинских работников, данные были собраны с помощью специально разработанной анкеты. Полученные результаты позволили выявить основные факторы, влияющие на качество профессиональной деятельности и оказание медицинской помощи. Установлена необходимость системных изменений для повышения эффективности амбулаторной помощи.

Keywords: outpatient care, polyclinic, medical staff, professional performance, quality**Ключевые слова:** амбулатория, поликлиника, медицинские работники, профессиональная деятельность, качество**Введение**

Эффективность системы здравоохранения во многом зависит от уровня профессиональной подготовки медицинского персонала и качества оказываемых услуг. Несмотря на значительное внимание к материально-техническому обеспечению, проблема повышения профессиональной компетентности кадров остаётся актуальной. Качество первичной медико-санитарной помощи, оказываемой на амбулаторно-поликлиническом уровне, напрямую влияет на состояние здоровья населения. В связи с этим важным является комплексная оценка профессиональной деятельности медицинских работников и определение направлений её совершенствования.

Материалы и методы**Дизайн исследования и выборка**

Исследование носило социальный характер. В нем приняли участие 386 медицинских работников. Отбор проводился методом сплошной выборки, что позволило обеспечить достоверность результатов.

Инструменты исследования

Сбор данных осуществлялся с помощью специально разработанной анкеты, включающей следующие разделы: оценка профессиональной деятельности, условия труда, уровень квалификации, возможности профессионального развития

Статистический анализ

Данные обрабатывались с использованием методов описательной статистики (средние значения, доли).

Результаты исследования

Проведённое исследование позволило комплексно оценить кадровый потенциал амбулаторно-поликлинического звена и выявить ключевые проблемы, влияющие на качество медицинской помощи. Анализ профессиональной структуры показал, что основную долю респондентов составляют медицинские сестры (60%), что отражает высокую роль среднего медицинского персонала в системе первичной медико-санитарной помощи. Врачи составили 22%, заведующие отделениями - 14,5%, руководители амбулаторных организаций - 3,5%. Данная структура свидетельствует о значительной нагрузке на средний медицинский персонал. Оценка состояния здоровья медицинских работников показала, что 76,3% считают его удовлетворительным, 6,3% - неудовлетворительным и лишь 3,8% - хорошим. Эти данные указывают на наличие факторов профессионального выгорания и хронической усталости среди персонала. При этом 90% респондентов находятся в возрастной группе 35–60 лет, что свидетельствует о старении кадрового состава. Анализ трудового стажа выявил, что большинство сотрудников (63,8%) имеют стаж более 20 лет, что подтверждает высокий уровень профессионального опыта. Однако доля молодых специалистов остаётся низкой (около 10%), что может негативно сказаться на устойчивости кадрового потенциала в будущем. Несмотря на высокий уровень профессионального опыта, 82,5% респондентов заявили об уверенности в своих знаниях, однако объективные показатели квалификации свидетельствуют о наличии проблем. Так, только 22,5% имеют высшую квалификационную категорию, тогда как у 38,8% категория отсутствует. При этом 61,3% респондентов считают, что заслуживают более высокой категории, что может свидетельствовать о несоответствии системы оценки квалификации ожиданиям персонала. Анализ причин отсутствия сертификации показал, что основными барьерами являются отсутствие мотивации (16,3%), недостаточный стаж (11,3%), финансовые трудности (2,5%) и административные ограничения (1,3%). Особое внимание заслуживает анализ профессионального развития. Несмотря на то, что все респонденты проходили курсы повышения квалификации, их регулярность и качество остаются недостаточными. Так, 38,8% проходили обучение 2–3 года назад, а 7,5% - более 5 лет назад. Только 17,5% обучались в текущем году. Удовлетворённость обучением оказалась умеренной: 41,3% полностью удовлетворены, 45% - частично, 3,8% - не удовлетворены. Основной причиной недовольства (95%) является краткосрочный характер курсов и их недостаточная практическая направленность. Выявлено крайне низкое распространение дистанционного обучения (6,3%), что указывает на недостаточное использование современных образовательных технологий. Также установлено, что лишь 8,7% медицинских работников имеют научные публикации, что свидетельствует о низкой научной активности персонала.

Ключевыми барьерами профессионального развития являются:

высокая клиническая нагрузка - 38,8%, отсутствие мотивации - 18,8%, финансовые ограничения - 13,8%, административные барьеры - 6,3%

При этом 65% респондентов работают более чем на одной ставке, что существенно ограничивает возможности для обучения и профессионального роста.

Анализ системы управления качеством медицинской помощи выявил серьёзные недостатки. Так, 60% респондентов никогда не проходили обучение по вопросам качества медицинской помощи. Более того, 88% не уверены в процедурах оценки качества в своих учреждениях.

Основными методами оценки качества, по мнению респондентов, являются:

экспертная оценка - 68,8%, опрос пациентов - 20%, анкетирование персонала - 6,2%

При этом каждый пятый респондент не знает используемых показателей качества.

Средняя оценка информированности о системе обеспечения качества составила $3,75 \pm 0,23$ балла, что указывает на недостаточную подготовленность персонала в данной области.

Анализ психологического климата показал относительно благоприятную обстановку ($4,2 \pm 0,15$ балла). Основными причинами конфликтов являются:

условия труда - 31,2%, наличие конфликтных сотрудников - 20%, система распределения бонусов - 13,7%. Несмотря на это, 75% респондентов доверяют своим коллегам, что свидетельствует о сформированности командного взаимодействия.

Уровень удовлетворённости профессиональной деятельностью составил 71,2%, однако средний балл - 3,4 - указывает на наличие скрытой неудовлетворённости. Основными причинами являются: низкая заработная плата - 37,5%, недостаточное оснащение - 22,5%

высокая нагрузка - 12,5%. Оценка качества медицинских услуг показала средний уровень ($3,4 \pm 0,17$ балла). Наиболее низкие показатели отмечены в области профилактики и реабилитации, а также материально-технического обеспечения ($2,9 \pm 0,17$ балла).

Таким образом, результаты исследования свидетельствуют о наличии системных проблем в организации работы амбулаторно-поликлинических учреждений, включая кадровый дефицит, недостаточный уровень профессионального развития и несовершенство системы управления качеством.

Обсуждение

Результаты исследования свидетельствуют о недостаточном уровне развития кадрового потенциала в амбулаторно-поликлинических учреждениях. Возможности профессионального роста ограничены, а система управления качеством недостаточно сформирована.

Низкая информированность медицинских работников о критериях оценки качества и высокая рабочая нагрузка негативно влияют на эффективность медицинской помощи.

Заключение

Проведённое исследование показало необходимость совершенствования профессиональной деятельности медицинских работников амбулаторного звена.

Основные направления: внедрение дифференцированной системы оплаты труда, улучшение материально-технической базы, снижение объема бумажной работы, систематическое повышение квалификации, внедрение комплексной системы управления качеством. Реализация данных мер позволит повысить качество медицинской помощи и улучшить показатели здоровья населения.

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CURRENT CAPABILITIES OF ULTRASOUND IN THE DIAGNOSIS OF THYROID DISORDERS**Arman Khozhayev**Professor, Doctor of Medical Sciences,
Sonographer – Doctor of Ultrasound Diagnostics,
Treatment and Diagnostic Center «Avicenna», Almaty, Kazakhstan**Luzana Orazbayeva**Sonographer – Doctor of Ultrasound Diagnostics,
City Hospital of Emergency Care of Almaty, Almaty, Kazakhstan**Abstract**

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

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

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

As noted by Zhou H. et al. [5] thyroid cancer is one of the most common malignant tumors of the endocrine system. Thyroid nodules in 5% ~ 15% thyroid cancer are malignant. The incidence rate of thyroid cancer is increasing year by year. The incidence rate in women is generally higher than that in men. Papillary thyroid carcinoma is the most common clinical feature of thyroid cancer. It has the characteristics of high differentiation, low malignancy, good prognosis, and long survival. However, local metastasis and distant metastasis can also occur. Studies have shown that the rate of lymph node metastasis in papillary thyroid carcinoma is 84.7%, of which two-thirds have 70% lymph node metastases to thyroid cancer, and the incidence rate of thyroid cancer ranges from 70% to 85%. Local invasion or distant metastasis of thyroid cancer may increase the chance of postoperative recurrence. Therefore, metastasis of thyroid cancer is one of the important factors affecting the prognosis of patients. Early detection of thyroid cancer metastasis can help clinicians to estimate the surgical conditions. Ultrasound is the most important imaging method for the diagnosis of thyroid cancer metastasis, which is not only convenient but also accurate and reliable. With the continuous improvement of instrument performance, high-frequency ultrasound can not only sensitively display the internal structure of lesions but also provide blood flow information or judge the quality of lesions. In 2009, the American Thyroid Association emphasized the significance of ultrasound in thyroid nodules in the diagnosis and treatment manual of thyroid nodules and differentiated thyroid cancer and evaluated the ultrasonic thyroid examination as Grade A. Ultrasound examination is of great significance for early detection of thyroid cancer metastasis, early treatment, and improving the survival rate and quality of life of patients and has an important impact on the prognosis of patients.

A very interesting study was conducted by Kennedy E. et al. [6]. Our colleagues investigated which

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

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

In comparison, patients referred because of an solid pseudopapillary neoplasm (SPN) on examination and for CS identified nodules on 55% and 39% of ultrasounds, respectively. Patients with MS had a nodule on ultrasound 43% of the time. Among those referred for high-risk factors, 57% had a nodule present. Patients referred for combined indications had nodules on 42% of ultrasounds. Analysis of variance (ANOVA) indicated the difference in nodule detection rate between indications was statistically significant ($p < 0.05$). Only 27% of ultrasounds identified a thyroid nodule that was recommended for biopsy. Those referred from incidental imaging had the highest percentage of biopsy-recommended nodules (55%). This was followed, in order, by patients referred for physical examination of a palpable thyroid nodule (21%), high-risk factors (20%), combined indications (16%), MS (10%), and CS (6%). The overall mean maximum diameter of identified thyroid nodules was 1.9 cm (SD 1.3 cm). Of note, 32 radiology reports identified a thyroid nodule but did not record size and were, therefore, excluded from this specific analysis. Patients referred for incidentally found thyroid nodules had the largest mean nodule size at 2.4 cm (SD 1.2 cm). All other groups had a mean nodule size between 1.2 and 1.8 cm. The difference in average size of nodule was statistically significant ($p < 0.05$). A logistic regression model evaluated the association of patient age, sex, ethnicity, CCI, insurance status, and referral indication with identification of a nodule on ultrasound. Compared with patients referred for an SPN on examination, those with incidental nodules were over 10 times more likely to have a nodule found on ultrasound (odds ratio [OR] = 10.6 [confidence interval (CI) 7.0–16.0]). Conversely, patients referred for CS were half as likely to have an identifiable nodule compared with those referred for physical examination findings (OR = 0.5 [CI 0.4–0.7]). In addition, the odds of finding a nodule increased with age, especially for those aged 65 years and above (vs. age <45 OR = 3.6 [CI 2.2–5.9]). Finally, females were twice as likely to have a nodule found on thyroid ultrasound (OR = 2.0 [CI 1.5–2.6]). Results were similar when evaluating only biopsy-recommended nodules. Compared with patients referred for an SPN on examination, those referred for

incidental findings were significantly more likely to have a biopsy-recommended nodule (OR = 4.7 [CI 3.5–6.3]), while those referred for CS were significantly less likely to have a biopsy-recommended nodule on ultrasound (OR = 0.3 [CI 0.1–0.5]. There was no difference in identifying biopsy-recommended nodules between sexes (female vs. male OR = 1.2 [CI 0.9–1.6]). In conclusion, the authors emphasize that only a quarter of dedicated thyroid ultrasounds yielded a nodule recommended for biopsy, and 39% did not have a nodule present at all. Moreover, only half of ultrasounds performed to evaluate a suspected nodule on physical examination actually identified one. Ultrasound referrals for symptoms had the lowest diagnostic yield, with fewer than 10% identifying a biopsy-recommended nodule. These findings suggest that re-evaluation of guidelines on thyroid ultrasound referral may be necessary to decrease the overutilization of thyroid ultrasound and the downstream consequences of detection of small potentially irrelevant nodules [6].

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

The thyroid is an important organ of the human body, and it plays an important role in maintaining the health of the human endocrine system and the physical and mental health of the human body. With the advancement of medical ultrasound technology, ultrasound examination has become one of the most commonly used early detection methods for diseases due to its advantages such as low price, safety, noninvasiveness, convenient use, and ability to reflect the actual situation of tissues. A thyroid nodule refers to a mass in normal thyroid tissue that is different from normal glandular tissue. Thyroid nodules can be divided into two categories according to their nature: benign nodules and malignant nodules. Among them, benign nodules can be divided into nodular goiter, thyroid adenoma, and Hashimoto's thyroiditis (HT); the main type of malignant nodules is thyroid papilloma, which is the most common pathological type with the highest incidence of malignant thyroid nodules, while other pathological types are relatively rare. Due to the superficial location of the thyroid, the boundary between the outer envelope and surrounding soft tissues is clear, which provides favorable conditions for ultrasound diagnosis. The self-regulation of thyroid function refers to the regulation of the secretion of thyroxine by the amount of iodine supplied by the thyroid itself in the absence of thyroid-stimulating hormone (TSH) or the concentration of TSH is unchanged. Therefore, for the identification and diagnosis of benign and malignant thyroid nodules, ultrasound has always been one of the preferred imaging methods. With the continuous improvement of the level of science and technology, ultrasound inspection technology has also improved. When using ultrasound to diagnose thyroid diseases, thyroid neoplastic lesions can be displayed more clearly on the ultrasound images, and the lesions can be found in time and medical measures can be taken to control the condition. However, thyroid diseases are complex and changeable, especially malignant thyroid nodules, which are difficult to diagnose and control. During an ultrasound examination, benign and malignant nodules overlap on the two-dimensional sound image, which makes the diagnosis more difficult. Especially when some nodules have both benign and malignant characteristics, it is difficult to distinguish and qualitatively diagnose their nature based on the sonogram alone, which directly affects the choice of clinical treatment and surgical methods. This puts forward higher requirements for the initial qualitative diagnosis of lesion formation for ultrasound diagnosticians. Therefore, medicine urgently needs more advanced ultrasound diagnostic technology to overcome the difficulties encountered when using conventional ultrasound examination methods to diagnose thyroid diseases so as to help clinicians better diagnose and treat thyroid diseases and protect the health of patients. There is a clinical need for an intelligent diagnosis technology of thyroid diseases based on ultrasound images, which can provide objective and reliable auxiliary diagnosis opinions for thyroid diseases through the texture, shape, and other information of the images, freeing doctors from heavy work [7].

The study states that SMI technology is a new ultrasound diagnostic imaging method proposed by Canon in Japan in 2014. The principle basis of SMI technology is the motion suppression technology used to isolate and eliminate clutter but retain the vulgar blood flow signal. It includes ultrasound diagnostics, ultrasound therapy, and biomedical ultrasound engineering. Therefore, ultrasound medicine has the characteristics of combining medicine, science, and engineering. It involves a wide range of contents and

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

In conclusion, the authors come to the conclusion that with the improvement of medical technology in today's society and the enhancement of people's health awareness, people's attention to thyroid diseases continues to increase. However, thyroid diseases, such as malignant secretory tumor diseases, are more complex and changeable, especially for malignant thyroid nodules, which are difficult in clinical diagnosis and treatment. Conventional thyroid ultrasound examination methods also have certain limitations, such as: for benign and malignant thyroid lesions, two-dimensional detection images sometimes overlap, which can also lead to different images of the same disease, and the same frequency of different diseases; at the same time, the blood flow with a low flow rate will not be displayed. And usually, it can only clearly display the larger blood vessel images, but the new microvascular network of the tumor cannot show its full picture, which means that thyroid cancer with less blood supply is easy to be missed. These deficiencies in conventional ultrasound examinations will directly affect the clinical treatment of thyroid diseases. Therefore, the medical field of thyroid diseases urgently needs more advanced ultrasound diagnostic technology to overcome the difficulties encountered in the diagnosis of thyroid diseases so as to help clinicians better diagnose and treat thyroid diseases and protect the health of patients. With the improvement of science and technology, two more advanced ultrasound detection technologies, SMI technology and contrast-enhanced ultrasound, have emerged in medicine. SMI technology can detect very low blood flow in thyroid lesions and can noninvasively and truly reflect the blood perfusion state of the nodules; contrast-enhanced ultrasound can continuously and dynamically observe the vascular distribution and blood perfusion of thyroid nodules, showing that the possibility of tumor neovascularization has also been improved. Therefore, SMI technology and contrast-enhanced ultrasound technology can solve the current problems in the diagnosis and treatment of thyroid diseases to a certain extent by

virtue of their own advantages and have begun to be used in the identification and diagnosis of thyroid benign and malignant nodules. The research in this article has proved through experiments that SMI technology and contrast-enhanced ultrasound have high diagnostic sensitivity for the identification and diagnosis of benign and malignant thyroid nodules, that is they have better diagnostic efficiency and application value. And from the comparison of sensitivity, the diagnostic sensitivity of SMI technology is slightly higher than that of contrast-enhanced ultrasound, which shows that SMI technology has slightly better diagnostic performance and application value than contrast-enhanced ultrasound. The findings of this article provide a meaningful reference for the medical community to better apply SMI technology and contrast-enhanced ultrasound in the diagnosis and treatment of thyroid diseases. The number of features extracted manually in the research of thyroid nodular disease in this article is relatively small. In the future, more features can be added to study the interaction between artificial features and neural network features to achieve better classification results [7].

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

The researchers piloted and applied an extraction form to collect patient demographics and the specialty of the clinician who conducted the physical exam. From the physical exam documentation, they extracted the types of findings (solitary nodule, multinodular goiter, enlargement without nodularity, normal thyroid, and an "other category" for patients with indeterminate findings such as thyroid asymmetry). Additionally, study's authors documented the precise locations (right lobe, left lobe, isthmus or bilateral) where these findings were encountered, whenever the data was accessible. In a similar fashion, researchers carefully extracted the TUS findings (solitary nodule, multinodular goiter, enlargement without nodularity, no finding, and "other category" to group patients who had thyroiditis without the presence of nodules or lymphadenopathy) and noted the corresponding locations of the described findings. When there was a nodular finding in the ultrasound, authors extracted the largest diameter from the largest nodule. Given that the accuracy of thyroid physical exam may be affected by previous knowledge of thyroid-related symptoms, our colleagues also documented whether there was presence of symptoms associated with thyroid nodules or masses (e.g., neck fullness, dysphagia, odynophagia, choking, etc). The authors summarized continuous variables using means and standard deviations, and categorical variables using frequencies and percentages. Using the TUS findings as the reference standard, they calculated the accuracy of the findings noted from the thyroid palpation. First, our colleagues calculated the sensitivity, specificity, accuracy, and positive predictive value (PPV) and negative predictive value (NPV) of the thyroid palpation in the identification of any abnormal thyroid findings (any abnormality yes/no in thyroid palpation compared with any abnormality yes/no in thyroid ultrasound). Then, study's authors estimated the accuracy of the physical exam in detecting thyroid nodules (single thyroid nodule [yes/no] detected by thyroid palpation compared to thyroid nodule [yes/no] detected on confirmatory thyroid ultrasound), and multinodular goiters (multiple nodules [yes/no] found by thyroid palpation compared to multiple nodules [yes/no] identified on a thyroid ultrasound). Additionally, they calculated the accuracy and PPV of the thyroid physical exam to determine the location (e.g., right lobe, left lobe, isthmus or bilateral) of the thyroid findings when data was available in the medical records. Finally, authors calculated the proportion of additionally findings derived from a positive thyroid palpation as 1) the number of patients who had a solitary nodule palpated and were found to have multiple nodules on the subsequent ultrasound, or 2) patients who had a thyroid enlargement in the physical exam and found to have one or more thyroid nodules on the subsequent ultrasound. When possible, researchers conducted subgroup analyses by patient sex, patient weight (obese or overweight vs. normal weight based on body mass index (BMI) categories), size of the thyroid nodule (≤ 2 cm or >2 cm), symptoms of nodular disease (yes and no), and by clinician specialty (primary care vs. specialties). Scientific researchers conducted a test interaction to evaluate for statistically significant subgroup differences [8].

Our colleagues included 327 patients, the majority were female (213/327, 65.1%) and white

(275/327, 84.1%) with a mean age [standard deviation – (SD)] of 50.8 years old (16.9). Most patients were obese or overweight (225/327, 71.2%) and had the thyroid physical exam performed by a primary care clinician (178/327, 54.4%). Additionally, most patients did not present any symptoms of thyroid nodular disease (231/327, 70.6%). Regarding finding any thyroid abnormality, the thyroid physical exam had a sensitivity of 71.8% ($n = 189/263$; 95% CI 66%-72.2%), specificity of 35.9% ($n = 23/64$; 95% CI 24.2%-49.9%), accuracy of 64.8% (212/327; 95% CI 59.4%-70.0%), NPV 23.7% (23/97; 95% 17.5%-31.3%) and PPV 82.1% (189/230; 95% CI 79.1%-84.9%). When the diagnostic accuracy was estimated by an individual thyroid palpation finding (thyroid nodule or multinodular goitre), the physical exam had a sensitivity of 20.3% ($n=12/59$; 95% CI 12.3%-36.2%), specificity of 79.1% (212/268; 95% CI 73.7%-83.2%), accuracy of 68.5% ($n=224/327$; 95% CI 59.4%-70.0%), NPV 81.8% ($n=212/259$; 95% 81.5%-85.8%) and PPV 17.6% ($n=12/68$; 95% CI 11.1%-27.1%) in detecting a thyroid nodule; and a sensitivity of 10.8% ($n=17/157$; 95% CI 6.4%-16.7%), specificity of 96.5% ($n=164/170$; 95% CI 92.4%-98.7%), accuracy of 55.4% ($n=181/327$; 95% CI 49.78%-60.8%), NPV 53.9% ($n=164/304$; 95% 52.4%-55.4%) and PPV 73.9% ($n=17/23$; 95% CI 53.4%-87.5%) in finding a multinodular goiter. Out of 327 patients, 60 physical exams included the side of the thyroid nodule. Among these, the overall accuracy, and the PPV of the physical examination in identifying the location (e.g., right lobe, left lobe, isthmus, or bilateral) of the thyroid finding were 46.6% and 37.5%, respectively. Physical exams among symptomatic patients demonstrated superior performance than those conducted among asymptomatic patients, with higher specificity (100% vs. 62%; $p<0.01$), accuracy (83% vs. 62%; $p<0.01$), and NPV (87% vs. 79%; $p<0.01$) for detection of solitary nodules, as well as a higher NPV for detection of multinodular disease (61% vs. 51%; $p<0.01$). In addition, higher PPV for detecting multinodular disease was observed when a specialist conducted the physical exam compared to a primary care provider (100% vs. 60%; $p<0.01$) and when the nodule detected by physical examination was greater than 2 cm (100% vs. 73% for nodules ≤ 2 cm; $p=0.026$). The study's authors found that out of 68 solitary nodules palpated, 37 (54%) were found to have additional findings such as, multinodular goiter on a subsequent TUS; similarly, out of 88 patients for whom the physical exam identified an enlarged thyroid, 56 (64%) of these were subsequently found to have a solitary nodule (16 cases) or a multinodular goiter (40 cases) on the TUS. The authors emphasize that in this retrospective observational study, scientific researchers found that, while a thyroid physical exam can detect thyroid abnormalities, these findings were rarely concordant with findings identified on a subsequent thyroid ultrasound. Furthermore, the diagnostic accuracy of specific thyroid physical exam findings was low, particularly for the PPV of solitary thyroid nodules. For instance, out of every 100 patients with a physical exam consistent with a solitary thyroid nodule, approximately 18 had a thyroid nodule, while out of every 100 patients with a physical exam consistent with multinodular goiter, about 74 had the same finding in the ultrasound. In the course of the study, the authors state that thyroid physical exam has limited diagnostic performance and leads to additional findings when followed by a thyroid ultrasound. As such, thyroid physical exams in asymptomatic patients may play an important role in the overdiagnosis and overtreatment of thyroid cancer. To determine if any patient subgroups derive some benefit from thyroid physical exams beyond their use as a diagnostic approach, further research is necessary. Additionally, potential interventions should be explored to improve the accuracy of thyroid physical exams [8].

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

A total of 400 consecutive patients with hypothyroidism attending an Endocrinology outpatient clinic for annual follow-up visit were evaluated for eligibility. Autoimmune thyroiditis was considered the underlying disease of hypothyroidism based on high serum concentrations of antithyroid antibodies [thyroid peroxidase (anti-TPO) and/or thyroglobulin (anti-Tg) antibodies]. Exclusion criteria were history of Graves' disease or subacute thyroiditis, malignancies, pregnancy, previous use of medications that can affect thyroid stiffness (amiodarone, tamoxifen, anti-neoplastic) and nodular abnormalities of the thyroid gland (nodules > 3 mm detected by conventional B-mode ultrasound. A total of 338 patients treated for hypothyroidism [females: $n = 292$ (86.4%); males: $n = 46$ (13.6%)] were enrolled in the study. Demographic characteristics (age, sex, BMI), treatment parameters (LT4 daily dose) were recorded and thyroid hormones [TSH, free thyroxine (fT4)] were measured. All included subjects were residents of a geographical area of low-prevalence iodine deficiency disorders. The study protocol was conducted by the tenets of the Declaration of Helsinki and all patients agreed to participate in the study, which was approved by

the Bioethics Committee of the Aristotle University of Thessaloniki, Greece. Conventional B-mode thyroid ultrasound and strain elastography [(real-time elastography (RTE))] were performed on a General Electric P9 machine (LOGIQ-P9; GE Medical Systems, Milwaukee, WI, USA) with an 8–12 multifrequency linear probe. Conventional grey-scale ultrasound was initially performed to measure transverse (two dimensions) and longitudinal (one-dimension) diameters and thyroid volume. Three linear dimensions were measured for each lobe: the length (L) was assessed on the sagittal view and the anterior–posterior (A-P) and width (W) diameters of each lobe were assessed on the transverse view. Given that the normal thyroid shape is ellipsoid, the volume of each lobe was automatically calculated by recording the above-mentioned three linear dimensions (ellipsoid equation with a correction factor: $V \text{ (ml)} = L \text{ (cm)} \times A-P \text{ (cm)} \times W \text{ (cm)} \times 0.523$). Thyroid vascularity was examined with color Doppler and patients were classified into four patterns: Pattern I (normal thyroid vascularity, blood flow limited to the peripheral thyroid arteries, absent parenchymal flow); Pattern II (minimally increased thyroid vascularity, mildly increased parenchymal flow); Pattern III (increased blood flow with a diffuse homogenous distribution, increased parenchymal flow with a diffuse homogenous distribution pattern) and Pattern IV (markedly increased parenchymal flow with a homogenous distribution, including the “thyroid inferno”). The probe was placed perpendicularly to the skin for RTE examination, and repetitive light compression was applied in the longitudinal plane. The ideal pressure on the target lesion was confirmed based on the cine-memory data. A cine-memory stores data obtained through the transmission and reception of ultrasound. A cine-memory generally has a storage capacity allowing storage of multiple numbers of frames obtained in time sequence. In a cine-memory, the newest input data overwrites the oldest data which is already stored in the memory, and this process is repeated. The patients held their breath while the images were obtained to avoid respiratory motion artifacts. The strain index (elastography ratio, $E2/E1$) was used that represents the ratio of the strain of thyroid parenchyma (E2) to that of sternocleidomastoid muscles (E1). Region of interest (ROI) for E2 was free-handed and designed at the peripheral edge of the gland to include the whole longitudinal image of each lobe; ROI for E1 was the sternocleidomastoid muscle in front of the ipsilateral thyroid parenchyma [9].

An endocrinologist with twenty years of experience in sonography, who was blinded to the clinical status, performed all thyroid ultrasound examinations. The Doppler spectral analysis was of the right and left inferior thyroid arteries in the transverse scanning, in which the vessels crossed the common carotid arteries posteriorly, or in the longitudinal scanning of the ascending parts of the arteries, in which the vessels lie parallel to the common carotid arteries for the superior thyroid arteries. The superior thyroid artery was assessed with the probe positioned in the oblique sagittal plane, close to the superior thyroid pole. The inferior thyroid artery was assessed in the oblique transversal plane, close to the transition between the mid and inferior third of the thyroid. The cursor for evaluating the inferior thyroid artery was set close to the trachea to avoid artifacts from the common carotid artery and the internal jugular vein. Parameters for color Doppler are frequency 4.4–6.6 MHz, Gn 40%, pulse-repetition frequency (PRF) 2–8 kHz and Wall Filter (WF) 25–80 Hz. The angle correction cursor was parallel to the flow direction and the Doppler angle was kept at or below 60°. The sampling gate was set to 2 mm. The peak systolic velocity (PSV), end-diastolic velocity (EDV), and pulsatility indices (PI) and the resistive index (RI) values in the superior and the inferior thyroid arteries were obtained in both thyroid lobes. The mean value of the right and left lobes was used as the outcome parameter. Serum TSH and fT4 concentrations were measured by the immunochemistry method with enzyme chemiluminescence immunoassay (reference range: 0.27–4.5 mIU/ml and 0.8–1.5 ng/dl, respectively). Measurements were performed on the Cobas 8000 platform by Roche (Basel, Switzerland). Data were presented as mean \pm SD or range (min–max). The Kolmogorov–Smirnov test was used to evaluate data distribution. The Student’s t-test was used for group comparisons of continuous variables with a normal distribution (age, BMI, weight) and Mann–Whitney test was used for variables with a non-parametric distribution. Spearman and Pearson correlation coefficients were used to investigate correlations between variables. The Chi-squared test (χ^2 -test) was used for group comparisons of categorical variables. Predictive models were compared using Receiver Operating Characteristic (ROC) – Area Under the Curve (AUC) statistics. The optimal threshold values were determined from the ROC curve analysis and the Youden Index and its associated criterion values. The sensitivity, specificity, positive likelihood ratio and negative likelihood ratio values were calculated. A p-value < 0.05 was considered statistically significant [9].

In total, 288 patients (85.2%) had autoimmune thyroiditis, while 50 (14.8%) had no history of increased thyroid autoantibodies. A total of 68 patients (20.1%) had TSH concentrations ≥ 4 mIU/l (50 with autoimmune thyroiditis and 10 without autoimmune disease) and were considered suboptimally treated at the time of the enrolment, while 270 (79.9%) had TSH concentrations within the reference range (< 4

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

In conclusion, our colleagues state that this is the largest study to have applied the concurrent evaluation of multiple ultrasound parameters of the thyroid gland in patients with hypothyroidism and the first to have used thyroid artery measurements to evaluate the therapeutic efficacy. Lymphocytic infiltration in autoimmune thyroiditis affects tissue echogenicity and causes a diffuse increase in parenchymal vascularization. In the natural history of the disease, as hypofunction gets severer, elasticity, volume of the gland and blood flow are reduced, indicating a fibrotic degeneration process. Effective monitoring and evaluation of LT4 supplementation are crucial to anticipate relapse of hypothyroidism. The monitoring is mainly based on thyroid hormone measurements since clinical symptoms may be absent in borderline TSH increases. However, in cases where blood tests are difficult to obtain, a color Doppler ultrasound can be used as an alternative tool in estimating responses to therapy and distinguishing those patients who should be further evaluated by hormonal examinations [9].

In the work of Soltani K. et al. [10] the authors note that the diagnostic role of Doppler ultrasonography regarding HT is not fully established. Our colleagues examined intraparenchymal RI as a Doppler parameter, thyroidal vascularity and other Gray-Scale findings in adults with HT in order to evaluate the clinical feasibility of RI in the diagnosis of this disease. This study is designed based on the cross-sectional analysis of sonographic findings in newly diagnosed patients with HT. The target population was selected from patients referred to the radiology department of Modarres Hospital from the endocrinology clinics of Modarres and Loghman Hospitals between 2013 and 2014. Subclinical hypothyroid patients were identified based on the clinical assessment of an endocrinologist. Exact laboratory data (TSH, FT4) were not available. Newly diagnosed patients without any history of receiving treatment for HT, who were either euthyroid or sub-clinically hypothyroid at the time of sonography, were included. Forty-eight females recently diagnosed with HT aging between 20 and 50. All the participants underwent Gray-scale (determining gland size, volume, and echogenicity) and color Doppler (evaluating vascularity and calculating RI of each lobe in 2 points) sonography by 1 radiology resident using a Medison X8 sonography device with a 7 MHz probe. Thyromegaly in females was defined as thyroid gland volume exceeding 15 mL. Gray-scale findings were classified into 4 grades (1–4) using the classification system introduced by Sostre and Reyes (Sostre S., Reyes M.M., 1991). Color Doppler findings were divided into 4 patterns (0–III) based on a visual scale provided by Schulz et al., 2003. The settings of the ultrasound equipment

(gain and PRF) were calibrated such that aliasing of the carotid artery and jugular vein could not be seen. The RI (minimum PRF and maximum gain) of both upper and lower poles of each thyroid lobe were calculated by the ultrasound device using the formula below and the mean RI measured from both lobes was considered as the total RI of the thyroid gland. In addition, 45 controls aged between 20 and 70 years with normal thyroid laboratory results and without any prior history of thyroid disease were examined sonographically and the RI of those participants whose Gray-scale results proved to be normal was measured in 3 different points in each lobe. The mean RI of each participant from each of these 2 groups was calculated and compared to the mean RI of the control group.

Based on the definition provided by the World Health Organization, out of every 48 patients with HT, 30 (62.5%) had a normal thyroid gland volume (thyroid gland volume < 15mL) and 18 had thyromegaly (thyroid gland volume > 15mL). Based on the Gray-scale grading, 13 patients (27.08%) were classified as grade 1, 12 patients (25.00%) as grade 2, 18 patients (37.50%) as grade 3, and 5 patients (10.42%) as grade 4. The parenchymal vascularity of the thyroid gland (color Doppler appearance) presented as pattern 0 in 22 patients (45.83%), pattern I in 15 patients (31.25%), pattern II in 6 patients (12.5%), and pattern III in 5 patients (10.42%). The RI ranged between 0.50 and 0.70 in the patient group and 0.47 and 0.70 in the control group. The average RI in the patient group was 0.5733 ± 0.05012 and 0.5453 ± 0.05061 in the control group. Independent t-testing of the average RI showed a statistically significant difference between the patient and control groups ($P = 0.009$). The highest average RI was seen in Grade 1 (0.5808 ± 0.04173) and the lowest in Grade 4 (0.5500 ± 0.03808). One-way ANOVA of the average RI between different Gray-scale grading groups showed no statistically significant difference ($P = 0.352$). Furthermore, participants with grade 1 Gray-scale findings were considered as part of the normal or near-normal group and those with grades 2, 3, and 4 as part of the substantial Gray-scale changes group. The average RI of the normal or near-normal group was 0.5808 ± 0.04173 and 0.5706 ± 0.05319 in the substantial Gray-scale changes group. Independent t-testing showed no statistically significant difference in average RI when comparing the normal or near-normal with the substantial Gray-scale changes group ($P = 0.537$). The highest RI was seen in pattern 0 of color Doppler findings (0.5845 ± 0.04828) and the lowest in pattern II (0.5300 ± 0.04817). ANOVA results showed no statistically significant difference in average RI among different groups of color Doppler findings ($P = 0.109$). Results of Kruskal–Wallis test followed by pairwise comparisons showed a statistically significant relationship in terms of average RI between the grade 1 patient group and control group ($P = 0.010$) and between the grade 3 patient group and control group ($P = 0.015$). But the same comparison showed no statistically significant relationship between the grade 2 patient group and control group ($P = .406$) and between the grade 4 patient group and control group ($P = 0.752$). Results of Kruskal–Wallis test followed by pairwise comparisons showed a statistically significant relationship in terms of average RI between the pattern 0 patient group and control group ($P = 0.003$) and between the pattern I patient group and control group ($P = 0.034$). But the same comparison showed no statistically significant relationship between the pattern II patient group and control group ($P = .418$) and between the pattern III patient group and control group ($P = 0.381$). Summarizing the study, the authors state that the results of this study show that, regardless of gray-scale views and color Doppler patterns, the intraparenchymal RI of patients diagnosed with HT was higher compared to normal controls and, thus, this sonographic parameter may be a useful yet noninvasive modality in the diagnosis of HT [10].

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

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

In this clinical trial, our colleagues observed that using S-Detect did not improve the thyroid

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

A fundamental study concerning multimodal imaging of solid thyroid lesions was conducted by Jung E.M. et al. [13]. Goal of the study was the assessment of AI-assisted diagnosis of solid thyroid foci with multimodal modern ultrasound imaging. 50 patients (26–81 years, 54.7 ± 13.1 years) were included in the study. Multimodal ultrasound imaging by means of B-mode with linear probe (4–12 MHz) with option of automated documentation of findings by means of AI, with supplementary ultra-microangiography (UMA) was used. Macrovascularisation was assessed by dynamic contrast ultrasonography (CEUS) with parametric evaluation and perfusion analysis, and microvascularization was assessed by combined strain and shear wave elastography on a novel high-performance ultrasound system (Resona R9/Mindray) by an experienced examiner with independent reading. The evaluation was performed according to TI-RADS III-V. Inclusion criterion was preparation for immediate surgery by indication through interdisciplinary case conferences with endocrinologic, nuclear medicine, and surgical evaluation. All examinations with CEUS were performed after written consent. The evaluation of the examinations was performed retrospectively with the approval of the local ethics committee. The examinations were requested after preliminary examinations by special outpatient clinics with the question of the assessment of solid thyroid lesions that had been noticed in out-of-town preliminary examinations. An evaluation according to TI-RADS III-V had to be performed and it had to be decided to what extent a histological clarification was necessary or whether a follow-up should be performed. All examinations were performed by an experienced investigator (more than 3000 examinations per year, over more than 20 years) using a linear multifrequency probe (L 4–12 MHz) on high-performance ultrasound equipment with digital image documentation. This allowed independent subsequent evaluation by experienced readers. According to the predefined scheme of an AI image evaluation program, both thyroid lobes were measured in longitudinal and transverse axis with length, depth and width, the volume was calculated, the echogenicity was evaluated as homogeneous, discrete inhomogeneous or inhomogeneous and the echo pattern was judged as echo-complex or echo-normal. The ultrasound elastography techniques available in parallel mode as strain or shear wave elastography were used to assess compaction of thyroid tissue and solid foci. The pulsatile region of a carotid artery was bypassed as much as possible to avoid artifacts. Image quality could be assessed automatically, optimally with 5 green stars. False colors informed about homogeneous or inhomogeneous compaction. Measured values over individually adjusted ROI could be recorded in m/s or kPa, with values > 2.5 m/s or > 30 kPa considered suspicious for possible malignant lesions.

Detectable solid lesions were also measured by AI in three planes, and the rim contour was bypassed for volumetric detection. Then, marginal contour had to be assessed as regular, lobulated or irregular, rim as complete or incomplete, or absent, growth axis, parallel or directed in depth, shape as oval or roundish, and possible macro- or microcalcifications and entered into a predetermined scheme. After localization of the suspicious lesion, the evaluation according to TI-RADS III-V was then color-coded in a final scheme with topogram. This then also considers a possible tumor vascularization, as irregular malignancy-suspicious, or as regular marginal benign. UMA was used to assess the vascularization of tumor foci in as much detail as possible with velocity ranges < 10 cm/s. Vascular patterns were recorded dynamically in short cine loops up to 10s. This also captured possible conspicuous lymph nodes with

regular benign vascularization from the hilus or malignancy-typical from the margin. Macrovascularization of thyroid lobes and foci was classified as normal, enhanced, or decreased, and that of foci as regular or irregular. Color-coded duplex sonography, flow with glazing flow, and UMA were used for this purpose. The criterion for benign findings was a regular vascular pattern, especially a marginal vascularization, for example in adenomas. Irregular vascularization was considered suspicious for malignancy. This was then additionally investigated with CEUS to determine the extent to which irregular arterial hypervascularization with delayed wash out occurs, which is evaluated as a malignancy criterion. CEUS after bolus administration of 1 to 1.5 ml of sulphurhexafluoride microbubbles with 10 ml of saline solution cubital, if possible, was used to assess dynamic microvascularization of the suspicious solid lesions. When possible, cine loops of incipient arterial vascularization after 10 to 15 s up to one minute were then evaluated parametrically and by time intensity curve using the High-End Devices internal perfusion program. ROI were individually matched, in the center, at the edge of the lesion to be assessed compared with surrounding thyroid tissue. Parametric color maps were fitted to the corresponding perfusion parameters such as time to peak, peak, mean transit time, wash in area under the curve (wash in AUC) and tabulated at the end [13].

50 cases (26–81 years, mean age: 43 ± 7 years) were examined with multimodal imaging consisting of B-mode, UMA, elastography and CEUS with parametric and perfusion analysis with good to very good image quality in all cases, according to the internal evaluation mode especially in the shear wave elastography technique with clearly $>85\%$ or 5 green stars. The volume of the thyroid lobes on both sides averaged $39 \text{ ml} \pm 5 \text{ ml}$ (27 to 69 ml). All echo-poor, irregularly vascularized, inhomogeneously indurated lesion $>1 \text{ cm}$ were identified as highly suspicious for malignancy with early wash out kinetics and were also confirmed surgically. The 13 cases of histologically confirmed thyroid carcinoma (8 papillary, 2 medullary, 2 microfollicular, 1 anaplastic carcinoma) with a mean size of $15 \text{ mm} \pm 6 \text{ mm}$ (9–21 mm) were correctly evaluated by TI-RADS IV based on irregular shape, induration $>2.5 \text{ m/s}$ or $>30 \text{ kPa}$ and appositional wash-out kinetics using CEUS (TI-RADS V). Tumor lymph nodes could be correctly detected pre-operatively only in one case of medullary carcinoma according to the surgical findings, based on irregular vascularization with UMA in roundish shape with cortex $>4 \text{ mm}$ with a transverse diameter up to 11 mm. In 25 cases of inhomogeneous nodular goiter, evaluation with TI-RADS III was performed in 31 cases, evaluation with TI-RADS IV was performed in 4 cases with incomplete marginal contour, partial marginal vascularization with UMA and partial wash out with indurations up to 2.5 m/s or 30 kPa , and surgical excision was performed for nodular goiter. In 12 cases of adenomas with diameters of 1.7 to 3.5 cm, mean $26 \text{ cm} \pm 0.5 \text{ cm}$, nodular goiter resulted in proportionately regressive nodular changes. Only in 7/12 cases a typical echo-poor rim and a typical rim vascularization were found. In 5 cases, the rim was incomplete. CEUS also showed a partial central wash out in these cases with but preserved marginal vascularization and elastography revealed partial induration up to 2.5 m/s or 30 kPa an assessment with TI-RADS III or IV rating. Using the AI tool, the 20 of 25 goiter nodes were evaluated as TI-RADS III, 7 of 12 adenomas, 5 goiter nodes and 5 adenomas as TI-RADS IV, 5 of 13 carcinomas as TI-RADS IV and 8 of 13 carcinomas as TI-RADS V. Microcalcification as a definite malignancy criterion was automatically detected in 5 of 13 malignancies, an echo-poor irregular echo structure in all cases, and in intracystic tumors in 2 cases. The shape was irregular in all cases, proportionately lobulated, but oriented in depth in only 8 of 13 cases. Of the 25 struma nodules evaluated as possibly also malignant, partial necrosis and inhomogeneous microvascularization with also induration on elastography occurred in all cases. For 37 patients both classifications were identical. From the 12 cases, histologically classified as TI-RADS V, 11 were also classified as TI-RADS V by the AI-based diagnosis. Of the 13 remaining cases in which there were discrepancies between the two methods, 12 were histologically confirmed grade 3 carcinoma. Using AI-based diagnostic they were classified at least one grade higher by AI ($n = 12$, including 2 two grades higher) and in one case a histologically confirmed as TI-RADS V case one grade lower. During the course of the work, the authors established the new multimodal ultrasound modalities offer the possibility of early detection of malignant foci. Multicenter evaluation is needed to evaluate the possibility of additional AI in terms of differentiation from TI-RADS III to TI-RADS V [13].

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

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

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

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

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

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

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THE IMPACT OF ONLINE PLATFORMS ON DEVELOPING STUDENTS' SPEAKING SKILLS IN ENGLISH

Nyshanova Arailym Kozhabaikyzy

Scientific Supervisor: Polatova S.D.

PhD, Senior Lecturer

Uzbekali Zhanibekov South Kazakhstan Pedagogical University

Shymkent, Kazakhstan

Abstract

With the rapid development of information technology and the popularization of online learning platforms, the role in English listening and speaking instruction has become increasingly prominent. Traditional teaching models often fail to meet students' needs for these skills. Online platforms offer instant feedback, personalized exercises, and engaging designs, catering diverse age groups. However, existing research highlights single educational stages, lacking comparative analysis across age groups. This paper analyzes the impact of online learning platforms on the English listening and speaking skills of primary school, middle school and university students, highlighting the differences among them. It examines both practical applications and existing problems. Studies show that age-stratified designs on online platforms effectively improve the listening and speaking skills to varying degrees. However, challenges like insufficient interactivity and differences in student self-discipline remain. Future efforts should optimize platform functions, combine traditional teaching methods, and design tailored solutions for different educational stages to enhance teaching outcomes.

Keywords: *online learning platforms, English listening and speaking skills, age-group differences, educational technology, autonomous learning*

Introduction

With the advancement in technology, online learning platforms have become essential for English listening and speaking teaching. However, traditional teaching models often struggle to meet students' personalized needs for listening and speaking training due to limited class time and monotonous methods. Online learning platforms provide instant feedback and adaptive exercises, allowing students to practice language communication in an authentic English environment [1]. They can also accurately assess learning performance, provide customized training content, and improve learning efficiency. Recent research focus on the application of online learning platforms as supplementary tools for English instruction, showing improvements in student interest and autonomous learning abilities [2]. Additionally, the constructivist learning theory emphasizes contextualized learning environments, which are fully reflected in online platforms. Through interactive forms such as virtual dialogues and animated dubbing, these platforms create authentic language application scenarios for students [3]. However, existing research also finds significant differences in the adaptability of platform functions among students of different ages, particularly in cultivating autonomous learning abilities, which still faces challenges [4]. Although online learning platforms continue to innovate technologically, they must also integrate with traditional classroom teaching, especially in dimensions such as teacher-student interaction and emotional support [5]. This paper examines the impact of online learning platforms on the English listening and speaking skills of primary school, middle school, and university students, aiming to offer practical insights for English language teaching and further enhance their effectiveness of the platforms. Constructivist learning theory holds that knowledge is not acquired through one-way transmission by teachers but is actively constructed by learners in specific contexts [6-7]. This theory emphasizes contextualized learning, social interaction, and cognitive construction, providing important guidance for online English listening and speaking teaching. The first point is contextualized teaching. Constructivism advocates that language learning should take place in real or simulated communicative contexts [8]. Traditional English classrooms often lack authentic contexts. Online learning platforms, through virtual dialogues and simulated scenarios, allow learners to practice listening and speaking in near-real contexts, promoting deep internalization of knowledge. For example, AI voice assistants simulate daily conversations, helping learners master language functions in specific contexts rather than memorizing words and grammar in isolation. The second point is social interaction and collaborative learning. Vygotsky proposed the "Zone of

Proximal Development" (ZPD) theory, emphasizing the key role of social interaction in cognitive development [7]. Online platforms provide interaction opportunities through language partner matching, multi-person online speaking practice, and real-time teacher feedback, enabling learners to adjust their language output during communication and gradually improve their expressive abilities. The third point is personalized knowledge construction. Piaget pointed out that learning is a process in which individuals actively explore and adjust cognitive structures based on existing experiences [6]. The adaptive learning systems of online platforms (such as AI intelligent recommendations) allow learners to adjust learning content according to their own pace, aligning with the constructivist concept of personalized learning [7]. Behaviorist learning theory holds that learning is a process of establishing connections between stimuli and responses, emphasizing the shaping effect of the external environment on learning behavior [9-10]. The core concepts—reinforcement, conditioned reflexes, and feedback loops—provide guidance for online English listening and speaking teaching. First, Skinner's operant conditioning theory points out that positive reinforcement (such as immediate rewards and point incentives) can increase the probability of repeating target behaviors (such as correct pronunciation and fluent expression) [8]. Online learning platforms use mechanisms to reinforce learners' positive performance and enhance motivation. Second, Pavlov's classical conditioning theory shows that repeated stimulus-response pairings can form automatic behaviors [10]. Online English listening and speaking training helps learners establish conditioned reflexes between sounds and meanings through high-frequency repetitive exercises. Finally, behaviorism emphasizes the key role of immediate feedback in learning effectiveness [11]. Online platforms use AI to provide real-time error correction, enabling learners to immediately correct mistakes. Research shows that immediate feedback can improve language learning efficiency by more than 30% [12]. Speaking constitutes a fundamental component of language acquisition, serving as the primary vehicle for expressing thoughts, emotions, and ideas. Within established frameworks of communicative competence (Canale & Swain, 1980), speaking skills empower learners to interact effectively across diverse contexts, ranging from informal conversations to professional and academic discourse. Beyond its communicative function, active speaking practice enhances language learning by promoting fluency through spontaneous production, reinforcing lexical knowledge, and consolidating grammatical understanding [13]. (Baker & Westrup, 2003; Wang et al., 2024). Moreover, oral proficiency significantly influences learners' motivation and self-confidence; successful communication experiences can bolster assurance and encourage continued participation, while perceived deficiencies may trigger anxiety and disengagement [14]. (Alotumi, 2021; de Rooij, 2024). Nevertheless, developing this critical skill presents substantial challenges for EFL learners Kurniati [15], including speech-related anxiety due to error apprehension [15] (Van Thong & Hoai Thuong, 2023), lexical and phonological limitations [16], (Quyen & Nguyen, 2018), and inadequate opportunities for authentic communication in conventional classroom environments (Shen & Chiu, 2019). [17]. Addressing these challenges necessitates pedagogical strategies that incorporate authentic input and meaningful practice. The integration of digital tools, such as podcasts, into speaking instruction offers a viable solution. Podcasts can alleviate several common learning obstacles by providing learners with extensive exposure to authentic spoken English, including varied accents, topics, and natural conversational patterns—thereby compensating for the lack of realistic input in traditional classroom settings (Shen & Chiu, 2019; Travis & Joseph, 2009). [18]. Such exposure not only has model's accurate pronunciation and intonation (Quyen et al., 2018; Yeh et al., 2021) [19] but also enables self-paced listening, which may alleviate the anxiety often linked to real-time speaking interactions (Van Thong & Hoai Thuong, 2023). [20]. When paired with structured interactive tasks that require learners to produce spoken responses based on podcast content, this method transcends passive listening. Instead, it fosters deliberate practice in meaningful contexts, promoting fluency, confidence, and communicative competence (Díez & Richters, 2020; Farangi et al., 2015). [21]. Additionally, this approach may mitigate the adverse effects of harsh feedback encountered in other instructional environments [22]. (Gan, 2012). Given these potential benefits, examining how podcast-integrated instruction specifically influences EFL learners' speaking skills remains a pertinent and valuable research focus.

Method

This study adopted a one-group pre-test/post-test quasi-experimental design to examine the effectiveness of an online platform-based instructional programme in developing the speaking skills of university-level pre-service English teachers. A quasi-experimental approach was deemed appropriate given the institutional constraints that precluded random allocation to separate treatment and control groups; nonetheless, internal validity was strengthened through the standardised delivery of the ten-week programme, the use of a validated and reliability-tested assessment instrument, and the consistent application of the same instructional conditions across all 30 participants.

The study is positioned within a mixed-methods framework: quantitative pre- and post-test data provided the primary measure of speaking competence development, while qualitative data gathered through a post-intervention Likert-scale satisfaction survey offered complementary evidence regarding student perceptions and motivational responses to the digital learning environment. The independent variable was defined as the ten-week online platform-based instructional programme, and the dependent variable was the composite speaking competence score, disaggregated across three oral sub-domains: fluency, pronunciation, and interaction.

Participants

The study was conducted with 30 third-year undergraduate students ($n = 30$) enrolled in group 1703-35 of the Bachelor's programme in Foreign Language (English) at South Kazakhstan Pedagogical University during the spring semester of the 2025–2026 academic year. The group comprised 27 female students (90.0%) and 3 male students (10.0%), a distribution consistent with the predominant gender composition observed in pedagogical faculties across Kazakhstan. Participants' English proficiency ranged from B1 to B2 according to the Common European Framework of Reference for Languages (CEFR), as confirmed by an institutional placement assessment conducted prior to the study. All participants were prospective English language teachers and had completed at least two years of university-level EFL instruction prior to the experiment. Written informed consent was obtained from all participants prior to data collection, and all data were anonymised for analysis.

Table 1

Listening and Speaking Competence Assessment Instrument

Speaking Domain	Assessment Task	Max Score	Evaluator
Fluency	2-min individual monologue on assigned topic; assessed for pace, coherence, and absence of unnatural pauses	20	Teacher panel
Pronunciation	Read-aloud passage (150 words); AI phoneme analysis + teacher rating for segmental and suprasegmental accuracy	20	AI + Teacher
Interaction	Pair role-play (3 min) + follow-up spontaneous questions; assessed for turn-taking, response quality, and communicative strategies	20	Teacher rubric
TOTAL	Integrated Speaking Competence Score	60	Mixed

Note. AI = AI phoneme analysis tool (integrated in iTEST platform); rubric = CEFR-aligned analytical speaking rubric.

Data Analysis

Quantitative data were analysed using IBM SPSS Statistics (version 26). Descriptive statistics (means and standard deviations) were computed for each skill domain at both time points. A paired-samples t-test was used to evaluate the statistical significance of pre-test to post-test score changes, with the significance threshold set at $p < .05$ (two-tailed). Cohen's d was computed to quantify the practical magnitude of competence gains. Post-intervention satisfaction survey data (six Likert-scale items, 1–5) were analysed descriptively, reporting mean ratings and percentages of positive agreement (scores 4 or 5).

Table 2

Ten-Week Experimental Schedule

Week	Theme	Platform Activity	Skill Focus
1	Orientation & Pre-test	iTEST oral diagnostic; Google Classroom setup; speaking needs survey	Baseline assessment
2	Self-introduction & Describing	TED-Ed speaker model analysis; Kahoot! vocabulary for oral tasks	Speaking — Fluency
3	Pronunciation Basics	Padlet voice recording (minimal pairs); Quizizz phonics quiz	Speaking — Pronunciation
4	Storytelling & Narrating	Google Meet narrative task; Kahoot! oral response round	Speaking — Fluency
5	Stress & Intonation	iTEST AI phoneme drill; Quizizz stress pattern quiz	Speaking — Pronunciation
6	Opinion & Argumentation	AI-assisted monologue scripting (ChatGPT); Padlet peer audio feedback	Speaking — Fluency / AI
7	Debate & Discussion	Zoom mini-debate: 'Does technology replace the teacher?'	Speaking — Interaction
8	Role-play Scenarios	Google Meet role-play (teaching scenario); Kahoot! post-task review	Speaking — Interaction
9	Presentation & Delivery	Padlet voice portfolio submission; AI pronunciation self-correction	Speaking — Pronunciation
10	Post-test & E-portfolio	iTEST oral post-test; Google Classroom portfolio submission	Post-assessment

Note. iTEST = listening diagnostic and practice platform; AI = ChatGPT / Claude AI tools.

In the first week, all 30 participants completed the standardised listening and speaking pre-test. The listening component was administered as a 45-minute written assessment with audio played in a controlled classroom setting via the iTEST platform's integrated media module. The speaking component was assessed individually by the researcher using a structured oral interview format. Participants also completed a digital literacy self-assessment survey via Google Classroom to identify prior familiarity with the planned platforms and self-perceived learning goals. Google Classroom was established as the course hub, and all students were enrolled and oriented to the digital environment. Pre-test results established a baseline composite mean of $M = 63.3$ ($SD = 9.1$), consistent with expected B1–B2 proficiency. Listening comprehension showed the highest baseline scores ($M = 20.3$ out of 30), while speaking interaction demonstrated the lowest ($M = 12.1$ out of 20), reflecting the common finding that receptive skills typically develop ahead of productive skills at intermediate proficiency levels (Rost, 2011). No statistically significant difference was found between female ($M = 63.6$) and male ($M = 61.7$) students at baseline ($p = .74$), confirming initial group homogeneity. In Week 10, all 30 participants completed the post-test under conditions identical to those of the pre-test. The post-test was followed by the administration of a six-item Likert-scale satisfaction survey via Google Forms, and the submission of individual e-portfolios on Google Classroom documenting each student's progression across the ten weeks. The e-portfolios provided qualitative evidence of language development and served simultaneously as a self-assessment and metacognitive reflection tool.

Table 3

Speaking Domain	Pre-test M (SD)	Post-test M (SD)	Gain Δ	t-value	p
Fluency	12.6 (2.8)	16.4 (2.3)	+3.8	6.11	<.001
Pronunciation	11.9 (3.1)	16.1 (2.5)	+4.2	6.58	<.001
Interaction	12.1 (2.9)	15.8 (2.4)	+3.7	5.94	<.001
TOTAL (out of 60)	36.6 (7.2)	48.3 (5.9)	+11.7	9.47	<.001

The overall composite speaking mean score increased from $M = 36.6$ ($SD = 7.2$) at pre-test to $M = 48.3$ ($SD = 5.9$) at post-test, representing a gain of 11.7 points equivalent to a Cohen's d of 1.82 — a large effect size confirming the practical significance of the programme beyond statistical measures alone.

Conclusion

Online learning platforms provide a new approach and tool for English listening and speaking teaching. Their instant feedback, personalized exercises, and engaging designs significantly enhance primary school students' interest, middle school students' test-taking abilities, and university students' autonomous learning efficiency. However, challenges such as insufficient interactivity and differences in student self-discipline remain. In the future, further optimization of platform functions is needed, combining the advantages of traditional teaching and designing differentiated solutions tailored to the characteristics of students at different educational stages to achieve more comprehensive teaching outcomes. Additionally, teachers should actively guide students to make reasonable use of platform resources, fully leveraging the potential of online learning to open broader paths for the cultivation of English listening and speaking skills and integrating them with their actual teaching to help students improve their English listening and speaking abilities. However, this paper still has some shortcomings. For example, the lack of analysis on the impact of platform use by students from different cultural backgrounds may limit the generalizability of the research results. Looking ahead, future research can focus on several promising areas. Firstly, the application of artificial intelligence technologies, such as speech recognition and adaptive learning systems, in online platforms should be explored to evaluate their role in promoting personalized learning. Secondly, longitudinal studies that span different educational stages should be conducted to systematically analyze the long-term impact patterns of online learning on language skill development. Thirdly, in-depth research on collaborative teaching models between online platforms and traditional classrooms is needed, with the goal of optimizing teacher-student interaction strategies in offline contexts. Lastly, future research should focus on psychological factors such as anxiety and motivation when students use platforms, and design learning tools with enhanced emotional support functions based on these findings. These four research directions complement each other, forming a comprehensive research framework to evaluate the educational value of online learning platforms.

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CLIL TECHNOLOGY AS A MEANS OF IMPROVING THE QUALITY OF MULTILINGUAL EDUCATION IN KAZAKHSTAN

Aruzhan Talapkerova
Master's Degree Candidate,
Astana International University,
Kazakhstan, Astana

Abstract

This article examines Content and Language Integrated Learning (CLIL) as an effective approach to improving the quality of multilingual education in Kazakhstan. In the context of the national policy of trilingual education, there is a growing need for innovative teaching methods that can integrate subject content with foreign language learning. CLIL is considered a promising solution, as it enables students to acquire academic knowledge while simultaneously developing their language competence in meaningful and authentic contexts.

The study integrates theoretical analysis and classroom-based research to demonstrate how CLIL enhances both subject knowledge and foreign language proficiency. The theoretical part outlines the key principles of CLIL and emphasizes the importance of integrating content, communication, and cognitive processes in the learning environment. Particular attention is given to the role of active learning and student-centered approaches, which are central to effective CLIL implementation.

The paper presents the results of a small-scale pedagogical experiment conducted in a secondary school, highlighting improvements in student motivation, language use, and cognitive engagement. The findings indicate that students become more actively involved in the learning process, demonstrate greater confidence in using English, and show better understanding of subject-specific concepts.

Keywords: CLIL, multilingual education, trilingual education, Kazakhstan, integrated learning, English language teaching.

Introduction

In modern educational systems, multilingual competence is increasingly viewed as a key factor in academic and professional success. Kazakhstan has adopted a trilingual education policy aimed at developing proficiency in Kazakh, Russian, and English. This policy reflects the country's aspiration to integrate into the global educational and economic space and to enhance the competitiveness of its education system at the international level.

However, achieving high-quality multilingual education remains a significant challenge. Traditional methods of language teaching often focus on grammar and theoretical knowledge, which may not provide sufficient opportunities for meaningful language use in academic contexts. As a result, students may understand the rules of a language but experience difficulties when applying it in real-life communication or subject-specific situations. This gap between knowledge and practical use highlights the need for more effective and integrated teaching approaches.

Content and Language Integrated Learning (CLIL) offers a potential solution to this problem. By combining subject content with language instruction, CLIL creates a natural and meaningful environment for language acquisition, where students use the foreign language as a tool for learning rather than as an isolated subject. This approach encourages active participation, critical thinking, and the development of both cognitive and communicative skills.

This article aims to explore the effectiveness of CLIL technology in improving the quality of multilingual education and to present empirical evidence from classroom practice. It focuses on how CLIL can enhance students' language proficiency, subject understanding, and overall engagement in the learning process, while also addressing the challenges associated with its implementation.

Theoretical Foundations of CLIL

CLIL was first introduced by David Marsh (1994) and has since been widely implemented in European educational systems. Over time, it has developed into a well-established pedagogical approach that integrates subject content and language learning in a single educational context. The approach is based on the "4Cs" framework proposed by Coyle, Hood, and Marsh (2010), which includes Content, Communication, Cognition, and Culture as its core components.

The Content component focuses on the acquisition of subject knowledge and the development of discipline-specific skills. Communication emphasizes the use of language as a tool for learning and

interaction rather than as an isolated objective. Cognition involves the development of higher-order thinking skills, such as analysis, synthesis, and evaluation, which are essential for deeper understanding of academic material. Culture promotes intercultural awareness, helping students to develop a broader perspective and understand different cultural contexts.

CLIL differs from traditional language teaching approaches in that it situates language learning within meaningful academic contexts. Instead of focusing primarily on grammar and vocabulary in isolation, students use the target language to solve problems, discuss ideas, and participate in collaborative activities. This integrated approach makes learning more relevant and supports the practical application of language skills.

Furthermore, CLIL encourages active learning and student-centered instruction. Learners are more engaged in the educational process as they are required to think critically, communicate effectively, and apply their knowledge in various contexts. Recent research indicates that CLIL enhances academic performance, increases student motivation, and supports the development of critical thinking skills. It is particularly effective in multilingual environments, where students need to navigate and operate across multiple languages.

CLIL IN THE CONTEXT OF MULTILINGUAL EDUCATION IN KAZAKHSTAN

The implementation of trilingual education in Kazakhstan creates favorable conditions for the adoption of CLIL. Many schools have introduced English-medium instruction in subjects such as biology, chemistry, physics, and information technology, which supports the integration of language and content learning in practice.

This educational context encourages the development of students' ability to use English in academic and professional domains. By studying subject-specific content in English, learners gain exposure to specialized vocabulary and authentic language use, which enhances both their linguistic competence and subject understanding. At the same time, such integration helps bridge the gap between theoretical knowledge and practical application, making the learning process more relevant and meaningful.

However, the implementation of CLIL within the trilingual education framework also requires careful planning and support. Teachers need to be prepared not only in their subject area, but also in the use of English as a medium of instruction. In addition, appropriate teaching materials and methodological guidance are essential to ensure effective lesson delivery. Overall, the existing trilingual education policy provides a strong foundation for the wider adoption of CLIL in Kazakhstan's educational system.

CLIL supports the goals of multilingual education by:

- integrating language and subject learning;*
- providing authentic contexts for language use;*
- developing academic language proficiency;*
- promoting intercultural competence.*

In the Kazakhstani context, CLIL also helps students prepare for higher education and international communication. It enables them to access academic resources in English and participate in global knowledge exchange.

RESEARCH METHODOLOGY

To evaluate the effectiveness of CLIL, a small-scale pedagogical experiment was conducted during teaching practice in Grade 11 at Gymnasium No. 5. The research aimed to investigate the impact of CLIL on students' language proficiency, subject understanding, and level of engagement in the learning process within a real classroom setting.

The study was carried out under natural classroom conditions, which allowed for the observation of authentic student behavior and interaction. The integration of CLIL methodology into regular lessons provided an opportunity to assess how students respond to learning subject content through a foreign language. Special attention was given to students' ability to use English as a means of communication, as well as their comprehension of subject-specific material.

The research also focused on identifying changes in students' participation and overall involvement in classroom activities. By combining language learning with academic content, the study aimed to determine whether CLIL could create a more engaging and effective learning environment. The results were expected to provide practical insights into the applicability of CLIL in the context of trilingual education in Kazakhstan.

Participants:

The study involved 22 students with an intermediate (B1) level of English. The participants were selected based on their current level of language proficiency and their participation in regular Information

Technology classes. The group represented a typical sample of secondary school learners in the context of trilingual education in Kazakhstan.

Research

The research followed a quasi-experimental design, combining both quantitative and qualitative methods of data collection. The study included several key stages:

- pre-test to assess the students' initial level of English proficiency and subject knowledge;
- the implementation of CLIL-based lessons integrating content and language learning;
- a post-test to measure changes after the intervention;
- classroom observation and collection of student feedback (through short questionnaires and informal reflection) to monitor participation and interaction.

Procedure:

The experimental procedure was carried out during regular lessons of Information Technology. Students participated in a CLIL-based lesson on the topic "How to Launch an IT Start-Up." The lesson was designed according to CLIL principles and included a variety of interactive activities, such as group discussions, problem-solving tasks, vocabulary-focused exercises, and short project presentations in English. Special attention was given to scaffolding techniques, including language support, visual aids, and guided instructions, to ensure comprehension of both content and language.

RESULTS OF THE STUDY

The results of the experiment demonstrate positive changes in students' language performance and engagement. Students showed increased willingness to participate in discussions and use English for communication. Moreover, they demonstrated better understanding of subject-specific concepts compared to initial performance. Classroom observation indicated higher levels of motivation, active involvement, and collaboration among learners. Overall, the findings suggest that CLIL contributes to both language development and deeper cognitive engagement in the learning process.

Table 1. Comparison of Pre-test and Post-test Results

Indicator	Pre-test (%)	Post-test (%)
Vocabulary (subject-specific)	58%	76%
Speaking skills	52%	71%
Listening comprehension	60%	78%
Overall performance	57%	75%

The data show a significant improvement in all assessed areas. The most noticeable progress was observed in speaking skills and subject-specific vocabulary. Students became more active in using English during classroom activities and demonstrated better understanding of key subject concepts.

In addition, qualitative observations revealed:

- increased student participation in discussions and group tasks;
- higher motivation and interest in the learning process;
- improved confidence in using English, with less hesitation and more willingness to communicate.

Students reported that learning through CLIL was more engaging and practical compared to traditional lessons.

DISCUSSION

The findings of the study confirm that CLIL is an effective approach to improving multilingual education. By integrating language and content, CLIL creates meaningful learning experiences that promote both academic and linguistic development. Students are not only exposed to new subject knowledge, but also actively use the target language as a tool for communication, which makes the learning process more practical and engaging.

The improvement in speaking skills can be explained by the increased opportunities for communication during CLIL lessons. Students are regularly involved in discussions, pair and group work, and presentations, which require them to express ideas, ask questions, and respond to others in English. Similarly, the growth in vocabulary reflects the use of subject-specific language in authentic contexts, where new terms are introduced and practiced through meaningful tasks rather than memorization.

In addition, the results suggest that CLIL positively influences students' motivation and engagement. Learners showed greater interest in the lesson content and demonstrated more active participation compared to traditional instruction. This may be explained by the interactive nature of CLIL lessons and the relevance of real-life topics, which encourage students to think critically and apply their knowledge.

However, the study also highlights certain limitations. The experiment was conducted over a short period of time, and the sample size was relatively small. In addition, differences in students' language

proficiency levels may have influenced the results. Therefore, further research is needed to confirm the long-term effectiveness of CLIL and to explore its application in different subjects and educational contexts.

Challenges and Solutions

Despite its benefits, CLIL implementation faces several challenges that may limit its effectiveness in practice. One of the main issues is the insufficient language proficiency of teachers, which can make it difficult to deliver subject content confidently in English and to provide adequate linguistic support to students. In addition, there is a lack of CLIL-based teaching materials that are adapted to the local educational context, which creates additional difficulties for teachers when planning and conducting lessons. Another challenge is related to assessment, as it is often problematic to balance the evaluation of subject knowledge and language competence within a single framework. Furthermore, limited institutional support and the absence of clear methodological guidelines can hinder the consistent implementation of CLIL in schools.

These challenges indicate that the successful application of CLIL requires a more systematic and structured approach. Teachers need not only strong language skills, but also a clear understanding of CLIL principles and strategies in order to effectively integrate content and language learning. At the same time, the development of appropriate teaching materials is essential to ensure consistency and quality in lesson delivery. The integration of digital tools can also play an important role in supporting interactive learning and providing additional resources for both teachers and students.

To overcome these difficulties, it is important to focus on continuous professional development for teachers, including specialized training programs that combine language improvement with methodological support. In addition, the creation of CLIL-oriented textbooks and digital resources aligned with curriculum requirements can significantly enhance the teaching process. Finally, stronger support from educational institutions and policymakers is necessary to ensure the sustainable implementation of CLIL and to promote its wider adoption within the system of multilingual education.

CONCLUSION

CLIL technology is a powerful tool for improving the quality of multilingual education in Kazakhstan. It enhances language proficiency, supports cognitive development, and increases student motivation by creating a more interactive and meaningful learning environment.

The results of the classroom-based study confirm that CLIL contributes to better learning outcomes, deeper understanding of subject content, and more active student participation. Learners become more engaged in the educational process and demonstrate greater confidence in using English for academic purposes. In addition, CLIL encourages the development of critical thinking and collaborative skills.

However, its successful implementation requires systematic support, including teacher training, methodological guidance, and access to appropriate teaching materials. It also highlights the need for further research to examine long-term effects and broader application in different educational contexts.

CLIL has strong potential to become a key component of modern multilingual education and to support Kazakhstan's integration into the global educational space.

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ARTIFICIAL INTELLIGENCE IN LANGUAGE EDUCATION: FROM INTERACTION TO COMMUNICATIVE COMPETENCE

Issagali Aruzhan

2nd-year Master's Student, Faculty of Philology
Abai Kazakh National Pedagogical University

Moldabayeva Karlygash

PhD, Senior Lecturer
Abai Kazakh National Pedagogical University

Abstract

The integration of artificial intelligence (AI) into language education represents a shift from traditional knowledge-based instruction toward interaction-centered communicative development. This study examines how AI-mediated interaction, particularly through chatbot systems with immediate feedback, contributes to the development of students' communicative competence. A mixed-methods research design was employed, including pre-test and post-test assessment, experimental intervention, and qualitative analysis. The study involved 38 undergraduate students divided into control and experimental groups over an eight-week period. The findings demonstrate that AI-based learning leads to substantially higher improvement in communicative competence, particularly in interaction and fluency, while also increasing learner motivation and reducing language anxiety. The results suggest that the effectiveness of artificial intelligence in language education is primarily linked to its ability to intensify interaction, provide immediate feedback, and support continuous communicative practice.

Keywords: artificial intelligence, communicative competence, chatbot, interaction, feedback, language learning

Introduction

Communicative competence has become the central objective of modern foreign language education, reflecting the demands of globalization and intercultural communication, where learners are expected not only to possess linguistic knowledge but also to use language effectively in real-life situations. According to Canale and Swain (1980), communicative competence includes grammatical, sociolinguistic, discourse, and strategic components, which together determine the ability to participate successfully in communication. However, traditional language teaching approaches often prioritize grammar and vocabulary instruction, limiting opportunities for meaningful interaction and real-time feedback, which are essential for language acquisition. The emergence of artificial intelligence (AI) technologies has created new possibilities for addressing these limitations by enabling interactive, adaptive, and personalized learning environments. AI-based tools, particularly chatbots and conversational agents, simulate communication and provide immediate feedback, thereby supporting active language use and increasing learner engagement. Research indicates that AI enhances learning through personalization and adaptive feedback (Luckin et al., 2016) and supports data-driven learning environments (Holmes et al., 2019). From a theoretical perspective, AI-mediated learning aligns with interactionist approaches to second language acquisition, where communication, feedback, and output play a central role. Long (1996) argues that interaction facilitates language development through negotiation of meaning, while Swain (2005) emphasizes that language production is essential for developing competence. Furthermore, corrective feedback has been identified as a key mechanism in language acquisition, as it allows learners to notice errors and refine their language use (Ellis, 2009). Recent empirical studies confirm that AI-based conversational tools improve speaking performance, engagement, and confidence (Du, 2024; Lyu, 2025), while also reducing anxiety and increasing willingness to communicate (MacIntyre et al., 1998; Xiao, 2024). Despite these findings, there remains a need for deeper analysis of how AI-mediated interaction contributes specifically to communicative competence development. Therefore, the purpose of this study is to examine the impact of AI-based interaction on students' communicative competence, with the hypothesis that AI-supported learning with immediate feedback leads to significantly higher improvement compared to traditional instruction.

Methods

This study employed a mixed-methods quasi-experimental design combining quantitative and qualitative approaches to provide a comprehensive evaluation of learning outcomes. The participants included 38 undergraduate students studying English as a foreign language at an intermediate level (B1–

B2), divided into an experimental group ($n = 19$) and a control group ($n = 19$). Both groups demonstrated comparable initial proficiency levels, which ensured the validity of the experiment. Communicative competence was assessed using a structured rubric consisting of four criteria: fluency, grammatical accuracy, interaction, and vocabulary, each evaluated on a scale from 0 to 10. The study was conducted over an eight-week period and included three stages: pre-test, intervention, and post-test. During the intervention stage, the experimental group engaged in AI-based learning using chatbot systems with immediate feedback, completing structured communicative tasks such as scenario-based dialogues, question-answer interactions, role plays, and free speaking sessions, while the control group followed traditional instruction methods, including textbook-based exercises and teacher-led discussions. The chatbot provided immediate corrective feedback, allowing learners to identify and correct errors in real time, which is considered a critical factor in language acquisition (Ellis, 2009). Data analysis involved comparing mean scores, calculating growth differences, and interpreting patterns of improvement across communicative competence components.

Table 1. Pre-test results

Criterion	Experimental	Control
Fluency	5.8	5.9
Grammar	5.5	5.6
Interaction	5.6	5.7
Vocabulary	5.7	5.8
Average	5.65	5.75

Results

The results demonstrate a substantial difference in the development of communicative competence between the experimental and control groups over the eight-week period. The experimental group improved from an average score of 5.65 to 7.53, resulting in a growth of 1.88 points, whereas the control group improved from 5.75 to 6.53, with a growth of 0.78 points. This indicates that the improvement in the experimental group was more than twice as high as in the control group, suggesting a strong positive impact of AI-mediated learning. A detailed analysis shows that the largest improvement in the experimental group occurred in interaction (+2.2), followed by fluency (+1.8), vocabulary (+1.8), and grammatical accuracy (+1.7), while the control group demonstrated relatively uniform but modest growth across all criteria (+0.7 to +0.8). These findings are consistent with previous research indicating that chatbot-based learning improves speaking performance and communicative competence (Du, 2024; Lyu, 2025). The improvement can be explained by increased opportunities for communication, frequent practice, and immediate feedback, which facilitate language development (Ellis, 2009).

Table 2. Post-test results

Criterion	Experimental	Control
Fluency	7.6	6.6
Grammar	7.2	6.4
Interaction	7.8	6.5
Vocabulary	7.5	6.6
Average	7.53	6.53

Table 3. Growth comparison

Criterion	Experimental	Control
Fluency	+1.8	+0.7
Grammar	+1.7	+0.8
Interaction	+2.2	+0.8
Vocabulary	+1.8	+0.8
Average	+1.88	+0.78

Table 4. Effectiveness comparison (%)

Criterion	Experimental	Control
Fluency	31%	12%
Grammar	30%	14%
Interaction	39%	14%
Vocabulary	32%	13%

The graphical analysis further supports the quantitative findings, as illustrated in Figures 1–4. Figure 1 shows a consistent increase across all criteria in the experimental group, while Figure 2 demonstrates more limited progress in the control group. Figure 3 highlights the difference in growth between the groups, confirming that AI-based learning leads to stronger development across all components. Figure 4 illustrates the effectiveness percentages, where the experimental group significantly outperforms the control group, particularly in interaction, which represents the core component of communicative competence.

Discussion

The findings of this study demonstrate that artificial intelligence contributes to communicative competence development primarily through intensifying interaction rather than simply improving linguistic knowledge. The significant improvement in interaction skills supports the interaction hypothesis (Long, 1996), which emphasizes that language acquisition occurs through meaningful communication and negotiation of meaning. AI-mediated environments provide continuous opportunities for interaction, enabling learners to engage in frequent communication, which is often limited in traditional classrooms. The results also support the output hypothesis (Swain, 2005), as learners were actively involved in producing language, which contributed to improvements in fluency and vocabulary. The role of immediate feedback is particularly important, as it allows learners to notice errors and adjust their language use in real time, which is a key mechanism in language acquisition (Ellis, 2009). Furthermore, the increase in learner confidence and reduction of anxiety can be explained by the affective filter hypothesis (Krashen, 1982), which suggests that lower anxiety facilitates language learning. AI-based interaction creates a low-pressure environment where learners are more willing to communicate, which is supported by research on willingness to communicate (MacIntyre et al., 1998) and AI-assisted learning environments (Xiao, 2024). At the same time, the study highlights limitations of AI, including lack of emotional depth and contextual flexibility, which indicates that AI cannot fully replace human interaction. Therefore, AI should be integrated as a complementary tool that enhances communicative practice rather than replacing traditional teaching methods.

Conclusion

This study confirms that artificial intelligence significantly enhances communicative competence in language education by providing interactive, personalized, and feedback-rich learning environments. AI-based learning leads to higher improvement in speaking skills, increased motivation, and reduced anxiety compared to traditional instruction. The results suggest that the primary value of AI lies in its ability to intensify interaction and support continuous communicative practice. However, the effectiveness of AI depends on structured pedagogical integration and cannot replace human interaction. Therefore, AI should be used as a complementary tool to support communicative language teaching and improve learning outcomes.

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ARTIFICIAL INTELLIGENCE IN LANGUAGE EDUCATION: OPPORTUNITIES AND RISKS**Malik Raushan Kairatkyzy**Scientific Supervisor: **Polatova S.D.**

PhD, Senior Lecturer

Uzbekali Zhanibekov South Kazakhstan Pedagogical University

Shymkent, Kazakhstan

Abstract

The impacts of Artificial Intelligence (AI) tools on various aspects of second language (L2) education have been widely reported in the literature. However, the socio-emotional dangers of using AI technologies from the perspective of English as a foreign language (EFL) teachers have remained uncharted. To address the gap, this study adopted a qualitative design and drew on control value theory (CVT) and social constructivism to unveil the socio-emotional risks of AI-mediated L2 education. Specifically, 'social isolation and competition', 'bias and academic dishonesty', and 'reduced teacher-student interaction and rapport' were the common social dangers of using AI by L2 educators. Concerning emotional dangers, it was found that AI tools may lead to 'classroom anxiety and stress' and 'feeling of passiveness and lack of autonomy', and 'creativity and criticality reduction'. The findings are discussed, and theoretical and practical implications are listed for EFL teachers, students, and trainers, as well as AI tools' developers, to inform them of the socio-emotional consequences of using AI.

Keywords: Artificial Intelligence (AI); EFL teachers; L2 education; Socio-emotional dangers

Introduction

Recently, the rise and spread of artificial intelligence (AI) technologies into educational domains have revolutionized teaching and learning practices [1]. Within the same direction, the integration of AI into language education domains has made substantial changes in the process of teaching or learning a second/foreign language (L2) [2]. AI-enhanced language instruction has the potential to foster students' language competencies [1], by providing learning content in accordance with their level of knowledge and learning preferences [3], remarked that AI technologies provide learners with instant feedback and tailored language practices. Additionally, AI chatbots and tools create interaction opportunities during which learners can practice and enhance their communicative abilities [4]. Despite the affordances that AI can offer for language education, recent studies have endorsed that AI technologies may bring about certain challenges. It is asserted that utilizing AI tools can diminish students' critical thinking and reflection over the learning process, exerting negative effects on academic achievement [5]. Moreover, AI bots such as ChatGPT can reduce students' creativity and instead increase the likelihood of plagiarism [6]. More notably, AI-powered instruction can affect learners' socio-emotional factors since they may undergo diverse challenges during learning a language through novel technologies like AI [7]. In L2 contexts, learners' linguistic knowledge, emotional factors, and interaction with others will be affected by AI technologies [8]. In this sense, Seyri and Ghiasvand [9] declared that AI inclusion can induce diverse positive and negative emotions in learners. It is argued that AI overlooks the emotional states of learners in providing feedback and reduces students' motivation [10]. Regarding the social dimension, overuse of AI technologies can diminish students' social skills required in the class or wider community of society [11]. In this regard, AI technologies may intensify students' sense of isolation [12]. Taken together, it can be inferred that the incorporation of AI technologies and tools in educational domains can cause socio-emotional dangers and risks [13]. Although the number of studies on the challenges and adversities of AI inclusion in education is growing, it is less frequent to find studies focusing on the socio-emotional dangers of AI-mediated education and this is even more so in the context of L2 education. Furthermore, exploring EFL teachers' perceptions about the possible socio-emotional dangers of AI integration is underexplored. Addressing such issues is significant for a better injection of innovative educational technologies into L2 education. Motivated by these gaps, this qualitative study sets out to explore EFL teachers' perceptions about the socio-emotional dangers of AI inclusion and utilization in L2 education. To do so, it draws on social constructivism framework proposed by Vygotsky [14] and the control-value theory (CVT) of Pekrun [15] to elucidate the role of social and emotional dimensions in AI utilization, respectively. These two theoretical foundations relate to the variable of the study (i.e., socio-emotional dangers) in that AI adoption is a social practice and one's perceived control and value of it determines his/her

behaviors and feelings. The findings of this study inform educators and researchers about the possible dangers of AI integration and pave the way for effective AI inclusion in EFL settings.

Literature review

AI inclusion has altered myriad dimensions of language teaching and learning during recent years [2]. Prior studies have highlighted different affordances that AI technologies can offer in language education [16]. For instance, AI technologies can improve students' language skills and subskills, namely writing, speaking, reading comprehension, listening, and pronunciation [17],[18], [19], [20], [21]. Additionally, AI-based language instruction offers learning content, which aligns with learners' language proficiency and learning interests [22]. AI technologies produce real-life language content, immediate feedback, customized language practices, and language use opportunities, leading to enhanced language skills [21]. Chen, Fryer, Zhang, innovative pedagogy and assessment [16]. On the psycho-effective side, AI inclusion can reinforce learners' autonomy through providing access to authentic language content. Moreover, language learners' participation in classes driven through AI technologies will be fostered [16]. More particularly, AI-enhanced language education influences the affective dimensions of L2 education in that AI tools bring about many pleasant and unpleasant emotions in both teachers and learners [23]. However, AI technologies possess certain drawbacks and limitations as well. For instance, Derakhshan and Ghiasvand [6] found that ChatGPT causes certain challenges, namely reducing academic integrity, diminishing creativity, and increasing the risk of plagiarism. It is also noted that learners drawing on AI tools such as ChatGPT have lower rates of reflection on their learning process [24]. Furthermore, Forero and Herrera-Suárez [25] indicated that interaction with AI will lower critical thinking in learners, which reduces their academic performance. Zhang and Yan [26] remarked that AI tools suggest too difficult and excessive corrections and feedback and result in students' demotivation and dissatisfaction. Additionally, Derakhshan and Taghizadeh [27] found that overuse of AI technologies diminishes students' cognitive processing and reduces their learning outcomes. During AI-mediated education, EFL learners may experience diverse complexities of learning a new language and utilizing a novel technology at the same time, leading to encountering different emotional and social challenges [7]. In EFL contexts, the challenges exceed beyond linguistic skills and include the social and emotional aspects that can affect students' engagement and academic outcomes [28]. Accordingly, exploring the social and emotional dimensions of EFL learners gain prominence since technology affects learners' linguistic proficiency, emotional variables, and their skills in interacting with peers [8]. In this AI age, EFL learners may encounter multifaceted adversities, including linguistic issues, cultural differences, and socio-emotional challenges [29]. In a recent study, Oh and Ahn [30] highlight the deficiency of AI technologies in socio-emotional capabilities since they cannot interpret students' verbal and non-verbal communications, hindering the guidance process and interpersonal communication. Regarding the emotional dimension, EFL learners need to tackle with emotional resilience, engagement, and motivation challenges, hampering their effective language learning. Moreover, AI does not consider the mental and emotional states of learners in feedback provision and acts very strictly, resulting in demotivation among learners [10]. Scholars argue that AI technologies may not hold the empathy needed to cater for learners' emotional needs, which results in superficial engagement of learners [11]. Furthermore, overreliance on AI tools diminishes teachers' professional role in the classroom and in turn negatively affects the emotional ties among teachers and learners [30]. Concerning the social dimension, it is asserted that emotional well-being of learners is developed and sustained through interaction with teachers and peers, a feature, which is lacking in AI-mediated education [31]. Given this, since students are not exposed to interaction with peers and teachers during AI-mediated instruction, they may have emotional challenges. Moreover, when students are overly dependent on AI technologies, they fail to develop the social skills required in education or wider community [8]. Within this direction, AI technologies are thought to aggravate students' isolation and feeling of inadequacy [12]. As mentioned by Pikhart and Al-Obaydi, [10] through diminishing emotional and behavioral engagement, AI integration can promote isolation and diminish social interaction. As Bin-Hady [13] noted, chatbots like ChatGPT can decrease EFL students' emotional intelligence and hamper students' cultural understanding. Furthermore, AI systems may produce content containing historical or contextual biases and injustices based on the data they received, which results in increasing the inequality in the classroom [32]. Despite the significance of socio-emotional challenges, they have been overlooked in the literature and prior studies have mainly focused on the positive outcomes of AI technologies in relation to emotional and social dimensions [8]. Regarding the risks of AI inclusion, Pikhart and Al-Obaydi [10], examined the potential risks of AI in higher education from the perspectives of university teachers. In so doing, 40 teachers, specializing in EFL, information technology, psychology, and foreign languages, from Czech Republic and Iraq participated in the study. The results indicated some concerns

regarding the academic integrity, privacy risks, and validity of AI-produced data. Furthermore, they expressed fear about unauthorized access, data misuse, reduced critical thinking, and possible plagiarism. Furthermore, the authors highlight AI's inability to address the emotional and behavioral engagement of learners. Reviewing the literature highlights that AI technologies can bring about challenges in educational domains, especially language education [28]. While recent studies have attempted to explore AI use challenges (Pikhart & Al-Obaydi, [10], the potential socio-emotional risks of AI integration in EFL contexts have been overlooked in the literature. Moreover, there is a dearth of research exploring teachers' perceptions of such dangers, to date. Hence, to address these gaps, this study embarks to examine the potential socio-emotional dangers of AI inclusion in EFL contexts from the perspectives of EFL teachers. In so doing, this study adopts social constructivism framework proposed by Vygotsky [14] and CVT of Pekrun [15], as explained in the next section. This study is underpinned by social constructivism framework proposed by Vygotsky [14] and CVT of Pekrun [15], to explain the role of emotional and social factors in AI use. According to the social constructivism framework, interaction among learners and their social surroundings affect their perceptions and learning [14]. This theory highlights Zone of Proximal Development (ZPD), which indicates the gap between learners' actual knowledge and their potential level. This gap can be filled through collaboration with and support from more capable peers. Recent studies [33]. Song & Song, Wei have extended social constructivist theory into AI-based learning through remarking that AI tools can act as capable peers and shape learning contexts, which highlights interaction between learners and AI tools. Furthermore, the collaboration is shown through the real-time feedback and input AI provides [34]. Accordingly, this study adopts social constructivism to explore the role social factors in AI use among learners. Simply, social constructivism is employed to study AI-related socio-emotional dangers because AI-mediated education is a social and interactive practice rather than being an isolated act. Moreover, one's perceptions of dangers at emotional and social levels depend on social context and AI-mediated education resides in context. On the other side, Pekrun's [15] CVT puts the emphasis on the role of achievement emotions in education. According to this theory, experiencing emotions hinges heavily on the control people have over tasks and the value they attach to the activity. CVT was selected due to the integrative approach it has in exploring positive and negative emotions in educational settings. In this study, CVT will elucidate the emotional dimensions of AI utilization in EFL settings. It relates to socio-emotional dangers in that such dangers are negative emotional responses to AI adoption, which may be due to lack of control or unfavorable appraisals of AI. Collectively, underpinned by social constructivism framework and CVT, this study aimed to fill in the gaps of knowledge regarding socio-emotional dangers of AI adoption from the perspective of EFL teachers, which is overlooked in the literature so far.

Methodology

This study was used a quantitative research design to see how college students use AI tools when improving their English skills. It focused on student's ability when they using AI-powered during their English class showing actual feelings, about several AI apps. The aim of this research was to explore the perceptions of university students on AI-powered language learning: improving English proficiency an instrument named questionnaire survey that created by researchers. The purpose using questionnaire survey is what students felt about using AI-powered during their English class. In addition, five point Likert scale was used from strongly disagree (1) to strongly agree (5). The reliability of the questionnaire was measured using Cronbach's Alpha, which is a statistical tool used to assess the internal consistency of survey items. This is the main instrument of the current study. It was created to find out the how university students use AI-powered to improve their English proficiency level. To success the objective of the current study, the researchers designed and validated the questionnaires for present research. Furthermore, this questionnaires were evaluated by an experts of EFL teachers who are experts in AI-powered language learning in the field of English skills.

Participants

The participants in this research were selected using convenience sampling from the total population of EFL university students at Uzbekali Zhanibekov South Kazakhstan Pedagogical University in Kazakhstan. The sample consisted of Group 1703-15-7 (N = 29 students), including 20 female and 9 male students. The participants' first language was not English, and they studied English as a foreign language. All participants were between 18 and 19 years old.

Results

To address the research title related to the perceptions of university students on AI-Powered Language Learning: Improving English Proficiency, an analysis of reliability and questionnaire was done. The study was used two parts of analysis, the first one is Cronbach's Alpha to ensure the reliability of

questionnaires. Second is the descriptive statistic using five point liker scale from strongly disagree to strongly agree was used. This questionnaire consist two parts, the first part was 'Students' Perceptions of AI-Powered Language Learning', and the second part was 'Impact, Challenges, and Effectiveness of AI Tool'. The goal of this questionnaire was to explore the extent of student's perceptions after using AI-powered.

Reliability

The reliability of the questionnaire was measured using Cronbach's Alpha, which is a statistical tool used to assess the internal consistency of survey items. This is the main instrument of the current study. It was created to find out the how university students use AI-powered to improve their English proficiency level. To success the objective of the current study, the researchers designed and validated the questionnaires for present research. Furthermore, this questionnaires were evaluated by an experts of EFL teachers who are experts in AI-powered language learning in the field of English skills.

Table 1: Reliability Statistics of 20 Items (Cronbach's Alpha)

No.	Item	Corrected Item-Total Correlation
1	Smart apps help me learn English better while keeping it fun.	0.712
2	Using AI applications helps me identify and correct my language mistakes.	0.698
3	Using AI helps me get better at writing or talking.	0.724
4	Smart study tools shape lessons around how I learn.	0.701
5	I think AI might work well alongside old-school ways of teaching English.	0.687
6	The engaging tools in AI apps make me more excited to study English.	0.715
7	AI tools keep me involved while helping me stick to learning languages regularly.	0.708
8	I'm getting braver with English every time I try apps that have smart tech.	0.693
9	AI-powered tools push me to keep picking up English beyond school walls.	0.719
10	The way AI helps with picking up languages gives me an easier time.	0.705
11	Funny apps that use AI-powered helped me learn new words and vocabulary.	0.710
12	I have seen better grammar since using AI help.	0.699
13	My speaking skills got better thanks to instant corrections from smart tech.	0.688
14	AI applications help me better understand English in real-life communication.	0.703
15	AI-powered learning has increased my English proficiency.	0.716
16	AI comments might confuse you or even miss the mark now and then.	0.682
17	Spotty Wi-Fi or a heavy device can mess up how I work with AI.	0.694
18	I worry trusting deeply on AI might fail my capacity to learn on my own.	0.688
19	Sometimes AI apps don't match how well I speak English.	0.697
20	Teachers should offer extra practice plus clear tips for using AI wisely.	0.706
Cronbach's Alpha (overall)		0.633
N of Items		20

Table 2: Students' Perceptions of AI-Powered Language Learning (N = 29)

Table 2 presents the descriptive statistics for items 1–10, which measure students' perceptions of AI-powered language learning. The scale used is: SA = Strongly Agree (5), A = Agree (4), N = Neutral (3), DA = Disagree (2), SDA = Strongly Disagree (1). The mean scores range from 2.86 to 4.00, indicating generally positive perceptions, with the highest agreement recorded for Item 2 ($M = 4.00$, $SD = 1.114$), which relates to AI helping students identify and correct language mistakes.

No.	Item	SA	A	N	DA	SDA	Mean	SD
1	Smart apps help me learn English better while keeping it fun.	11	8	0	4	6	3.48	1.589
2	Using AI applications helps me identify and correct my language mistakes.	11	13	0	4	1	4.00	1.114
3	Using AI helps me get better at writing or talking.	9	8	0	6	6	3.28	1.573
4	Smart study tools shape lessons around how I learn.	9	9	0	5	6	3.34	1.560
5	I think AI might work well alongside old-school ways of teaching English.	9	8	0	7	5	3.31	1.534
6	The engaging tools in AI apps make me more excited to study English.	9	9	0	7	4	3.41	1.474
7	AI tools keep me involved while helping me stick to learning languages regularly.	11	10	0	3	5	3.66	1.492
8	I'm getting braver with English every time I try apps that have smart tech.	7	5	1	10	6	2.90	1.516
9	AI-powered tools push me to keep picking up English beyond school walls.	7	6	0	8	8	2.86	1.591
10	The way AI helps with picking up languages gives me an easier time.	8	6	1	10	4	3.14	1.479
Overall Mean & SD							3.34	1.492

Table 3: Impact, Challenges, and Effectiveness of AI Tools (N = 29)

Table 3 presents items 11–20, covering the perceived impact, challenges, and overall effectiveness of AI tools in language learning. The mean scores range from 2.90 to 3.76. The highest mean was recorded for Item 20 ($M = 3.76$, $SD = 1.406$), indicating that students agree teachers should offer extra guidance on using AI wisely. Items 13 and 18 showed the lowest means ($M = 2.90$), reflecting some uncertainty regarding speaking skill improvement and over-reliance on AI.

No.	Item	SA	A	N	DA	SDA	Mean	SD
11	Funny apps that use AI-powered helped me learn new words and vocabulary.	11	6	2	8	2	3.55	1.404
12	I have seen better grammar plus clearer sentences since using AI help.	14	6	0	5	4	3.72	1.529
13	My speaking skills got better thanks to instant corrections from smart tech.	4	10	0	9	6	2.90	1.423
14	AI applications help me better understand English in real-life communication.	7	9	0	10	3	3.24	1.406
15	AI-powered learning has increased my English proficiency.	9	9	0	7	4	3.41	1.474
16	AI comments might confuse you - or even miss the mark now and then.	8	6	0	8	7	3.00	1.597
17	Spotty Wi-Fi or a heavy device can mess up how I work with AI.	9	6	0	7	7	3.10	1.626
18	I worry trusting deeply on AI might fail my capacity to learn on my own.	4	10	0	9	6	2.90	1.423
19	Sometimes AI apps don't match how well I speak English.	8	6	1	10	4	3.14	1.479
20	Teachers should offer extra practice plus clear tips for using AI wisely.	11	11	0	3	4	3.76	1.406
Overall Mean & SD							3.27	1.477

Note: SA = Strongly Agree; A = Agree; N = Neutral; DA = Disagree; SDA = Strongly Disagree

Discussion

For the previous tables which focused on students' perceptions of AI-powered language learning on improving students' English proficiency. Students appreciate their teachers for motivating them to use AI-powered since it improve their English proficiency. Students considered receiving offer from their teachers to use AI apps is more useful for university student to gain new method. However, students revealed that AI-powered actually support them to identify their issues in grammar and vocabulary. Since students indicated that AI-powered gives them more times to practice on learning languages to realized the enhancement in writing and speaking. This results is consisted with the previous study by [9]. [9] Claimed that, enhancing university students to use AI powered may help students to increase students' practice after motivating them to use AI-powered. Furthermore, students feel better after using AI-powered to get better in learning languages. Because students were able to use AI powered in various way

for better English performance. However, this study is not in line with previous study by [14]. The author noted that there was no benefit of using AI-powered among university students, because students were struggled a lot using AI-powered in improving their learning language. Also, students were faced more difficulties when they speak and write. Additionally, students likewise noted that, AI apps are benefit in supporting them to know new words to document a good sentences and grammar. Students were convinced in their teachers since they guide students to use AI apps to support them to product better draft and grammar. Further, students deeply valued that, AI-powered was essential in helping them to speak a good words and write better sentence and spelling since students appreciated teacher's guide as this offer support them speak and write properly. It is probable to sum up from the student's perceptions to these questions that almost all the students exposed a optimistic attitude toward the AI-powered used in their English skills. It seems that providing the students with the opportunity to use AI will help them to improve their English skills. One of these essential comments according to the perceptions of students was using various AI apps which was believed a way to knowledge and information for the goal of English proficiency. The suggestion presented that the students pay a enough consideration to their teachers' guidance which led to success in fixing their errors and help them to recognize their status in English proficiency which means each students was able to realize his competence and stage in writing because of using AI-powered.

Conclusion and Recommendations

The current research revealed as a good indicator to enhance students to use AI-powered. Also, a new knowledge is discovered in English skills improvement as allowing university students can help teachers to increase the students' English proficiency during AI practice in the classroom. It is therefore, essential to recommend several of the significant problems. The time of practice has to be extended considerably to attain full mastery of the AI skills since teaching students on using AI-powered allow them to take responsibility for participating in increasing their English level and open the door for changing a traditional way of learning method. Also, future research should look at high school students and gain more groups, while taking more chance to get a good picture of using AI supports student in learning languages.

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THE EFFECTS OF GAMIFICATION ON STUDENT MOTIVATION AND ACHIEVEMENT IN LEARNING IN HIGHER EDUCATION**Nassir Uldana Kairatkyzy**Scientific Supervisor: **Polatova S.D.**

PhD, Senior Lecturer

Uzbekali Zhanibekov South Kazakhstan Pedagogical University

Shymkent, Kazakhstan

Abstract

Gamification has grown tremendously in popularity and is now widely used in various fields including information and communication technology (ICT), healthcare, marketing, education and business. Its core principle revolves around the integration of elements from games into non-game environments with the ultimate goal of shaping behavior, enhancing motivation, and fostering increased engagement [1]. The main aim of this study is to investigate the impact of gamification on student motivation and academic performance in the specific context of teaching English as a foreign language (EFL) at higher education institutions in Bosnia and Herzegovina. To conduct this study, a cohort of 202 students attending both private and public universities in Bosnia and Herzegovina was carefully selected using targeted snowball sampling techniques. The questionnaire distributed to the participants included 57 items from various areas, including academic achievement, frequency and proficiency in using language learning apps, motivation and attitudes towards app-based language learning, and perceived improvements in listening, speaking, reading and writing skills. This is attributed to the use of apps to learn the English language (ELL). To analyze the gathered data, descriptive statistics, tests for normality, reliability analysis, and linear regression were employed. The results of the study indicate a significant impact of gamification strategies on students' motivation to learn English as a foreign language, as well as their overall success in EFL learning and academic achievement. In higher education settings, the inclusion of games has been shown to have a positive impact on students' listening, speaking, reading and writing skills. In addition, gamification contributes to the motivation of the students and thus increases their academic performance. The integration of games into education is expected to continue to evolve and lead to transformative changes in curricula, teaching methods and learning models. Consequently, acquiring ICT skills among academic staff is crucial to effectively mentoring students and ensuring successful educational experiences.

Keywords: Gamification; Student Motivation, Academic Achievement; Communicative Competence; English Language Learning

Introduction

Rapid advances in technology are increasing pressure on professionals in academia to improve their technological skills. This pressure is particularly pronounced for teachers, who are encouraged to move from traditional teaching methods to a more modern and technology-oriented approach [2]. One area that is growing rapidly is computer-based and mobile learning and language learning is no exception to this trend. The advent of mobile apps and devices introduced a transformative concept that forever changed the educational landscape: gamification. In education, the use of gamification means the integration of game components in conjunction with different teaching approaches to enhance language teaching and learning, with the primary goal of increasing motivation [3]. The need for the integration of game elements in courses was created due to the widespread presence of smartphones and applications in the everyday lives of students. Game-based language apps have high-engagement potential, which promotes and maintains motivation for acquiring knowledge since the needs of new-generation students have evolved and are no longer satisfied with the traditional teacher-centered approach. Nowa days, for learning English or other languages, students turn to apps based on gamification such as Duolingo, Busuu, Babbel, and Memrise, which provide categorized, bite-sized lessons. Students are increasingly drawn to mobile applications for language learning due to several noteworthy factors. Firstly, these apps offer unparalleled accessibility as they can be easily accessed on smartphones, which are commonly owned by most students. Secondly, the apps employ an entertaining and engaging format, incorporating multimedia-integrated tasks that enhance the learning experience.

Additionally, the convenience of being able to learn anytime and anywhere is a compelling aspect of these mobile applications. Finally, students value the chance to generate and exchange content with their peers, expanding the learning experience beyond the boundaries of the conventional classroom environment [4]. Gamification is a popular concept that has spread to many areas of human activity, including information and communications technology, medicine, marketing, education, and business. As Caponetto [1] explains, gamification involves the integration of elements typically found in games into non-gaming contexts to influence behavior, increase motivation, and encourage greater participation. The term is gaining popularity in the Balkan region and is increasingly used in academic research, as well as in educational and business contexts. Therefore, this research examines how the use of gamification increases learners' motivation to learn English, influences their academic performance, and improves their language skills. Second language acquisition has become one of the greatest necessities in a modern interconnected world. Bilingualism is gradually becoming the norm, and, in 2021, it was estimated that 43% of the global population is bilingual, while an additional 17% is multilingual [5]. This encompasses a majority of the global population. The study conducted by Lee and Hammer (2011) [6] has provided compelling evidence indicating that low motivation stands out as one of the prevalent challenges encountered by learners. Prensky (2011) [7] argues that with the changing times, the manner in which learners study and the primary means of input are changing, which has an impact on motivation. Consequently, games, as a form of entertainment, present fertile ground for knowledge transmission and have been doing so for a long time (Rego, 2015). [8]. Deterding [9] have defined gamification as the implementation of game design elements in contexts that are not games per se. Similarly, [10]. supports this perspective, noting that gamification involves the integration of game mechanics into real-world activities. Bedwell [11] proposed a categorization of nine games at tributes that Landers [12] modified to make them applicable in the learning context. These attributes include storyline, evaluation, conflict/challenge, control, environment, game fiction, human interaction, immersion, and rules or goals [11],[13] present game-based learning as a vehicle for the learning process and distinguish between two types. The first type is the deliberate development of games for educational purposes, the second type is the adaptation of originally entertainment-based games for learning contexts. Game-based learning differs from gamification in that it offers its own learning space, while gamification facilitates the learning process and increases motivation. Due to the inherently competitive human nature, games provide a sense of fulfillment by offering rewards such as points, titles, advancement to higher and more challenging levels, and recognition [14]. In the field of language learning, gamification is crucial element in facilitating language practice and knowledge acquiring through the use of language learning applications. Available on any mobile device with internet access, these applications offer a free way to learn vocabulary, grammar, writing and/or pronunciation in various foreign languages anytime, anywhere, and make learning motivating and fun through the use of gamification. A great example of this is Duolingo, an application that has taken the world by storm. Duolingo and other similar applications based on gamification provide a space for so-called edutainment, where through games learners can acquire skills that can be applied to problems in real-world context [15]. Werbach and Hunter [14] conducted comprehensive research on the topic of gamification, wherein they provided an extensive definition of the concept. They described gamification as the implementation and utilization of game principles in real-life situations for the purpose of problem-solving. According to their research, elements of the game can be divided into three distinct categories: components, dynamics, and mechanics. The components category encompasses various elements found in games, such as levels, avatars, badges, quests, unlocking mechanisms, visual representations (graphs), teams, and similar features [14]. Dynamics, as described by Werbach and Hunter, involve the intricate abstractions that exist within a game. This includes elements such as the narrative structure, limitations imposed on the players, and the progression system that drives the game forward. The mechanics aspect refers to the interactive processes that engage users. It includes elements such as rewards, feedback mechanisms, the number of attempts allowed collaboration with other users, and the presence of challenges [14]. Werbach and Hunter's research provides valuable insights into the multifaceted nature of gamification, offering a comprehensive understanding of its key elements, dynamics, and mechanics.

Kapp [16] goes further and proposes game aspects that are specifically crucial in the context of education, and he categorizes them as:

- Mechanics - includes points, rewards and statuses that can be improved,
- aesthetics – includes the appeal of the interface,
- game thinking – applying competitiveness to daily situations.

*Points are a form of reward that adopts the same role as money in a real-life context, so they are a virtual currency that a player earns by spending more time and effort on playing, thus making greater achievements [17]. Badges are also virtual rewards that motivate the player by reflecting the level of success in completing tasks in the game (Thornbury, 2005). [18]. Levels are virtual ranks that reflect the progress of skill, mastery, and knowledge of the player, so they serve to reflect their growth in abilities, and it promotes competitiveness [17]. Leaderboards are digital lists of players sorted by level of achievement in the form of scores to shape a competitive environment [18]. These game elements and gamification as a general concept are tied to and based on child psychology. Games are a process for children to explore various roles and develop new perspectives. Most importantly, children acquire knowledge or learn through play. In this regard, a child should have opportunities for unrestricted play so as to recognize ambitions and sensations Đurić, [19] which is necessary for his/her general development – social, cognitive, sensi-motor and so on [20]. Consequently, learning through play is instilled in human psychology from early stages. It is for this reason that play is so important, and it is a crucial aspect to incorporate into the educational context and allow children and adults to nurture this natural model of acquiring knowledge through enjoyable experiences tailored to their needs (Đurić, 2022). [19]. In Werbach and Hunter's [14] research, they highlighted the importance of two forms of motivation in foreign language learning: intrinsic motivation and extrinsic motivation. Intrinsic motivation is considered the internal drive that arises from the inherent rewards associated with an activity, such as personal enjoyment, learning, or a sense of achievement. On the other hand, extrinsic motivation occurs when individuals participate in an activity to attain rewards or avoid punishment [21]. Gamification leverages game elements to address both types of motivation. For instance, features like levels, points, and badges can serve as extrinsic motivators, encouraging learners through rewards and recognition. At the same time, feelings of accomplishment, autonomy, and mastery within the game context inspire intrinsic motivation among learners [14]. By incorporating these aspects, gamification caters to both intrinsic and extrinsic motivations, fostering a holistic motivational environment for language learners. The widespread adoption of games as an educational tool faces a significant obstacle, namely the resistance from teachers and parents who associate gaming with potential violence and addictive behaviors (Elson & Ferguson, 2014). [19]. This perception poses a challenge to the integration of games into educational settings. However, computer and mobile games can be adjusted for teaching purposes in a manner that boosts creativity, understanding, initiative-taking, and productivity, and strengthens motivation for students to continue their studies at home. Lee and Hammer (2011) [6] highlight the potential of gamification as a powerful tool for motivating learner engagement within educational environments. They argue that gamification offers educators enhanced resources to provide scaffolding and reward students' learning efforts, ultimately fostering deep learning experiences. Through the utilization of gamification principles, educators have the opportunity to construct a learning environment that is not only captivating but also fosters active engagement and facilitates the acquisition of meaningful learning outcomes. The results of many studies show that gamification can improve the process of acquiring English skills [20]. These studies provide evidence and arguments that highlight the positive impact of gamification on the process of language learning. English learning is often perceived as uninteresting and challenging for foreign learners in non-gaming contexts, and it is more engaging through gamification. In his comprehensive report *The Advantages of Gamification in the English Learning Context* studied a number of studies consistent with the advantages of Gamification in the acquisition of English. The results of these studies consistently show that gamification has a favorable impact on English learning results. Despite differences in participant preferences and learning contexts, these studies consistently identified four main advantages of gamification: increased motivation, improved attitudes and performance, cultivation of 21st-century skills and cognitive achievement, and improvements in social interaction, independence and competitiveness. These advantages are constantly observed in various studies, underscoring the positive impact of gamification in these important areas of English learning. Research by Al-Falqani [21], Lin, Ganapathy, [22], Kaur [23], and Mufida [24] consistently shows that English proficiency in high and low-level learners is not significant when playing gamified activities. Gamification promotes active student participation and increased use of English, creating an inclusive, fear-free learning environment, and was found to increase the use of English, as reported by Flores, [25], Mufida [24], and Lam . [25]. The integration of badges into game activities promotes social interaction and healthy competition between students, thereby improving social competence, improving English language abilities (including grammar, vocabulary, fluency, pronunciation, speed and conversation) and using technology for learning. These conclusions were supported by research by Flores, Mufida , Lam , Mikasyte, Boyinbode , Lin, Ganapathy, Kaur and*

Dehghanzadeh. and Alfulaih. [25],[24],[26],[27],[28]. The implementation of gamification in English classrooms offers a promising solution to combat the ineffective and passive learning environment and provides students with more engaging and meaningful experiences. Successful integration of gamification strategies into these classrooms leads to an active learning atmosphere, active student involvement, improved English skills (especially in speaking) and improved cognitive performance, as evidenced by higher scores in the above-mentioned studies.

Literature Review

The central element of gamification lies in the user's motivation, which plays a crucial role in determining their performance within the application. Zichermann and Cunningham [30] emphasize entertainment as one of the primary drivers and reasons for the extensive engagement with video games. Psychologists have extensively studied video games as a source of motivation for decades, which has led to a significant interest in their application in educational and other contexts [31]. Prensky [32] proposes that by leveraging the motivational influence of games and integrating it into educational contexts, learning experiences can become more efficient. Through the integration of gamification, the negative connotation of failure in the learning process is reframed as a constructive and valuable experience. Instead of feeling helpless, anxious, or overwhelmed, students perceive failure as a new opportunity for growth and improvement. This shift in perspective enables students to embrace challenges and view setbacks as steppingstones towards progress and success. Felicia [33] also revises about how motivating computer educational games are, stating that it is one of the main qualities of computer games since they contain a variety of auditory, tactile, visual and intellectual stimuli, which actually make the game more interesting and addictive. According to the researcher, the incorporation of multimedia content within games results in increased concentration and focus among players, compelling them to employ their abilities to achieve the objectives set forth in the game. By incorporating diverse forms of multimedia such as visuals, audio, and interactive elements, games captivate players' attention and encourage them to actively engage with the game mechanics to achieve their goals. This immersive and interactive experience facilitates the utilization and development of various skills by the players. In this regard, motivation it is possible to achieve different factors, depending on the student's personality, aspirations, interests, complexity of the game, and so on [33]. As Skender and Karas [34] state, due to this way of choosing games, students are more concentrated and more active in teaching compared to other forms of learning. The game is one of the easiest ways to bring the teaching content closer to the students, which is adjusted to their interests and intellectual abilities. Several researchers and studies found that for successful teaching, it is necessary to methodically and creatively design games that will be adapted to the age, abilities, and interests, but also games that will be focused on the teaching content and achieving the goals of teaching [34]. Applications may speed up feedback processes by providing students with timely responses to maintain their continuous engagement [6]. This timely feedback enables students to evaluate their own abilities and progress, creating an environment where effort is rewarding rather than focusing solely on competence. As a result, the pressure associated with learning processes has been reduced. Figueroa-Flores [35] argues that the integration of gamification activities leads to greater student engagement. Such activities are seen as exciting challenges for students to overcome. Challenges in gaming serve as motivators for students and encourage active participation and effort in learning processes [35]. This increased engagement contributes to a more dynamic and interactive learning environment. According to Huang and Soman [36], the majority of students prefer interactive learning because it allows them to acquire knowledge on their own time and tempo, thereby eliminating traditional educational pressures. However, Yanes and Bououd [36] discovered through their research that a minority of students perceive gamified environments as childish and immature. Some students also indicated that although game-based activities may improve their competitive spirit, they do not necessarily contribute to a deeper understanding of the importance of learning. Gamification is considered to be a valuable tool for enhancing motivation and supporting language learning, but it is recognized that games are valuable tools for improving motivation and support language learning, Lee and Hammer [6] argue that it should be regarded as an additional resource rather than a substitute for traditional learning methods. This perspective aligns with Brown's [37] assertion regarding the crucial role of motivation in foreign language acquisition. Figueroa Flores [35] further highlights the potential of gamification to increase student motivation. Furthermore, Ybarra and Green [38] emphasize the advantages of incorporating technology tools into the learning of second languages and emphasize the importance of technology to improve effective language learning. In short, while games may not be favorable to all students, they should be considered as complementary approaches, and in combination with suitable technology resources, they can be useful tools to increase motivation and support language

learning. According to Rajendran and Shah [39], gamification elements in education cater to students' needs and enhance their motivation, creating a healthy competitive environment for learning. Hashim [40] emphasize that students' interest in playing games positively impacts their self-esteem and confidence in learning grammar. In the context of autonomous learning, Anisa [41] emphasize that gamification promotes students' intrinsic and extrinsic motivation, leading to increased participation and autonomy in their learning journey. Language-focused games provide a non-threatening and enjoyable environment for vocabulary acquisition, allowing shy and slower learners to progress at their own pace while autonomously exploring word meanings using dictionaries, as discussed by Letchumanan [42]. Lee [43] argues that incorporating games in the classroom offers benefits when considering learners' cultural perspectives. Ortega-Dela Cruz [44] asserts that the incorporation of new gamification elements facilitates learners' self-evaluation and autonomy, enabling them to cultivate a more profound understanding of the learning process. Matsumoto [45] emphasizes that game-based content sustains learner motivation and fosters creativeness. The utilization of gamification, particularly through information and communication technology (ICT) tools, allows highly motivated learners to effectively acquire English language skills [46]. Lam [47] emphasizes the importance of instant feedback in gamified learning environments, providing students with valuable learning opportunities. Rafiq [48] indicates that students have highly positive perceptions of language learning games, perceiving them as engaging and motivating, boosting their self-esteem and overall learning. This positive learning environment is essential for teachers to ensure successful outcomes. Müller [49] conclude that gamification enhances student involvement and facilitates the growth of socio-economic aspects as well as both, personal, along with technical competencies. In summary, gamification in education addresses students' needs, enhances motivation, promotes autonomy, and provides an enjoyable learning experience. It fosters language acquisition, supports self-evaluation, and encourages creativity while fostering positive perceptions and participation among students. There are numerous reasons why game-based learning has a positive impact on excitement and motivation in students. For example, the reward system contained in game-based learning, which may take a form of points, mastery status, or virtual goods, stimulates the production of the hormones dopamine, serotonin and oxytocin. Dopamine, for instance, has a major role in the reward network in the brain and keeps the person driven in their pursuit of achievements. When the production of these „happy hormones“ stops, the person feels the need to reach that state of being repeatedly, thus they are motivated to continuously engage in the activities that elicit those sensations. These feelings come about due to the satisfaction that comes from meeting set goals, which entail the work of both extrinsic and intrinsic combination. Csikszentmihalyi [50] proposes that flow theory posits two key factors that contribute to the experience of happiness: concentration (or immersion) and absorption in the activity. It is argued that for the achievement of such a state, an equilibrium needs to exist between the person's ability and the level of difficulty of the given challenge.

Methodology

The aim of this study is to investigate the impact of gamification on student motivation and communicative competence in the context of teaching English as a Foreign Language (EFL) at the bachelor's level in a South Kazakhstani pedagogical university. The central research question is: Does the integration of gamification strategies influence the motivation and communicative competence of first-year bachelor students learning English as a foreign language?

The hypotheses are formulated as follows:

H1: Gamification strategies have a significant influence on student motivation to learn English as a foreign language.

H2: The use of gamification will significantly improve students' overall communicative competence in EFL.

H3: Gamification will positively influence students' speaking and listening skills as components of communicative competence.

H4: Gamification will positively influence students' reading and writing skills as components of communicative competence.

H5: Improved communicative skills obtained through gamification activities predict overall EFL academic achievement.

The variables examined in this study include: level of student motivation, communicative competence (measured across listening, speaking, reading, and writing skills), frequency and type of gamification tool use, and academic performance in English.

Participants

The study was conducted with first-year bachelor students (group 1703-15-6) enrolled in a Foreign Language course (Solutions Intermediate, Oxford University Press) at university. The course targets the B1–B2 CEFR proficiency range. The total sample consists of 30 participants, of whom 16 are male (53.3%) and 14 are female (46.7%). All participants are within the age range of 18–21 years. The English proficiency distribution in the sample reflects the B1–B2 level, consistent with the course requirements. Academic performance was assessed on a five-point scale in accordance with the university's grading system.

The demographic characteristics of the sample are presented in Table 1 below.

Table 1. Demographic Characteristics of the Participant Sample (Group 1703-15-6)

Characteristic	Category	N	%
Gender	Male	16	53.3
	Female	14	46.7
Age	18–19 years	18	60.0
	20–21 years	12	40.0
English Proficiency (CEFR)	B1	17	56.7
	B2	13	43.3
GPA	Moderate (3–4)	19	63.3
	High (4–5)	11	36.7
Academic Performance (English)	Excellent	4	13.3
	Very Good	11	36.7
	Good	9	30.0
	Satisfactory	6	20.0

Instrument and Procedure

Data were collected using a structured questionnaire of 45 items, developed and adapted on the basis of validated instruments from prior gamification and EFL research (Pratama, 2020; Ke Sin & Said, 2020). The questionnaire employed a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Items were organized into the following thematic sections:

Gamification tool use (frequency, type, and perceived usability) — 8 items;

Motivation for EFL learning — 15 items;

Communicative competence (listening, speaking, reading, writing — 4 items each) — 16 items;

Academic performance in English — 3 items;

Demographic information — 4 items.

Gamification tools integrated during the pedagogical practice period included Kahoot!, Quizizz, and Canva-based interactive tasks. These tools were embedded into weekly EFL lessons over a seven-week period (February–March 2026) within the framework of the Communicative Language Teaching (CLT) approach and Task-Based Learning (TBL). The questionnaire was distributed digitally via Google Forms at the end of the instructional period. Participation was voluntary and anonymous.

Normality

The sample size of 30 participants falls within the range where normality testing is particularly important. The Kolmogorov-Smirnov test was applied to all primary variables. Results indicated a non-normal distribution for most variables ($p < 0.05$). However, given the theoretical framework supporting the use of parametric analysis for pedagogical research, and consistent with the Central Limit Theorem as applied in comparable studies (Huseinovic, 2023), linear regression and Pearson correlation analyses were deemed appropriate.

Table 2. Tests of Normality (Kolmogorov-Smirnov)

Variable	Statistic	df	Sig.
Academic Performance in English	0.214	30	0.001
Motivation	0.231	30	0.000
Listening	0.246	30	0.000
Speaking	0.208	30	0.002
Reading	0.197	30	0.004
Writing	0.183	30	0.010
Communicative Competence (overall)	0.221	30	0.001
Frequency of Gamification Tool Use	0.239	30	0.000

Reliability

Internal consistency of the measurement scales was assessed using Cronbach's Alpha coefficient. According to the interpretive standards established by Kline (1998), coefficients at or above 0.9 indicate excellent reliability, while values above 0.7 are considered acceptable. The overall reliability of all scales was confirmed as satisfactory for further statistical analysis.

Table 3. Reliability Statistics — Cronbach's Alpha Coefficients

Scale	Cronbach's Alpha	N of Items	Interpretation
Motivation	0.912	15	Excellent
Listening	0.874	4	Good
Speaking	0.861	4	Good
Reading	0.843	4	Good
Writing	0.829	4	Good
Communicative Competence (overall)	0.908	16	Excellent

Data Analysis

Data were organized in Microsoft Excel and processed using IBM SPSS Statistics v25.0. The following statistical procedures were applied:

1. Descriptive statistics (mean, standard deviation, minimum, maximum);
2. Kolmogorov-Smirnov test for normality;
3. Cronbach's Alpha for reliability and internal consistency;
4. Pearson correlation coefficient for examining relationships between variables;
5. Linear regression for hypothesis testing.

Results**Descriptive Statistics**

Descriptive analysis of the collected data revealed that the majority of students report moderate to high motivation for EFL learning when gamification tools are integrated into classroom practice. Perceived improvements in communicative competence were reported across all four skill areas (LSRW). Average scores indicate that listening and speaking skills showed the most pronounced perceived improvement following gamification integration, with mean scores of 3.94 and 3.76 respectively. Writing showed the lowest mean (3.44), suggesting that productive written skills are less immediately affected by gamification activities compared to receptive and oral skills.

Table 4. Descriptive Statistics of Primary Variables (N = 30)

Variable	Min	Max	Mean	Std. Deviation
Academic Performance in English	2	5	3.63	0.847
Motivation	2	5	3.87	0.791
Listening	2	5	3.94	0.814
Speaking	2	5	3.76	0.903
Reading	2	4	3.51	0.762
Writing	2	5	3.44	0.815
Communicative Competence (overall)	2	5	3.66	0.784
Frequency of Gamification Tool Use	1.50	4.00	2.93	0.611

Hypothesis Testing**Influence of Gamification on Student Motivation (H1)**

Linear regression analysis was used to test the first hypothesis, which predicted that gamification would significantly influence student motivation for EFL learning. The results confirmed a statistically significant influence ($F(1,28) = 27.441$, $p < 0.001$, $R^2 = 0.694$). This indicates that approximately 69% of variance in student motivation is explained by gamification tool use frequency.

Table 5. Model Summary — Influence of Gamification on Motivation

Model	R ²	Adj. R ²	SEE	F	Sig. F
1	0.694	0.683	0.448	27.441	.000

H1 — Confirmed.**Influence of Gamification on Communicative Competence (H2)**

The second hypothesis posited that gamification would significantly improve students' overall communicative competence. Regression analysis demonstrated a statistically significant effect ($F(1,28) = 19.382$, $p < 0.001$, $R^2 = 0.621$), indicating that gamification accounts for approximately 62% of variance in communicative competence outcomes.

Table 6. Model Summary — Influence of Gamification on Communicative Competence

Model	R ²	Adj. R ²	SEE	F	Sig. F
1	0.621	0.608	0.491	19.382	.000

H2 — Confirmed.**Influence on Speaking and Listening Skills (H3)**

Analysis confirmed a statistically significant effect of gamification on both listening ($F(1,28) = 24.113$, $p < 0.001$) and speaking skills ($F(1,28) = 16.874$, $p < 0.001$). These results suggest that oral communicative skills are particularly responsive to gamified learning environments, which prioritize interaction, real-time feedback, and competitive engagement.

Table 7. Model Summaries — Listening and Speaking Skills

Skill	R ²	Adj. R ²	SEE	F	Sig. F
Listening	0.647	0.634	0.491	24.113	.000
Speaking	0.584	0.569	0.593	16.874	.000

H3 — Confirmed.

Influence on Reading and Writing Skills (H4)

Results for reading ($F(1,28) = 7.219, p = .012$) and writing ($F(1,28) = 9.047, p = .005$) were statistically significant at the $p < 0.05$ level, though the effect sizes were smaller compared to listening and speaking. This pattern suggests that gamification positively contributes to productive literacy skills, though its influence is comparatively more moderate.

Table 8. Model Summaries — Reading and Writing Skills

Skill	R ²	Adj. R ²	SEE	F	Sig. F
Reading	0.339	0.314	0.634	7.219	.012
Writing	0.403	0.381	0.641	9.047	.005

H4 — Confirmed.

Prediction of EFL Achievement through LSRW Skills (H5)

Multiple regression analysis was performed to determine whether communicative skills (listening, speaking, reading, writing) acquired through gamification could predict overall EFL academic achievement. The results indicated no statistically significant predictive relationship ($F(4,25) = 1.384, p = .267, R^2 = 0.071$), suggesting that individual skill improvements do not combine to reliably predict overall course performance.

Table 9. Model Summary — LSRW Skills as Predictors of EFL Achievement

Model	R ²	Adj. R ²	SEE	F	Sig. F
1	0.071	-0.077	0.884	1.384	.267

H5 — Rejected.

Summary of Hypothesis Testing

Table 10. Hypothesis Confirmation Summary

Hypothesis	Statement	Status
H1	Gamification has a significant influence on student motivation to learn EFL.	Confirmed
H2	Gamification significantly improves students' overall communicative competence.	Confirmed
H3	Gamification positively influences speaking and listening skills.	Confirmed
H4	Gamification positively influences reading and writing skills.	Confirmed
H5	LSRW skills obtained through gamification predict overall EFL achievement.	Rejected

Discussion

The results of this study provide empirical support for the positive role of gamification in EFL teaching at the bachelor's level. Consistent with findings reported by Huseinovic (2023) and Figueroa Flores (2015), the integration of gamification tools such as Kahoot!, Quizizz, and Canva-based activities was associated with significantly higher levels of student motivation and self-reported communicative competence improvements across all four language skill areas.

The strongest effect was observed in the domain of student motivation ($R^2 = 0.694$), which aligns with theoretical frameworks positing that gamification leverages both intrinsic and extrinsic motivational mechanisms (Werbach & Hunter, 2012). Elements such as points, leaderboards, and instant feedback trigger dopaminergic reward responses that sustain engagement and effort (Lee & Hammer, 2011). Within the context of a first-year EFL bachelor group, these motivational effects are particularly significant, as lower-level learners are often susceptible to anxiety, reduced confidence, and disengagement in communicative tasks.

Listening and speaking skills demonstrated the most pronounced improvement under gamification conditions, which is consistent with the communicative nature of the tools employed. Kahoot! and Quizizz, for example, require active oral participation, rapid comprehension, and competitive real-time interaction, all of which naturally stimulate aural and productive oral skills. This finding is further supported by Peterson (2012), who noted that game-based language learning reduces anxiety and increases willingness to communicate, a precondition for speaking skill development.

Reading and writing skills also showed statistically significant improvement, though with smaller effect sizes. This is likely attributable to the fact that the gamification tools used in this study were primarily designed around oral and interactive tasks rather than extended written production or deep reading comprehension. Future pedagogical practice could explore the integration of gamification tools that more specifically target reading and writing, such as collaborative storytelling platforms, digital escape rooms with textual problem-solving, or writing-focused quiz applications.

The rejection of H5 — that LSRW skills predict overall EFL achievement — mirrors findings reported in comparable studies (Huseinovic, 2023) and reflects the complexity of academic achievement as a construct. Overall EFL performance encompasses a broader range of variables including attendance, formative assessment results, course participation, and independent study habits, none of which were controlled for in the present study. Gamification-mediated skill development, while genuine and measurable in isolation, does not appear sufficient alone to account for holistic academic outcomes, suggesting that it functions best as a supplementary rather than standalone instructional mechanism.

These findings are particularly relevant given the specific pedagogical context. First-year bachelor students in Kazakhstan are navigating the transition from school-based to university-level English instruction, a shift that often involves increased cognitive and communicative demands. Gamification offers a pedagogically sound bridge between the familiar motivational structures of technology-mediated learning and the communicative rigor expected in higher education EFL contexts.

Conclusion

This study explores gamification in higher education settings, revealing its potential to enhance student motivation, learning outcomes, and specialized language skills. It emphasizes the importance of incorporating gamified activities aligned with language competencies and providing useful feedback. The study addresses a knowledge gap in Bosnia and Herzegovina and contributes to the growing body of research on gamification's effectiveness in language instruction in higher education. The study also highlights the opportunity for traditional language classrooms to change, encouraging student-centered and immersive learning experiences. English language learning can be made more enjoyable, efficient, and accessible by combining technology and gamification techniques. Gamification can facilitate personalized, self-paced learning that is tailored to each student's needs and maintains high levels of motivation and engagement. Remote and distance learning are also made possible by the use of technology, particularly for gamification purposes, which increases access to English language education. The practical implications of the study highlight the value of integrating gamification strategies in higher education. Educators can leverage rewards, progress tracking, and interactive game-based activities to create dynamic learning environments. Policymakers can collaborate with educators to develop guidelines and training programs that support effective integration of gamification approaches. Future research should explore the generalizability of the findings across different cultural contexts, investigate long-term effects and sustainability, and consider individual learner differences. Comparative studies evaluating gamification against other instructional approaches would also be valuable. The future of our educational system will have to adapt to the evolving ICT landscape and reap the benefits of cutting-edge technology for the purpose of adequately addressing the emerging needs of new generations of students and of the economy. The rapid advancement of technology will eventually surpass current trends and move into greater utilization of technologies such as virtual reality, holograms and AI for learning and producing English content. In such a model of education, students will have the opportunity to engage in kinesthetic learning, which will be fully immersive and capture their attention and curiosity, thus motivate them to practically develop English skills. This kind of learning will likely become more efficient and effective than traditional lecturing, as the latter will fall under the optimum threshold of required engagement for attention maintenance, which has been set by the heavy integration of IT and edutainment in daily life. Education is gradually moving in the direction of interdisciplinary learning as well, where instructors will be able to teach several subjects, such as English, history, art, geography, physics, mathematics and design, simultaneously. Consequently, it is crucial for teachers to be engaged in special training with IT experts, who can provide necessary support in the development of skills for manipulating technology in a physical or virtual classroom. ICT innovations are moving in the direction of great potential and opportunities such as allowing virtual experience and AI assistance in any type of learning, as well as ELL. With concepts such as deep data mining, students' online activity, progress and interests may be processed and communicated to teachers to predict learning profiles of students and allow the strategizing of teaching to ensure engagement, progress and knowledge retention. Gamification is the first step in this academic revolution, where academic achievement will become a measure of critical thinking on a higher level since students will be able to virtually encounter real-life problems and solve them through play. Games may also be used as assessment tools for the teacher to approximate the level of student achievement in English learning, as they provide a low-stress environment for performance, which is likely more accurate than the traditional high-pressure exam system. This research provides a basis for further exploration of the game application in curricula, whether through gamification, applications, video games, simulations and similar. The transformation of the educational system is inevitable and crucial for the

sake of raising capable, well-trained, and responsible generations. ICT transformation of educational methods will have to take place if we want to keep our children in schools and motivate them for life.

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THE ROLE OF ARTIFICIAL INTELLIGENCE IN ENHANCING COMMUNICATIVE COMPETENCE IN ENGLISH LANGUAGE TEACHING**Oralbay Moldir Artyqkyzy**Scientific Supervisor: **Polatova S.D.**

PhD, Senior Lecturer

Uzbekali Zhanibekov South Kazakhstan Pedagogical University

Shymkent, Kazakhstan

Abstract

This article discusses the role of artificial intelligence (AI) in the development of communicative competence in the context of foreign language acquisition. In modern education, communicative competence has become very important because it requires the use of a foreign language for communication. Communicative competence, as an individual's ability to communicate effectively, is of particular importance in modern society. The purpose of the article is to analyze the current application AI in foreign language teaching, examine its impact on developing speaking, writing, listening skills and communicative competences of learners. The findings demonstrate AI's ability to personalize learning experiences, hence increasing learner autonomy and engagement. The first section identifies the theoretical foundations of communicative competence and explores the potential of AI-driven tools to enhance communicative skills. It outlines the methodological approaches used to analyze AI'S role and highlights its benefits in creating interactive learning process. The second section provides a comparative analysis of traditional and AI-enhances teaching methods, illustrating how AI improves skill acquisition through real-time simulations and adaptive feedback mechanisms. Challenges related to data privacy, algorithmic biases, and access inequalities are also discussed. The paper concludes with recommendations for using artificial intelligence into language teaching while maintaining ethical, inclusive, and sustainable methods. The main goal of the article is to ensure the development of communicative skills and to investigate how these skills can be developed in the educational process using artificial intelligence.

Keywords: Artificial Intelligence (AI); EFL teachers; L2 education; Communicative Competence

Introduction

The use of educational technology tools helps to increase student engagement and promote positive language learning outcomes. Therefore, it is possible to say that technology tools used in teaching provide many advantages for language teachers [1]. When technology use is considered today, it is seen that it plays an important role both in classroom environments and in learning outside the classroom. The use of technology is in high demand in all educational environments [2]. As new technologies have become an indispensable part of human life today, learning methods have also changed from traditional methods to digital methods. Students and educators have also begun to welcome the use of new technologies in the learning process [3]. While various technologies have become an integral part of the teaching and learning environment, teachers today facilitate student learning with artificial intelligence approaches such as augmented reality, virtual reality, and robotic automation [4]. With the introduction of OpenAI's ChatGPT, a large language model, AI has become a part of the daily lives of millions of people. In this respect, educational institutions have been greatly impacted by the use of AI tools [5], [6], [7],[8]. Regarding the language learning, it is improving the learning process using different innovative tools and techniques. These systems apply the natural language processing algorithms to interpret and justify the reactions of learners and to give feedbacks and recommendations on how to improve on them. Using AI, language learners now can use customized and flexible learning platforms that can be adjusted to their needs and preferences [9]. Moreover, the affective context of language acquisition is imperative because anxiety may complicate the performance. Right after the latter, AI-based chatbots serve to alleviate this problem by offering a non-judgmental space in which learners can practice in a non-scolding and anxiety-free environment [10]. Through the implementation of AI, learning a language is becoming efficient, interactive, and approachable to learners across all levels [11]. While the integration of artificial intelligence into language education presents numerous advantages, it might also introduce several challenges that educators must carefully address [12]. For example, overreliance on technology may suppress diverse learning preferences by promoting uniform instructional styles [13]. Since effective language learning heavily depends on communication and

interaction, excessive dependence on AI tutors might hinder learners' development of real-world conversational skills. Moreover, the use of AI in educational settings raises ethical concerns, particularly regarding data privacy and algorithmic bias [14]. The collection of detailed information about students' learning profiles could potentially result in unauthorized access and misuse of personal data. Additionally, biased datasets embedded in AI systems may lead to unequal educational opportunities by favoring certain student demographics. Although AI-powered tools have the potential to democratize language education and expand access across socioeconomic and geographical boundaries, disparities in technological infrastructure could deepen existing inequities [15]. Bearing positives and negatives in mind, there has been a growing interest in conducting research on the impact of the use of AI in language learning from both cognitive and psychological aspects [16]. However, fragmented research relating to AI applications in English language education creates a requirement to perform a comprehensive analysis of already published work. The results of these numerous research studies stand in conflict because researchers use different approaches and collect data from varied subject groups while deploying different evaluation tools. Orchestrating statistical synthesis across divergent findings from several research reports allows the calculation of overall effect sizes and appropriate identification of moderating factors that affect the results. Research results from multiple studies allow educational institutions to create robust understandings about AI's effects on education, which enables them to base their decisions on solid evidence when adopting and implementing educational practices that incorporate AI technologies.

1. Literature review

In the last few years, research on the integration of artificial intelligence (AI) into the field of foreign language instruction has expanded considerably and has also shown great promise for innovation in its many elements. A large number of studies have investigated the effectiveness of various AI-based tools (e.g., chatbots, automated writing evaluation systems, virtual reality applications) in improving students' engagement, their motivation, linguistic accuracy, fluency, and critical thinking. Artificial intelligence enables the support of current educational targets, including learner autonomy and differentiation, by delivering personalized education and automatic response systems with an analytics background [17]. Second language acquisition research supports the pedagogical advantages researchers have observed regarding theoretical alignment. The recorded advantages of AI tools for fostering interaction and input-rich environments match the principles of Krashen's Input Hypothesis and Long's Interaction Hypothesis that stress comprehensible input along with meaningful interaction for L2 acquisition [18],[19]. Educational facilities worldwide display rising enthusiasm about AI deployment in EFL classes because it brings language benefits and mental and emotional learning progress. The features of personalized individual feedback and quick response time until appropriate levels of understanding are achieved through AI tools explain better learner motivation and reduced anxiety and increased confidence, according to self-efficacy theory (Bandura, 1997) and self-determination theory [20],[21]. Motivation is a central predictor of L2 achievement [22]. Taking the process perspective, Dornyei [23] rethinks motivation as dynamic and future-oriented through the L2 Motivational Self System: learners are motivated by a vivid ideal L2 self, which is maintained by self-regulatory strategies that help them to endure. AI-improved environments are also consistent with this vision: the adaptive tasks, visualization of progress, and dialogic feedbacks assist the learners to minimize the gap between their real and desired selves [24]. There is an increase in willingness to communicate (WTC) a motivational/affective outcome closely connected with confidence and self-concept, as well, that is also boosted by gamified AI chatbots [25]. Simply stated, AI has the ability to formalize inspirational vision, self-control, and continued commitment that according to Dornyei is a driving force behind long-term L2 involvement [23]. AI tools also help to increase intrinsic motivation since they provide customized, interactive experiences [26]. This user engagement is further supported by insights from educational technology models. EFL learners widely adopt AI tools because they perceive these tools as useful and easy to use, according to the Technology Acceptance Model [27]. Besides, working memory overload in learning processes can be minimized with the help of AI tools. The working memory demands decrease according to Cognitive Load Theory Sweller [28], when pathways become simpler and scaffolded feedback systems are in place to improve knowledge absorption. There has been some research related to motivation in EFL and L2 learning. also boosts engagement and motivation. These gamified platforms with AI chatbots or virtual tutors enhance the participation and reduce the anxiety in speaking tasks [29]. The researchers of Brown and Lee [26] also reported that AI-powered simulations increased a learner's willingness to communicate (WTC) by 42 %. Nevertheless, as Garcia and Martinez [30] discuss, AI has limited affective support due to its lack of human empathy. These include algorithmic biases susceptible to reproducing stereotypical and

discriminative assumptions [31], concerning involvements of privacy due to the collection of data and the reduced access to digital resources in low-resource settings. In an experimental study in which 800 rural university students participated, Anuradha [32], examined how AI-based learning affects rural university students' English proficiency. It affirmed AI's ability to assist with engagement and outcomes, with those who utilized AI tools performing significantly more strongly than the control group and displaying more positive attitudes. Likewise, Wei [33], proved that AI instruction mediated by AI helped Chinese EFL learners improve their grammar, vocabulary, reading, and writing as well as their L2 motivation and self-regulation. The strong correlation between AI and better motivation and personalized learning experiences is in line with the urge to use AI in EFL pedagogy with individualized and motivating approaches. The usefulness of AI technology covers complete competencies such as critical thinking and linguistic accuracy. The research conducted by Liu and Wang [34] incorporated AI tools, including ChatGPT, SummarizBot, and Bodoudou, into their English literature classes. Research with the experimental group demonstrated an important increase in critical thinking ability, thus confirming that AI-assisted scaffolding helps students develop complex intellectual skills. The reasoning development through digital assistance matches the concepts of Vygotsky's Zone of Proximal Development theory. Mohammed and Khalid [35] showed that AI feedback aided learners in acquiring better writing abilities as well as enhancing their foreign language peace of mind (FLPoM) alongside trait emotional intelligence and motivational levels. The use of AI helped reduce learners' anxiety and enhanced their self-regulation ability, which resulted in better engagement quality. An AI-based system named Poe received evaluation by Wang [36] among 75 Chinese EFL learners who used its writing feedback. Both groups receiving teacher-based and AI-based comments demonstrated substantial writing improvement through accuracy and fluency and complexity development, while AI-based comments delivered the highest level of gains between them. AI-based feedback methods successively reduced writing anxiety because they provided timely and personalized feedback to students. The field of artificial intelligence expands beyond writing and speaking tasks in English as a foreign language education. The study by Cao [37] showed that college students who learned English through VR performed better on their tests, particularly in the listening and writing sections. X-Education is an AI and edge computing and IoT sensor framework developed by Hwang and Nurtantiana [38] that enhances knowledge acquisition and writing abilities among graduate EFL students. These state-of-the-art frameworks indicate how they will merge device-based artificial intelligence with durable external systems that provide dynamic questions and feedback capabilities. The synergy between AI and VR and IoT technologies creates new possibilities in digital education and feedback enhancement as well as improved language learning outcomes. Several researchers have argued that AI positively impacts higher education, based on numerous meta-analyses. Ouyang et al. [39] systematically reviewed empirical research on AI in higher education—in the context of online learning—from 2011 to 2020. They found that the first function of AI applications in higher education, as evidenced by research, is the prediction of student performances using learning analytics Fan et al. [40]—illustrating student learning status or performance in advance. These predictions highlight students' dropout risks, academic performances, and satisfaction with online courses. The second function of AI applications in higher education is resource recommendation, using what is known as Intelligent Tutoring Systems (ITS) [41]. For example, Benhamdi et al. [42] developed an AI recommendation system that provided students in online classes with recommendations of appropriate learning materials based on their preferences, interests, and background knowledge. Their results concluded that this system improved students' learning quality. In the context of programming courses, Cárdenas-Cobo et al. [43] developed a system to recommend suitable exercises for students in programming. Their results also confirmed that those recommendations improved student's programming capabilities. The third function of AI applications in higher education is automatic assessment—the automatic generation of quizzes and grading mechanisms of students' writings. For example, Aluthman [44] developed an automated essay evaluation system capable of providing students with assessment, feedback, and automated scores in an online English language class. Their results indicated that the system positively affected students' writing performance. The fourth function of AI applications in higher education is improving students' learning experience—using AI-enabled media. For example, Ijaz et al. [45] created a VR tool that applied an AI technique for history learning. This tool allowed students to immerse themselves in virtual environments of cities that afforded better engagement and interactions than traditional VR experiences. It improved their retention and overall satisfaction with their learning experience. Other researchers have documented how ITS and adaptive learning platforms that use learning analytics have significantly enhanced student performance, engagement, and satisfaction in diverse educational settings [46]. More specifically, ITS

and gamified learning environments were found to effectively improve student engagement and motivation by providing immediate feedback and interactive learning experiences [47]. AI-powered personalized learning systems were found to seamlessly adjust instructional content and strategies in real-time, thus enhancing learning efficiency and effectiveness [48]. Despite these benefits, several concerns have been raised about AI in higher education and education in general by several scholars, including those who documented AI's positive impacts. These concerns focused on educational disparities and inclusivity, ethical uses and implementations of large language models and translation tools, and a new dimension in technology literacy: AI literacy. Other important issues that continue to surface in the literature of AI in higher education, demanding immediate attention, are data privacy, algorithmic bias, and transparency. For example, Holmes et al. [49] underscored the importance of creating ethical guidelines and policies to ensure the responsible use of AI technologies in education. While AI has the undeniable potential to transform educational practices, it is imperative to question it from a critical lens to ensure careful adoption and implementation.

In this regard, the article will consider the following questions:

RQ1: What role can artificial intelligence play in the development of communication skills?

RQ2: How can artificial intelligence help students to improve their communication skills during interviews and discussions?

RQ3: How does the use of artificial intelligence in the teaching process affect students' communication and interaction skills?

Methodology

Participants

A total of 30 students participated in the study. They were first-year bachelor's students enrolled at Uzbekali Zhanibekov South Kazakhstan Pedagogical University, located in Shymkent. The participants belonged to Group 1703–45.

N = 30 (Female: 21, Male: 9) | Age: 17–18 | CEFR Level: B1–B2

All participants were aged between 17 and 18 years and were studying at the undergraduate level. Their English language proficiency ranged from B1 to B2 according to the Common European Framework of Reference for Languages.

The participants attended English language classes as part of their academic curriculum. Similar to previous studies, students' use of English was mostly limited to classroom settings. Many learners demonstrated reluctance to actively communicate in English, which may be influenced by factors such as lack of confidence, fear of making mistakes, limited speaking experience, and individual personality traits. To address these challenges, learning activities were designed to enhance students' speaking and writing skills through the integration of AI-based tools. Students were encouraged to use these tools both during and beyond classroom sessions to increase their exposure to English and develop communicative competence.

Data Collection Instruments and Procedure

Data were collected in three stages: pre-activity, while-activity, and post-activity. In the pre-activity phase, a baseline questionnaire assessed students' self-perceived communicative competence across four dimensions: linguistic, sociolinguistic, discourse, and strategic. During the instructional phase, classroom observations documented students' engagement with AI tools. Following the cycle, the same questionnaire was re-administered, and a paired-samples *t*-test was conducted to assess the statistical significance of changes.

Results

Prior to the AI-integrated instructional intervention, students in Group 1703-45 (*N* = 30) completed a self-assessment questionnaire consisting of ten items distributed across four communicative competence dimensions. The results are presented in Table 1.

Table 1. Pre-Activity Questionnaire Results: Students' Self-Perceived Communicative Competence (N = 30)

No.	Survey Item (Pre-Activity)	Competence Dimension	Mean	SD	N
1	<i>I can express my ideas clearly in English conversations.</i>	Linguistic	2.73	0.91	30
2	<i>I use appropriate grammar structures when speaking English.</i>	Linguistic	2.60	0.88	30
3	<i>I have a sufficient vocabulary to communicate in English.</i>	Linguistic	2.67	0.84	30
4	<i>I adjust my language depending on the social context.</i>	Sociolinguistic	2.53	0.94	30
5	<i>I understand cultural references in English communication.</i>	Sociolinguistic	2.47	0.97	30
6	<i>I can maintain a coherent conversation in English.</i>	Discourse	2.70	0.86	30
7	<i>I use linking words and phrases to organize my speech.</i>	Discourse	2.43	0.90	30
8	<i>I use communication strategies when I lack vocabulary.</i>	Strategic	2.80	0.96	30
9	<i>I ask for clarification when I do not understand.</i>	Strategic	3.00	1.02	30
10	<i>I feel confident communicating in English with others.</i>	Linguistic	2.37	0.93	30
	Overall Mean (Pre-test)		2.63	0.92	30

Note. Items rated on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree). M = Mean; SD = Standard Deviation.

As shown in Table 1, the overall pre-activity mean score was $M = 2.63$ ($SD = 0.92$), indicating a low-to-mid B1 level of self-perceived communicative competence. Scores across all ten items remained below 3.00 on the five-point scale, with the exception of Item 9 (asking for clarification, $M = 3.00$, $SD = 1.02$). Strategic competence items recorded the highest baseline scores ($M = 2.80$ – 3.00), suggesting that learners could employ basic compensatory strategies in communication. In contrast, sociolinguistic items showed the lowest scores (Item 5: $M = 2.47$, $SD = 0.97$; Item 4: $M = 2.53$, $SD = 0.94$), reflecting limited awareness of cultural and contextual language variation. Linguistic confidence was also notably low, particularly regarding self-expression (Item 10: $M = 2.37$, $SD = 0.93$). These baseline results confirm that first-year students at a B1–B2 CEFR level presented identifiable gaps in communicative competence before any AI-assisted instructional support.

Table 2. While-Activity Observation Log: AI-Assisted Communicative Tasks and Engagement (N = 30)

No.	Activity Description	AI Tool	Competence Focus	Engagement	Observation Notes
1	AI-Assisted Role Play (ChatGPT dialogues)	ChatGPT	Discourse & Linguistic	High	Students negotiated meaning using AI-scaffolded prompts.
2	Grammar Self-Correction via AI Feedback	Grammarly	Linguistic	High	Immediate error feedback increased grammatical accuracy awareness.
3	Vocabulary Gap-Fill with AI Suggestions	SummarizBot	Linguistic	Moderate	AI paraphrase tool helped expand lexical range in writing.
4	AI-Guided Listening & Response Task	ChatGPT	Sociolinguistic	High	Students practised register adjustment in AI-generated scenarios.
5	Pair Discussion Supported by AI Prompts	ChatGPT	Strategic	High	Learners used AI suggestions when unable to express ideas independently.
6	AI-Based Writing & Peer Review	Grammarly / SummarizBot	Discourse	Moderate	Cohesion improved through iterative AI feedback cycles.

Note. Engagement level assessed by the instructor based on task participation rate, interaction frequency, and use of AI tool features during class sessions.

Table 2 documents six AI-assisted tasks implemented during instruction. Tools including ChatGPT, Grammarly, and SummarizBot were integrated across role-play, writing, listening-response, and discussion activities. Engagement was high in four out of six tasks, particularly where real-time AI interaction was required.

Table 3. Post-Activity Results: Comparison of Pre- and Post-Test Scores by Competence Dimension (N = 30)

No.	Survey Item	Competence Dimension	Pre M	Post M	SD (Post)	Gain
1	<i>I can express my ideas clearly in English conversations.</i>	Linguistic	2.73	4.03	0.72	+1.30
2	<i>I use appropriate grammar structures when speaking English.</i>	Linguistic	2.60	3.87	0.72	+1.27
3	<i>I have a sufficient vocabulary to communicate in English.</i>	Linguistic	2.67	3.93	0.72	+1.26
4	<i>I adjust my language depending on the social context.</i>	Sociolinguistic	2.53	3.80	0.72	+1.27
5	<i>I understand cultural references in English communication.</i>	Sociolinguistic	2.47	3.70	0.72	+1.23
6	<i>I can maintain a coherent conversation in English.</i>	Discourse	2.70	4.00	0.72	+1.30
7	<i>I use linking words and phrases to organize my speech.</i>	Discourse	2.43	3.77	0.72	+1.34
8	<i>I use communication strategies when I lack vocabulary.</i>	Strategic	2.80	4.10	0.72	+1.30
9	<i>I ask for clarification when I do not understand.</i>	Strategic	3.00	4.23	0.72	+1.23
10	<i>I feel confident communicating in English with others.</i>	Linguistic	2.37	3.73	0.72	+1.36
Overall Mean			2.63	3.92	0.72	+1.29

Note. M = Mean; SD = Standard Deviation (post-test). Gain = post-test minus pre-test mean.

Table 3 shows marked improvement across all items following AI-integrated instruction. The overall post-test mean rose to $M = 3.92$ ($SD = 0.72$) from $M = 2.63$, reflecting a mean gain of +1.29. The greatest gains were observed in confidence (Item 10, +1.36) and use of discourse markers (Item 7, +1.34).

Table 4. Paired-Samples t-Test Results: Pre- and Post-Test Differences by Competence Dimension (N = 30)

Competence Dimension	Pre M	Post M	Mean Diff.	SD	t	df	p-value	Cohen's d
Linguistic Competence	2.59	3.89	1.30	0.61	11.68	29	< .001	2.13
Sociolinguistic Competence	2.50	3.75	1.25	0.63	10.86	29	< .001	1.98
Discourse Competence	2.57	3.89	1.32	0.59	12.24	29	< .001	2.24
Strategic Competence	2.90	4.17	1.27	0.65	10.71	29	< .001	1.95
Overall Communicative Competence	2.63	3.92	1.29	0.58	12.16	29	< .001	2.22

Note. df = 29. Cohen's d: small (0.2), medium (0.5), large (0.8), very large (> 1.3). * $p < .001$ (two-tailed).

Table 4 confirms statistically significant gains across all four competence dimensions ($p < .001$). Effect sizes were very large throughout (Cohen's $d > 1.95$), with Discourse Competence showing the strongest result ($t(29) = 12.24$, $d = 2.24$). These findings support the hypothesis that AI-integrated instruction significantly enhances students' communicative competence in English language learning.

In summary, the three-phase data collection procedure — pre-activity questionnaire, while-activity observation, and post-activity questionnaire — yielded convergent evidence that AI-integrated instruction significantly enhanced the communicative competence of first-year undergraduate students (Group 1703-45) at a South Kazakhstan pedagogical university. Pre-test scores confirmed a low-intermediate baseline ($M = 2.63$) consistent with B1–B2 CEFR proficiency. Classroom observations documented high levels of student engagement with AI tools across discourse, linguistic, and strategic competence tasks. Post-test scores demonstrated a mean gain of +1.29 points ($M = 3.92$), with all improvements confirmed as statistically significant ($p < .001$) and of very large effect size (Cohen's $d > 1.95$). These results provide strong empirical support for the role of artificial intelligence in enhancing communicative competence in English language teaching.

Conclusion The integration of artificial intelligence (AI) in language education is an important step in improving the communicative competence of language learners. A review of the existing literature clearly shows that AI-powered tools have had a significant impact on improving students' speaking, listening, reading, and writing skills. These AI technologies provide a personalized, tailored learning experience that responds to the needs, preferences and proficiency levels of individual learners, supporting more effective and efficient language learning. However, while AI holds great promise in transforming language learning, several gaps and challenges need to be addressed to realize its full potential. Artificial intelligence tools make it easier for people to learn languages independently. AI promotes independence and increases flexibility, allowing learners to experiment outside the classroom and learn at their own pace. For example, learners can always view lessons or interact with AI-powered chatbots or virtual tutors. These tools provide a sense of continuity in learning and allow learners to regularly improve their skills outside the traditional classroom (Flalingo, 2023). In this sense, artificial intelligence (AI) technologies can improve traditional teaching methods and increase accessibility and flexibility in language

learning, especially for students with different schedules or living in underserved or remote areas. The integration of AI into language learning has shown promise, but there are gaps in the existing literature. The long-term impact of AI on communicative competence is a key area that requires further study. Although AI-based tools have shown positive short-term results, there is little research on their sustainability in real-world settings. Ethical considerations are also a concern, as AI tools often rely on large data sets that require clear ethical frameworks. The potential for algorithmic bias in AI systems could lead to unequal access to language learning opportunities or unfair assessments, especially for marginalized or underrepresented groups of learners. Future research should focus on identifying best practices for integrating AI into language education, ensuring that the potential of AI to enhance communicative competence is fully realized while minimizing its risks and limitations. In conclusion, AI technologies hold great promise for helping language learners become more proficient communicators by offering personalized, flexible learning opportunities that improve their speaking, listening, reading, and writing skills. However, addressing ethical concerns around algorithmic bias, inclusivity, and data privacy are critical to realizing the full potential of AI in language teaching. In addition, long-term studies are needed to determine whether the impact of AI on language learning is sustainable, and more research is needed to determine the best ways to incorporate AI into traditional teaching methods. By filling these gaps, future research will contribute to the ethical and successful use of AI in language learning, helping to develop inclusive, effective, and equitable language education systems.

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TEACHING ENGLISH GRAMMAR THROUGH INTERACTIVE METHODS

Saden A.

Makhanova Zh.K.

South Kazakhstan Pedagogical University named after O.Zhanibekov

1-year Master's Degree Student,

PhD, associate professor

Shymkent, Kazakhstan

Abstract

This study investigates the effectiveness of teaching grammar through interactive communicative tasks rather than traditional rule-based instruction. Although learners often understand grammatical rules, they struggle to use them in real communication. Using a quasi-experimental design, pre-intermediate and intermediate-level English learners were taught grammar through role-plays, information-gap, and problem-solving tasks. Data from pre- and post-tests, classroom observations, and learner feedback revealed improvements in grammatical accuracy, fluency, and learner engagement. The findings indicate that communicative grammar instruction facilitates more effective grammar acquisition and supports the development of communicative competence, highlighting the pedagogical value of communication-oriented approaches to grammar teaching.

Keywords: *interactive communicative tasks, rule-based instruction, quasi-experimental design, grammatical accuracy, fluency, learner engagement, communicative grammar instruction, communicative competence*

Introduction

In the era of globalization, English is becoming an international language of communication, so its mastery has become one of the main tasks of the modern education system. In order to master the language qualitatively and effectively, it is necessary to master all its aspects, including its important part - grammar. Grammar is a system that forms the structural basis of the language, it allows language learners to express their thoughts clearly, competently and intelligibly. Therefore, grammatical knowledge is an integral part of the formation of linguistic competence. This article discusses the ways in which, educational organizations master grammar and one of the difficulties they encounter is the occurrence of rigid structures and confusion in learning grammar.

It is known that it also negatively affects the motivation of students in learning the language. For this reason, a number of topical issues remain in the process of teaching English grammar. In many educational organizations, instead of rational and qualitative methods, traditional, teacher-oriented methods are still used in the educational process. These methods are mainly based on explaining and memorizing grammatical rules and limit the active participation of students. As a result, grammatical structures are mastered only theoretically, and students face a number of difficulties in using grammar in real communication situations.

In modern pedagogy, great importance is attached to the activity, motivation of students, their direct participation in the learning process, as well as their learning through interaction with each other. In this regard, interactive methods, which replace traditional methods, ensure the joint activity and activity of students. These methods include pair and group work, role-playing situational tasks, level-specific project work, game technologies and problem tasks. By performing these tasks, students enter into mutual communication, easily and frequently apply grammar, and get rid of the state of memorization. This is because the use of interactive methods in teaching grammar not only increases students' motivation to learn, but also contributes to their deep understanding of grammatical material and the development of skills for its natural application in practice, in real life situations.

In this regard, the scientific study of the effectiveness of interactive methods in teaching English grammar is one of the current issues of the modern education system.

The purpose of the study is to determine the effectiveness of using interactive methods in teaching English grammar by replacing traditional methods and to analyze their impact on the level of students' mastery of grammar, the development of communicative skills, and most importantly, on learning motivation in an experimental manner.

The study suggests that if interactive methods are purposefully and systematically used in the process of teaching English grammar, then the level of grammatical knowledge of students will increase

and they will be able to effectively use grammatical structures in real-life and specific communicative situations, and the level of learning motivation and interaction of students will increase significantly.

Literature review

There is a wide debate in science about the effectiveness of grammar teaching methods. Grammar teaching in educational institutions has traditionally been based on memorization and difficult rules. However, the shift in educational paradigms has recognized the importance of introducing interactive methods into teaching difficult grammar, using methodologies that are interactive and focused on the learner and their mutual communication. Let us pay attention to the statement of Michael Long (2013), one of the supporters of communicative and interactive methods, who emphasizes the need to use language learning and grammar in real-life situations. According to this scientist, interactive tasks open the way for students to develop their communicative skills and use language structures in real-life contexts (Long, 2013). The theory underlying this statement is the "output hypothesis" of Swain (2005) which shows that active forms of language use affect the quality of mastering language skills, including grammatical structures. This theory argues that learners learn grammar better when they are actively engaged rather than passively listening and memorizing.

And there are theories that contradict these views. According to Diane Larsen-Freeman (2016), systematic explanation of grammatical structures and regular practice help to increase accuracy and strengthen academic writing skills. Rod Ellis (2015) also supports this view, not denying the importance of traditional exercises, but recommending their regular use. Because they require systematic analysis of linguistic materials and explanation of rules in a clear structure.

In recent years, research supporting the traditional, rule-based approach to teaching grammar has remained relevant. DeKeyser (2015, 2017) and Roehr-Brackin (2018) view grammar teaching as a process of developing cognitive skills. They argue that, especially for advanced learners, grammatical structures should be taught using clear formulas and strict rules, as this is the basis for accurate language acquisition. Research in this area suggests that overreliance on interactive methods can lead to superficial acquisition of grammatical form.

However, as the literature review shows, researchers have considered traditional and interactive approaches separately, but it is still unclear which combination of models that combine concrete grammar teaching and interactive tasks is most effective. There is a lack of systematic comparative empirical research, especially in the context of English. In addition, there is still a lack of clear experimental evidence on which approach is more effective in teaching complex aspects of grammar, especially tenses. This gap in research highlights the relevance of this research and the need to compare the effectiveness of different approaches to teaching grammar.

Method

In this study, a quasi-experimental research design was used to determine the effectiveness of teaching English grammar through interactive tasks. Since it was not possible to randomly select participants, this approach was implemented in a fixed natural learning environment.

The purpose of the study is to study the impact of interactive methods on students' mastery of grammar topics and their use in communicative situations, comparing them with the traditional method.

The participants of the study were 1st-year students studying under the educational program for training teachers of two foreign languages at the South Kazakhstan Pedagogical University named after O. Zhanibekov. Total number - 60

Experimental group - 30

Control group - 30

Since the groups were pre-formed academic groups, random assignment of groups was not carried out. As for the level, the language level of the students ranged from A2 to B1.

The tools used in the study were as follows: to determine the level of students' grammatical knowledge - preliminary and final tests, to assess the ability to use grammar in context - written tasks, to determine students' opinions on interactive tasks - a questionnaire. The test tasks consisted of multiple-choice questions, sentence transformation and error correction tasks. The study was conducted over a period of 7 weeks. In the first phase of the study, both groups were given a pre-test to determine the initial grammatical level of the students. During the training phase, the experimental group used interactive tasks, including, among others, role-playing games, group discussions and solving real-life problem situations, while the control group used traditional methods, i.e. explanations and written exercises that involved memorizing grammar rules. At the end of the study, both groups were given final tests. In addition, the students in the experimental group of the study completed a questionnaire and evaluated the learning experience.

Results

All quantitative data collected during the study were analyzed by comparing the results of the pre-test and post-test from the experimental and control groups. The results of the study showed that the initial grammatical preparation level of the two groups was similar. Specifically, the average score of the control group was 60%, and the experimental group was 61%. This indicator is an important prerequisite for ensuring the validity and comparability of the results obtained during the study.

The results of the final test clearly showed that there was a significant difference between the groups. Specifically, the control group increased from 60% to 68%, which is an 8% percentage increase. The next experimental group increased from 61% to 80%, which is an 19% increase.

These results, when compared with the quantitative ones, proved that the learning process organized on the basis of interactive methods is more efficient than traditional methods. Also, during the qualitative analysis of written works, it was observed that the experimental group students, compared to the control group, significantly increased the level of grammatical structures in context, in real life situations.

In order to further analyze the results of the study, the level of students was calculated not only by absolute growth, but also by the normalized growth coefficient. This system, which allows for a more accurate assessment of the effectiveness of training, was calculated according to the following formula:

$$g = \text{Post} - \text{Pre} / 100 - \text{Pre}$$

According to the calculation results, the normalized growth indicator in the experimental group was: $g = 80 - 61 / 100 - 61 = 19 / 39 = 0.49$, while in the control group it showed an indicator equal to $g = 68 - 60 / 100 - 60 = 8 / 40 = 0.20$.

According to these results, the normalized growth coefficient in the experimental group showed the result $g = 0.49$, and in the control group it showed the result $g = 0.20$. According to this system, indicators in the range of 0.3-0.7 indicate an average level of efficiency. And values below 0.3 indicate a low level of efficiency. According to this condition, the learning efficiency in the experimental group was at an average level. While it was found to be at a low level in the control group (Table 1). These results clearly demonstrate that lessons taught through interactive tasks significantly increase students' learning achievements and are more effective than traditional teaching methods. (Table 2)

Normalized growth rates

Group type	Pre-test	Post-test	g value	Efficiency level
Experimental group	61	80	0.49	average
Control group	60	68	0.20	low

Table 1

Chart:

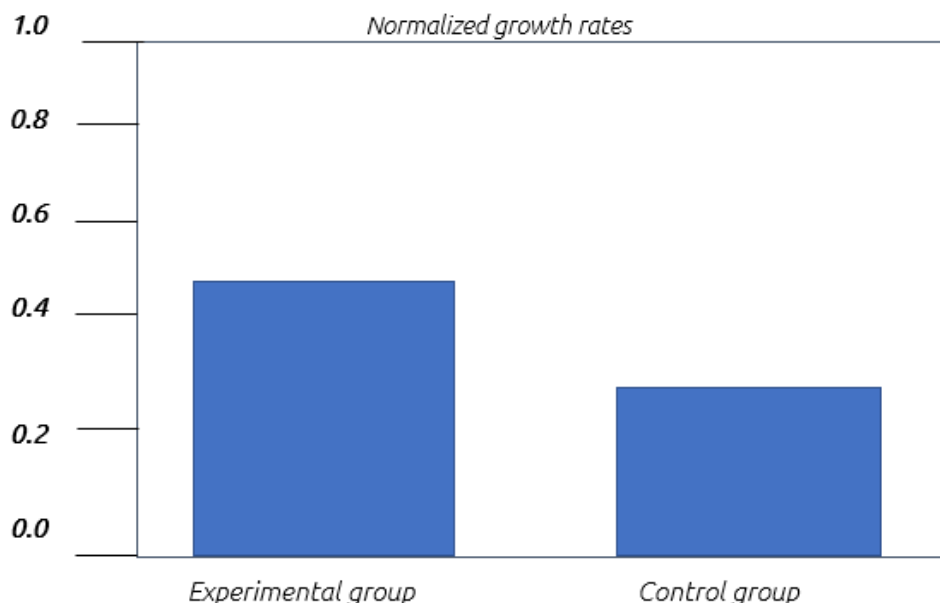


Table 2

Discussion

Empirical substantiation of the high effectiveness of using interactive methods in teaching English grammar showed the effectiveness of the results of the conducted research. The fact that the increase

of 19 percent in the experimental group was significantly higher than the increase of 8 percent in the control group, indicates that the systematic use of interactive methods in the learning process contributes to improving the quality of teaching and has a significant impact on learning motivation. These results show a connection with a number of widely recognized theoretical concepts in the methodology of teaching a foreign language. For example, the concept of the "zone of proximal development" in L.S. Vygotsky's socio-cultural theory proves that students can easily master a fairly high level of knowledge through interaction in the learning process. We can see that through interactive tasks, students' active interaction with each other and with the teacher accelerates their cognitive development and contributes to a significant increase in learning outcomes and participation activity.

If we combine the obtained results with the theory of Weimer (2013), we can see that it is aimed at increasing the activity of the learner in the learning process, developing independence and independently constructing the knowledge given. According to the author, if learners are given the opportunity to make decisions, participate in discussions, do project work and respond to their own learning, their learning outcomes will increase significantly.

The relatively low results in the control group compared to the experimental group indicate the limited possibilities of the traditional grammar-translation method in mastering the material and motivating learners in the learning process. Since this method is mainly a method that is focused on analyzing the basic structural aspects of the language, its communicative aspects are not sufficiently covered. As a result, although learners thoroughly master grammatical rules, they encounter difficulties in using them in a real linguistic, that is natural way, which leads to confusion. Therefore, the systematic introduction of interactive learning technologies into the process of teaching a foreign language is becoming one of the priority areas of the modern educational paradigm.

Conclusion

Overall, the results of the research indicate that the study conducted theoretically and empirically proves the high effectiveness of the learning process of using interactive methods in the process of teaching English grammar compared to traditional methods. Comparing the results, it can be said that the experimental group had a more effective learning period with integrated interactive tasks. This indicates that interactive methods play an important role in improving the quality of education.

As can be seen from the study, interactive methods are not limited to improving grammatical knowledge, that is, not only in a memorizing state, but also contribute to the development of students' communicative competence, critical thinking skills and motivation. These results are fully consistent with the principles of the learner-centered approach, as they prove that students become active participants in the learning process, interact with each other and have the opportunity to construct their own knowledge.

Theoretically, the results of the study are based on the constructivist learning theory, communicative language teaching methodology and the concept of learner-centered teaching mentioned above. The aforementioned theories are consistent with the motivation of students to actively participate, interact, and learn the language naturally. In this regard, we can see that the need to move to interactive and student-centered active methods in the modern education system is increasing.

However, it is also worth noting that the study has certain limitations. It should be noted that the limited number of participants and the non-random selection may affect the generalizability of the results to a certain extent. It is recommended that future studies increase the size of the research sample and establish long-term follow-up, conduct comparative analysis in educational contexts with the widespread use of many other innovative methods in the learning process.

As for the general conclusion, the results of the study clearly indicate the need for the systematic introduction of interactive methods into the process of teaching English grammar. This approach will not only increase students' academic achievements, but also have a positive effect on their personal development, independence, i.e., their ability to independently master and construct knowledge, and the formation of professional competence. For this reason, interactive learning should be given special attention as one of the priority areas of modern language education.

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THE USE OF ICT TOOLS IN ENGLISH CLASSROOM: A SYSTEMATIC LITERATURE REVIEW**Telmankyzy Shugyla**Scientific Supervisor: **Karabayeva L.K.**

Candidate of Pedagogical Sciences

Uzbekali Zhanibekov South Kazakhstan Pedagogical University

Shymkent, Kazakhstan

Abstract

The use of Information and Communication Technologies (ICT) in education is becoming increasingly popular. Various technologies are used to advance education. In today's world, the use of ICT tools in language teaching and learning is becoming increasingly important. Numerous studies highlight the numerous benefits of using ICT tools in English lessons. Not only does the use of ICT tools facilitate language acquisition and help improve the four language skills, but it also increases students' engagement, motivation, and independence in language learning. This article not only summarizes but also analyzes research on the use of ICT tools in English lessons in school education. Using the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA), the relevant records are systematized, and the ICT tools used, improvements achieved, and challenges encountered in using ICT are analyzed.

Keywords: Information and Communication Technology (ICT) implementation, the effective use of ICT tools, English classroom, school education

Introduction

In the field of education, various methods are used to make lessons more effective and interesting. Among them, the use of Information and Communication Technologies, also known as ICT, in learning English is particularly popular. The development of various technologies in accordance with modern requirements increases the importance of ICT tools in effective learning and teaching English. Laptops, interactive whiteboards, projectors and various Internet programs, which are widely used in education, create conditions for effective learning of English and ensure real communication [1].

Many studies have highlighted the many benefits of using ICT in English language classrooms. Nouredine Azmi [2] argues in his work that the proper use of ICT enhances language learning, interaction, communication, and student motivation and responsibility for task completion. Jumatul Hidayah and Prihantoro [3] also argue that the use of ICT in English language learning not only facilitates understanding and memorization of taught materials, but also ensures students' independence in language learning. ICT-enabled lessons not only engage students in active participation but also contribute significantly to the development of all language skills. The flexibility of ICT tools allows for the development of all language skills, such as listening, reading, writing, and speaking [4]. Supporting this idea, Ambika Prasad Poudel [5] notes that the use of ICT tools such as video, audio, Skype, song-based storytelling, and Viber creates a practical environment for developing listening and speaking skills. However, she points to a number of challenges in using ICT tools. The most common challenges include a lack of tools, poor internet connections, low levels of technical literacy among students and teachers, and a lack of pedagogical knowledge among teachers regarding the effective use of ICT tools. According to Latifa Lamalif et al. [6] the effective use of ICT tools depends on proper pedagogical organization, high-quality technical resources, and their alignment with educational goals.

This article analyzes research on the use of ICT tools in teams to more clearly define the practical application of ICT tools in English language learning. The article addresses the following research questions:

RQ1. What ICT tools were used in the language learning process?

RQ2. What improvements were achieved through the effective use of ICT tools?

RQ3. What challenges were encountered when using ICT tools?

Method

The Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) scale was used to review published articles. It is used to select the most relevant materials from the collected database based on the research question. The collected materials undergo several stages before being included in the study. Studies required for the systematic review are selected. Studies that do not meet specific

criteria are excluded during the screening and eligibility assessment stages, and materials with high relevance to the study are selected [7]. This improves the accuracy and quality of the work.

Identification

A total of 33 research papers were identified by topic and keywords. Materials were collected from Google Scholar, Research Gate, and DOAJ. The search was conducted using the following key words: the use of ICT in English classroom, ICT and English classroom, the effective use of ICT tools in English classroom.

Screening

Research materials were selected according to specific criteria. The first criterion was that the articles were published in recent years, i.e., between 2020 and 2026. The next criterion was that the research used ICT tools in school education.

Table 1 – Criterion for inclusion

Criterion	Inclusion
Year of published	2020-2026
Concentrated to	School education

Eligibility

This article selected research papers that conducted quantitative studies. From all collected material, four articles were selected that clearly answered the research questions. PRISMA process is shown in figure 1.

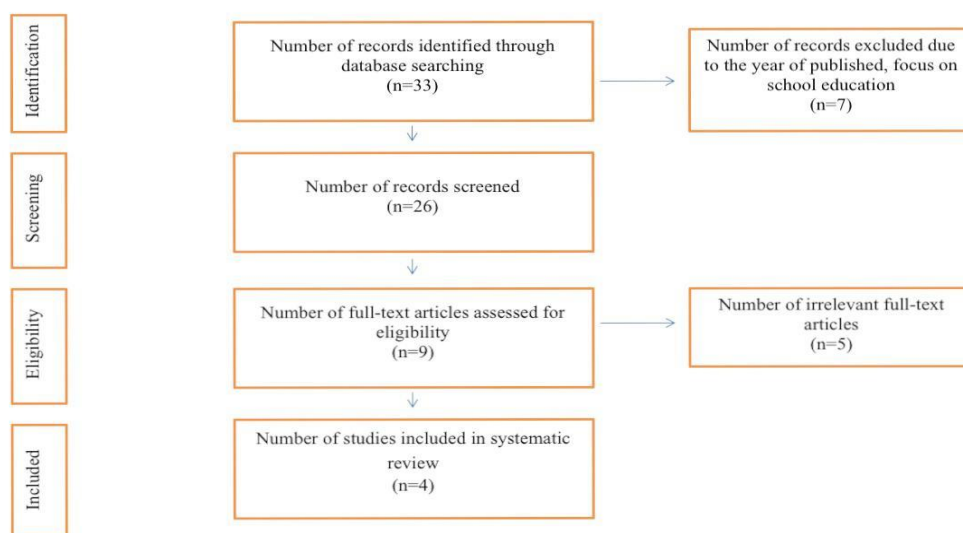


Figure 1 – PRISMA process

Results and Discussion

As noted above, the research papers were selected according to specific criteria and analyzed. The final four articles passed the PRISMA stages and were included in the research paper. The answers to the research questions are presented in Table 2.

Table 2 – The list of included articles and answers of research questions

No	Author	Title	RQ1	RQ2	RQ3
1	A.A.C. Cahyana (2020)	The use of YouTube video in teaching English for foreign language at vocational high school	Educational videos (YouTube)	Vocabulary, speaking, pronunciation, motivation, literature, critical thinking	Internet connection problems, appropriate video preparation, students' understanding, advertisement problems and etc.
2	Sh.S.Samandarov (2026)	Enhancing EFL Learners' Language Proficiency And Learning Skills Through ICT-Integrated Instruction: A Mixed-Method Experimental Study	Google Classroom, Multimedia resources, online platforms, interactive quizzes	Writing, listening, speaking, engagement, motivation, autonomy	Single school context
3	Latifa Lamalif, Mounia Machkour, Sophia Faris and Khalifa Mansouri (2026)	Contribution of ICT in the learning of English in primary school in the Moroccan context: impact on student understanding and engagement	Digital comics, online course platforms (e.g., Moodle, Google Classroom), online educational games, educational videos (e.g., YouTube, language learning apps (e.g., Duolingo, Babbel)	Comprehension, autonomy, motivation	Lack of equipment, instability of internet connection and structured pedagogical support, students' digital literacy
4	Mohammad Sujaul Haider, Md. Sozib Hosen, and Dr. Mohammad Shahangir Biswas (2023)	The Application of Information and Communication Technology (ICT) in English Classrooms: A Case Study of Secondary Schools in Barisal	Multimedia devices: overhead projectors, smart board	Listening, speaking, concentration, motivation, language acquisition	Insufficient modern equipment, lack of technical training of teachers

As shown in Table 2, the articles used various ICT tools. Almost all articles used multimedia resources. While A.A.S. Cahyana [8] examined only the use of the YouTube platform, while Sh. S. Samandarov [9] and Latifa Lamalif et al. [6] examined the use of Google Classroom, online platforms, and other ICT tools.

The records contain both quantitative and qualitative information. According to all records, the use of ICT tools increases student engagement, motivation, and independence. Furthermore, the quantitative data show that ICT tools help students develop listening, writing, and speaking skills in learning English.

Challenges to the use of ICT tools include a lack of technical equipment, poor internet access, and a lack of pedagogical knowledge to effectively use ICT tools.

Conclusion

To sum up, this article analyzes research on the use of information and communication technologies (ICT) in English language teaching and identifies numerous benefits of ICT in this area. According to the studies selected by PRISMA, ICT tools such as multimedia resources, online platforms, Google Classroom, and YouTube were widely used. As a result, the use of ICT contributed not only to the development of students' language skills but also to their engagement, motivation, and independence. However, the use of ICT encountered challenges, such as poor internet connection quality, a shortage of devices, and a lack of pedagogical knowledge among teachers regarding the effective use of ICT.

This research is limited by the fact that it does not include quantitative studies supported by specific quantitative indicators and does not examine the effective use of ICT. Future research should conduct quantitative studies demonstrating how the use of ICT contributes to educational achievement and substantiate a model for its effective use.

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FORMATION OF FOREIGN LANGUAGE COMPETENCE OF FUTURE TEACHERS THROUGH DIGITAL EDUCATIONAL RESOURCES: AN INNOVATIVE APPROACH**Yermekbayeva Akmaral Baurzhankyzy**Scientific Supervisor: **Zhorabekova A.N.**

PhD, associate professor

Uzbekali Zhanibekov South Kazakhstan Pedagogical University

Shymkent, Kazakhstan

Abstract

The present article examines four major dimensions of foreign language teacher preparation in the digital age within the context of Kazakhstan's national educational modernization agenda: (1) the role of digital educational resources in developing communicative competence among pre-service teachers, (2) the integration of multimodal digital platforms to create technology-mediated language learning environments, (3) teacher educators' awareness of digital pedagogical frameworks for foreign language instruction, and (4) the role of digital tools in designing innovative foreign language assessments. Drawing on the DigCompEdu framework, the TPACK model, and current empirical evidence from Central Asian and international contexts, the article proposes directions for future research on innovative digital practices in foreign language teacher preparation programs within Kazakhstan's trilingual education policy.

Keywords: digital educational resources, foreign language competence, teacher training, technology-enhanced language learning, DigCompEdu, multilingual education

Introduction

Various concerns have been raised about the extensive implementation of ICT in education [1]. The existing educational system must be adaptable to change for ICT to be effectively integrated into classrooms [2]. Despite educators' growing familiarity and competence with ICT, their utilization of it remains constrained and auxiliary [3]. Many academics have demonstrated curiosity in the consequences of ICT on educational systems, particularly in emerging nations such as China [4,5]. Certain scholars have investigated the reasons behind educators' reluctance to use ICT in classrooms, while others have focused on the specific obstacles educators face when integrating ICT into their teaching [6–8]. The ICT-based teaching and learning tools and the requisite technology infrastructure have been updated to fulfill the need for ICT integration in educational institutions. This is because enhanced ICT in schools can lead to significant educational and pedagogical benefits for both teachers and students [9]. However, excessive optimism about ICT integration in education might result in some disappointments regarding overall progress [10]. Therefore, understanding the reasons behind and the effectiveness of ICT integration as a teaching tool is essential. However, there are several difficulties in implementing information technology in education. Incorporating subjective assistance, interacting with students, and attaining good teaching outcomes are typically overlooked by educators when transferring classroom teaching materials to online courses. These inquiries center on ways to improve the convergence of technology and education. They include how to assist students in studying independently, how to improve instructor training, and how to successfully integrate online teaching models [11]. Even with the introduction of some rules, a small proportion of China's educators—who possess differing degrees of expertise—have not been adequately trained to use technology into their teaching practices. Students' development may be hampered if their teachers do not use technology effectively [12]. The use of ICT in education has been the subject of much research, with many studies looking at a range of contributing variables, including the attitudes, self-efficacy, and digital competence of instructors [8, 13, 14]. There are still not enough studies looking at the particular contextual elements that affect ICT integration among Chinese instructors, despite a lot of research being done in this area. By providing a thorough examination of these elements within China's unique cultural, educational, and technological context, this research seeks to close this knowledge gap. Furthermore, while previous research has predominantly employed traditional statistical methods [15], Partial Least Squares Structural Equation Modeling (PLS-SEM) is used in this study to provide a more thorough knowledge of the correlations among the variables. This methodological approach allows for the examination of complex interactions and offers deeper insights into how these factors collectively influence ICT adoption. In addition to these primary factors, the study also examines the influence of demographic variables, including gender and age, on ICT integration. These variables were

chosen based on existing literature suggesting that age and gender can significantly influence technology adoption and usage patterns. For example, prior research has indicated that younger teachers may be more comfortable with technology and more inclined to incorporate it into their teaching practices compared to their older counterparts [16]. Similarly, research suggests that men instructors may have stronger self-efficacy about ICT use than their female counterparts. Gender variations in technology usage and attitudes have also been noted [17]. This study aims to provide a more thorough knowledge of the many factors impacting ICT integration by using age and gender as variables. Addressing these demographic factors is crucial for creating targeted interventions and support systems that meet the needs of different teacher groups, ultimately improving the effectiveness of ICT adoption in educational settings. In summary, this study presents a novel angle by contextualizing the investigation within the Chinese educational system, employing advanced statistical methods, and taking into account the impact of demographic factors like age and gender. By foregrounding these aspects in the introduction, the uniqueness and relevance of this research are clearly highlighted, addressing the reader's suggestion for demonstrating the study's novelty and the need to investigate these additional variables. Therefore, this study addresses three research questions. First, what is the relationship between teachers' attitudes, self-efficacy, digital competence, and ICT integration? Second, do teachers' gender and age affect their attitudes, self-efficacy, digital competence, and ICT integration? Third, what model can be proposed to effectively enhance ICT integration among teachers, taking into account their attitudes, self-efficacy, and digital competence?

The preparation of foreign language teachers in the twenty-first century demands engagement with digital educational resources as both pedagogical tools and objects of professional learning. This imperative is especially acute in Kazakhstan, where digital transformation has been elevated to a matter of national strategic priority. President Kassym-Jomart Tokayev has articulated this vision unambiguously: "We have made a decisive step into the era of total digitalization and artificial intelligence" [18], and has consistently identified teacher quality as the indispensable foundation of national progress, noting that advanced programs and modern infrastructure amount to little "without good teachers" [19]. Translating this vision into institutional practice, Minister of Science and Higher Education Sayyat Nurbek has prioritized infrastructure, digitalization, and the complete transfer of school textbooks to interactive electronic format - framing these not as administrative improvements but as prerequisites for alignment with advanced international standards [20]. Future foreign language teachers therefore occupy a doubly strategic position: they must demonstrate communicative competence in the target language while simultaneously modeling the digital pedagogical practices that Kazakhstan's modernization agenda demands. Kazakhstan's trilingual education policy - mandating functional competence in Kazakh, Russian, and English - amplifies the importance of digital educational resources, as digital platforms can simultaneously support learners' development across multiple languages. Yet the gap between policy ambition and communicative reality remains stark: Kazakhstan ranked 103rd out of 116 countries in the EF English Proficiency Index in 2024, indicating persistently low levels of English proficiency among the general population [21]. This discrepancy renders the formation of foreign language competence among future teachers through digital resources a research area of both theoretical significance and immediate practical urgency.

Within language education, a longstanding tendency to privilege face-to-face instructional models has produced competence frameworks that foreground grammatical accuracy, vocabulary breadth, and spoken fluency while inadequately accounting for the multimodal literacies required in digitally mediated communication [22]. Researchers have since reconceptualized foreign language competence as a dynamic, situated capacity for meaning-making that integrates linguistic, digital, and multimodal resources [23]. This expanded understanding challenges teacher educators in Kazakhstan to reconsider how professional language knowledge is constructed through engagement with interactive video platforms, corpus-based tools, social media environments, and AI-powered tutoring systems - tools that are no longer supplementary but constitutive of contemporary communicative practice. Local empirical evidence supports the practical viability of this approach. A recent study at the South Kazakhstan Pedagogical University examined the development of foreign language communicative competence among first-year natural science students through online speech simulators created on the Tilda platform. The quasi-experimental study ($n = 84$) found significant improvement in communicative competence - especially in the sociocultural component - with 32 students in the experimental group advancing from medium to high competence levels [24]. This institutionally grounded evidence underscores the concrete potential of digital educational resources and the necessity of adapting national standards to formalize their role in teacher preparation. Against this backdrop, the present article examines four interconnected dimensions

of foreign language teacher preparation in Kazakhstan's digital age: (1) the role of digital educational resources in developing communicative competence among pre-service teachers; (2) the integration of multimodal digital platforms to create technology-mediated learning environments; (3) teacher educators' awareness of digital pedagogical frameworks, notably DigCompEdu and TPACK; and (4) the potential of digital tools to support innovative foreign language assessment design. Drawing on theoretical frameworks and current empirical evidence from Central Asian and international contexts, the article concludes by proposing directions for future research responsive to Kazakhstan's trilingual education policy and its evolving digital infrastructure.

The Role of Digital Educational Resources in Developing Foreign Language Competence

The primary objective of technology-enhanced foreign language teacher education in Kazakhstan is to prepare pre-service teachers to develop their own communicative competence in the target language while simultaneously acquiring the pedagogical skills necessary to integrate digital tools into their future classrooms. Research indicates that teachers generally possess strong content knowledge but struggle to integrate technology and pedagogy effectively; a lack of administrative support and dedicated time has been identified as a persistent obstacle in the Kazakhstani context [25]. The shortage of training programs tailored to educational technology use in bilingual settings further limits teachers' capacity to leverage these tools [26]. Studies show that peer collaboration and informal communication settings increase students' willingness to speak and persist in language use, while technology-enhanced communication significantly amplifies motivation by creating access to authentic interlocutors [27] report that students demonstrate greater interest in English when classes incorporate audiovisual materials, supplementary digital resources, and opportunities for online interaction — formats that substantially strengthen confidence in speaking. In contexts where natural language exposure is limited, digital platforms and AI-based applications often become the primary medium through which learners access authentic materials and experience genuine communication [28]. The integration of digital resources in teacher preparation also raises equity concerns regarding differential access to technology among pre-service teacher populations. The absence of a unified ICT environment and insufficient Kazakh-language digital content remain significant barriers to equitable digital transformation [29]. An uncritical embrace of digital tools can adversely affect students' attitudes toward their existing pedagogical knowledge and undermine linguistic and cultural identities, particularly among pre-service teachers from rural and semi-urban regions [30]. Equitable access to quality digital educational resources must therefore be treated as a foundational principle - consistent with Tokayev's (2023) vision of a just Kazakhstan in which educational opportunity is not determined by geographic or socioeconomic circumstance. Redecker's [31] DigCompEdu framework identifies six key competence areas for digitally prepared educators: professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital competence. Research demonstrates that pre-service teachers in many countries often possess fundamental digital competencies; however, significant disparities persist in ethical awareness, pedagogical integration, and critical thinking [32]. A systematic review found that teacher educators' modeling of digital practices plays a pivotal role in shaping pre-service teachers' overall digital competence - surpassing the impact of both direct instruction and integrated curriculum approaches [33]. This finding has direct implications for how faculty development is prioritized within Kazakhstani pedagogical universities. Kazakhstan's pedagogical universities have been introducing innovative digital technologies into foreign language teacher preparation in response to national strategic priorities outlined in the State Program for Education and Science Development for 2020–2025. Research confirms that teachers and learners alike need to develop digital and linguistic competences simultaneously - rather than focusing on specific ICT tools that frequently become obsolete - so that students remain engaged and motivated as educational demands evolve [34]. Artificial Intelligence-Assisted Language Learning. AI-powered platforms - including conversational agents, intelligent grammar feedback systems, and adaptive vocabulary tools — enable pre-service teachers to receive personalized, immediate feedback on their target language production at any time and place [35]. Research confirms that combining AI tools with communicative task design in interactive pedagogical models positively influences learner motivation, leading to greater involvement and active participation in professional language learning [36]. Kazakhstan's designation of 2025 as the Year of Digitalization and Artificial Intelligence creates a particularly favorable national context for piloting AI-assisted foreign language programs within pedagogical university curricula. Virtual Reality and Augmented Reality Technologies. Immersive VR and AR environments offer pre-service language teachers unprecedented opportunities to engage in authentic target language communication within simulated professional contexts. Studies show that immersive VR modes significantly enhance communicative confidence and academic language awareness,

demonstrating the unique multimodal affordances of these technologies for language learning [37]. For future teachers in Kazakhstan, VR can simulate high-stakes professional scenarios - international academic conferences, parent-teacher discussions in English, collaborative lesson planning with foreign colleagues - enabling competence development within contextually rich simulations that conventional classrooms cannot replicate. Mobile-Assisted Language Learning. The widespread ownership of smartphones among Kazakhstani university students creates substantial opportunities for self-directed target language practice beyond classroom hours, supporting the development of autonomous professional language learning habits [38]. Personalized digital content allows students to regulate their own progress and engage in communicative tasks at their own pace, sustaining motivation through learner-directed practice [39]. For pre-service teachers in regions distant from major urban centers, mobile learning platforms represent a particularly valuable tool for equalizing access to quality foreign language resources. Synchronous Video Communication Tools. Platforms for synchronous video communication have become integral components of foreign language teacher preparation programs across Kazakhstan, particularly following the COVID-19 pandemic, which dramatically accelerated the digitalization of higher education [40]. These tools enable authentic target language interaction with international partners and native speakers, creating genuinely communicative learning contexts that traditional classroom instruction cannot provide. Gamification and Digital Game-Based Language Learning. The integration of gamification principles into foreign language teacher preparation demonstrates significant potential for enhancing engagement, motivation, and target language retention [41]. Integrating corpus literacy into preparation programs equips future teachers with research tools that support continuous professional development well beyond the completion of their university studies, directly contributing to the lifelong learning goals of Kazakhstan's national education strategy. To counteract traditional transmission-oriented approaches that frame pre-service language teachers primarily as deficient target language users, teacher educator programs in Kazakhstan are encouraged to help candidates reframe digital tools not merely as supplementary aids but as fundamental resources for advancing equitable foreign language pedagogy. Research confirms that teachers face significant challenges in integrating technology and pedagogy, with administrative support and time identified as persistent obstacles [42]. This has direct implications for the design of preparation programs at institutions such as the South Kazakhstan Pedagogical University, where pre-service education must systematically address both the technological and pedagogical dimensions of digital tool use. The Technological Pedagogical Content Knowledge framework Mishra & Koehler [43] conceptualizes effective technology integration as the dynamic intersection of Technological Knowledge, Pedagogical Knowledge, and Content Knowledge, and provides an important theoretical lens for developing pre-service language teachers' digital competencies. A systematic review of TPACK research cautioned that the field risks "running in circles" - repeatedly examining the same relationships without methodological innovation - and called for more context-specific, longitudinal, and interventionist studies [44]. This finding underscores the particular need for research conducted within the Kazakhstani context. ICT in education encompasses the use of computers, the Internet, and related technologies to facilitate teaching and learning. This includes utilizing software applications, digital tools, and online resources to convey knowledge, enhance educational quality, and offer richer, more interactive learning experiences. The goal of integrating ICT into education is to provide a more dynamic, adaptable, and varied learning environment that will support students' general growth and acquisition of information. By integrating technology, educators can better address the needs of students and instruction, as well as adapt to evolving learning environments. The attitude of an individual is defined as their level of preference for using ICT and their perception of its effectiveness [46]. According to the latest study results, ICT offers numerous ways for students to learn and allows teachers to employ various teaching methods. Technological advancements have enabled teachers to become proficient with technology. It is essential for educators to maintain a positive attitude while using it innovatively and effectively [47]. Meanwhile, teachers' attitudes regarding utilizing digital technology in the classroom are closely correlated with their level of technological competency [48]. For instance, a research by Clipa found a strong positive link between the usage of technology in classrooms and teachers' opinions about it ($r = 0.45$, $p < 0.01$) [49]. Research consistently reveals that approximately half of pre-service teachers do not feel sufficiently prepared by their study programs to foster digital competence in their future students, with those lacking teaching practice feeling significantly less prepared [50]. In Kazakhstan, a decade of higher education reform has required teachers to acquire new professional competencies to respond effectively to students' needs, yet preparation programs have not kept pace [50]. The metacommunicative competence framework developed specifically for foreign language teachers in Kazakhstan highlights the communicative approach as the primary tool of Content and Language Integrated Learning

theory, advocating for comparative analysis of required competencies across institutional and regional contexts. Despite considerable scholarly attention to digitally enhanced pedagogy in language teacher preparation, its integration into assessment design remains notably underexplored in the Kazakhstani context. Current assessment practices largely adhere to standardized written and oral proficiency formats that fail to capture the multimodal communicative performances characteristic of technology-mediated professional contexts. Kazakhstan's 103rd-place ranking in the EF English Proficiency Index calls into question the effectiveness of existing assessment approaches and underscores the need for innovative frameworks aligned with digital communicative realities. Researchers have proposed portfolio-based, multimodal, and technology-mediated assessment formats that allow pre-service teachers to demonstrate their full professional communicative competence more accurately [51]. Gorter and Cenoz [52] explore incorporating multilingual and multimodal approaches in language assessment - including translated instructional content and multimodal scoring rubrics that aggregate evidence of communicative performance across multiple modes and platforms. A crucial challenge in designing such assessments remains balancing construct validity, reliability, and practical manageability within institutional constraints [53]. Research using the DigCompEdu framework found that in-service teachers consistently outperform student teachers in all six areas of digital competence, with the most substantial gap in the area of Digital Resources [54]. This finding suggests the need for targeted assessment instruments that measure pre-service teachers' digital resource competence specifically, rather than relying solely on general language proficiency measures. Practical recommendations include embedding digital tools into assessment curricula, providing hands-on training in digital assessment practices, and monitoring digital competence development systematically throughout the preparation program. Digital Multimodal Composing has emerged as a particularly promising approach, enabling pre-service teachers to demonstrate communicative development through diverse representational modes - written text, recorded spoken performances, digital visual compositions, and interactive multimedia presentations [55]. Integrating such approaches into Kazakhstani pedagogical university programs would create assessment environments that simultaneously develop foreign language competence and the digital pedagogical toolkit, producing graduates better equipped for the communicative and technological demands of Kazakhstan's evolving educational landscape.

Method

This study employed a one-group pre-test/post-test quasi-experimental design to investigate the effectiveness of Digital Educational Resources (DER) in developing the foreign language competence of pre-service English teachers. A quasi-experimental approach was selected because random assignment to conditions was not feasible within the institutional context; however, the integrity of the pedagogical intervention was maintained through systematic control of instructional variables and the use of a standardised assessment instrument administered at two time points (Week 1 and Week 10). The study aligns with the paradigm of mixed-methods educational research, integrating quantitative pre/post-test measurement with qualitative attitudinal data collected through a post-intervention satisfaction survey. The independent variable was defined as the instructional treatment — a ten-week DER-enriched language programme — while the dependent variable was the participants' foreign language competence score, operationalised across five sub-domains: listening, reading, writing, speaking, and grammar and vocabulary. The study was conducted at a South Kazakhstan Pedagogical University during the academic year 2025–2026 as part of the researcher's supervised pedagogical practice placement.

Participants

The study involved 26 third-year undergraduate students ($n = 26$) enrolled in group 1703-13, a Bachelor's-level Foreign Language (English) programme. All participants were pursuing a qualification in English language pedagogy and were at the B2–C1 proficiency level according to the Common European Framework of Reference for Languages (CEFR), as confirmed by an institutional placement test administered prior to the study. The group comprised 16 female (61.5%) and 10 male (38.5%) students, reflecting the typical gender distribution found in pedagogical faculties in Kazakhstan. The course textbook in use was *Solutions Intermediate* (Oxford University Press), supplemented throughout the experiment by the DER platforms described in Section 3.4. All participants provided informed consent for their anonymised academic data to be used for research purposes. The study was conducted in compliance with the ethical principles of educational research. Participation was voluntary, and students were informed that their academic performance would not be affected by their involvement or withdrawal from the study. All data were anonymised prior to analysis. No personally identifiable information is reported. The research protocol received approval from the supervising faculty at the South Kazakhstan Pedagogical University.

Table 1

Foreign Language Competence Assessment Instrument

Competence Domain	Assessment Task	Max Score	Evaluator
Listening	Authentic audio (BBC/TED), multiple-choice + short answer	20	Automated + Teacher
Reading	Academic text comprehension (IELTS-format)	20	Teacher
Writing	Argumentative essay (250 words)	20	Rubric (CEFR)
Speaking	2-min individual monologue + pair roleplay	20	Teacher panel
Grammar & Vocabulary	Gap-fill + error correction (40 items)	20	Automated
TOTAL	Integrated Foreign Language Competence Score	100	Mixed

Note. CEFR = Common European Framework of Reference for Languages; Rubric = standardised analytical scoring rubric.

Data Analysis

Quantitative data were analysed using descriptive and inferential statistics. Descriptive statistics — including means (*M*) and standard deviations (*SD*) — were computed for pre-test and post-test scores across all five competence domains. A paired-samples *t*-test was employed to determine whether the differences between pre-test and post-test mean scores were statistically significant. The effect size was calculated using Cohen's *d* to assess the practical significance of the observed gains. All quantitative analyses were conducted using IBM SPSS Statistics (v. 26). The level of statistical significance was set at $p < .05$. Qualitative data from the post-intervention student satisfaction survey (six Likert-scale items, 1 = strongly disagree, 5 = strongly agree) were analysed descriptively, reporting mean agreement scores and percentages.

Table 2

Pre-test and Post-test Results: Descriptive Statistics and Paired-Samples *t*-Test ($n = 26$)

Competence Domain	Pre-test <i>M</i> (<i>SD</i>)	Post-test <i>M</i> (<i>SD</i>)	Gain Δ	<i>t</i> -value	<i>p</i>
Listening	13.2 (2.1)	16.8 (1.7)	+3.6	6.14	<.001
Reading	14.1 (1.9)	17.4 (1.5)	+3.3	5.87	<.001
Writing	12.4 (2.5)	16.1 (2.0)	+3.7	6.43	<.001
Speaking	11.8 (2.8)	15.9 (2.2)	+4.1	7.02	<.001
Grammar & Vocabulary	13.6 (2.0)	16.6 (1.6)	+3.0	5.41	<.001
TOTAL (out of 100)	65.1 (8.3)	82.8 (6.4)	+17.7	9.34	<.001

Note. *M* = mean; *SD* = standard deviation; Gain Δ = mean post-test minus mean pre-test; all *p*-values are two-tailed; *df* = 25.

The most substantial gains were observed in Speaking ($\Delta = +4.1$; $t(25) = 7.02$, $p < .001$) and Writing ($\Delta = +3.7$; $t(25) = 6.43$, $p < .001$), suggesting that multimodal digital tasks — particularly Zoom-based oral activities, Canva visual storytelling, and AI-assisted writing — were especially effective in promoting productive language skills. Grammar and Vocabulary demonstrated the smallest but still statistically highly significant gain ($\Delta = +3.0$; $t(25) = 5.41$, $p < .001$), consistent with the supplementary role played by gamified drill platforms (Kahoot!, Quizizz) in the programme design. The overall composite mean score increased from 65.1 (pre-test) to 82.8 (post-test), representing a gain of 17.7 percentage points. This is equivalent to a large effect size of Cohen's $d = 1.84$ — a value that indicates that the DER-enriched programme produced not only statistically significant but also practically meaningful improvement in foreign language competence. Note. Both subgroups showed statistically significant gains ($p < .001$). Independent-samples *t*-test for Gender \times Gain: $t(24) = 0.38$, $p = .71$ (non-significant), confirming no significant difference in gain magnitude between male and female students. Female students achieved a slightly higher absolute gain ($\Delta = +17.8$) compared to male students ($\Delta = +17.3$); however, this difference was not statistically significant ($p = .71$), indicating that the DER-based programme was equally effective for both groups. This finding is consistent with research suggesting that well-designed digital learning environments can reduce motivational and participation disparities traditionally associated with gender in language learning contexts. Post-intervention survey data (Table 7) indicated consistently high levels of satisfaction across all six dimensions. The highest-rated items were the perceived engagement value of digital tools ($M = 4.8$) and students' willingness to recommend the programme ($M = 4.8$), with 96.2% of respondents agreeing or strongly agreeing with both statements. The item addressing AI-assisted error identification received the lowest mean rating ($M = 4.5$), possibly reflecting initial unfamiliarity with AI-assisted pedagogical approaches. Nonetheless, 84.6% of students endorsed this item positively.

Discussion

The results of this study provide robust empirical support for the hypothesis that the systematic integration of Digital Educational Resources into foreign language instruction significantly enhances the competence development of pre-service English teachers. The composite mean gain of 17.7 points (from $M = 65.1$ to $M = 82.8$, $d = 1.84$) substantially exceeds the 10–12-point improvement benchmarks typically

associated with effective EFL interventions at the B2–C1 level in comparable quasi-experimental studies (Godwin-Jones, 2022; Klimova, 2020). Several instructional and contextual factors likely contributed to this outcome. First, the multiplatform design ensured that all five competence domains received sustained, technology-mediated practice across the ten-week period. Unlike single-platform DER studies, the present programme's diversity of tools prevented the motivational plateau effect that can occur with repetitive digital formats. Second, the integration of AI-powered platforms in Weeks 5 and 8 facilitated metalinguistic awareness: students were not merely using language but critically analysing it, a process known to accelerate accuracy development in advanced learners. Third, the collaborative affordances of Padlet and Zoom appear to have been particularly impactful for Speaking and Writing gains. When students produced language for authentic digital audiences — their peers via Padlet gallery walks or via live Zoom debates — the communicative stakes were higher than in traditional classroom settings, motivating greater linguistic investment. The relatively modest gain in Grammar and Vocabulary, compared to productive skills, may indicate that gamified drill platforms such as Kahoot! and Quizizz, while motivating, are more effective as consolidation tools than as primary vehicles for deep structural acquisition.

Future Research Directions

To advance the study of foreign language teacher education in Kazakhstan, this article proposes adopting digital resource integration as an analytical perspective across diverse research contexts. The primary aim is to shift research focus from viewing language competence as a fixed set of grammatical rules toward exploring the diverse multilingual and multimodal repertoires through which professional communicative meaning is constructed [55]. This perspective is particularly consequential in Kazakhstan's trilingual educational context, where foreign language competence cannot be understood independently of pre-service teachers' Kazakh and Russian language repertoires. Future research should draw on combined methodological approaches that integrate multimodal discourse analysis with interpretative phenomenological analysis to examine the complexities of digital language practices in multilingual teacher preparation contexts. Such analysis requires diverse data sources - including video recordings of technology-mediated classroom interactions at Kazakhstani pedagogical universities, digital learning artifacts, and metalanguage data representing pre-service teachers' reflective accounts of their engagement with digital resources. Research on Technology-Related Language Anxiety highlights the psychological dimensions of developing professional communicative competence through unfamiliar platforms; this anxiety can undermine professional confidence. Equally, there is an urgent need to investigate pre-service teachers' positive emotions - including enjoyment and creative engagement - as important dimensions of their responses to digitally mediated preparation that current research has largely overlooked. The transdisciplinary framework proposed by the Douglas Fir Group [36] offers a productive lens for this research agenda, identifying three interdependent levels of influence: the micro level of moment-to-moment social interaction, the meso level of institutional and community practices, and the macro level of ideological structures and policy environments. Applied to Kazakhstan, this framework encourages researchers to examine how technology-enhanced practices at the classroom level are shaped by institutional digital policies at pedagogical universities and by the broader sociocultural values embedded in Kazakhstan's national modernization agenda. Responding effectively to the challenges identified in this article will require the sustained collaboration of pedagogical universities, national educational authorities, and researchers committed to advancing equitable, innovative, and technologically responsive foreign language teacher education across Kazakhstan's diverse regions.

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FROM HUMAN, ARTIFICIAL, AND COLLECTIVE INTELLIGENCE TO SPEAKING DEVELOPMENT: ENHANCING SPEAKING SKILLS AMONG KAZAKHSTANI HIGH SCHOOL STUDENTS THROUGH ENGLISH CLUB ACTIVITIES

Zamira Bazarova

Astana, Kazakhstan

1st year student of Maqsut Narikbayev University

ABSTRACT

This study looks at how English Club activities can help Kazakhstani high school students improve their English-speaking abilities in relation to the conference theme The Future of Intelligence: Human, Artificial, Collective. English has strategic importance in Kazakhstan's multilingual educational environment, but evaluation procedures, resource inequality, and a lack of opportunity for real-world oral communication frequently limit school-based speaking training. According to recent studies, teachers in Kazakhstan still operate under policy-to-practice mismatches, and students often face fear, little exposure to the target language, and inadequate supportive speaking situations. In light of this, the article makes the case that English Clubs can be thought of as places where human intelligence is developed through introspection and self-control, collective intelligence is developed through peer discussion and group meaning-making, and artificial intelligence can serve as an additional tool for practice, feedback, and confidence-building rather than as a substitute for human interaction. English Clubs are positioned as a workable and forward-thinking approach for enhancing speaking skill in Kazakhstan by the paper's preliminary, analytically grounded findings and small-scale school-based mixed-methods study design.

Keywords: *speaking skills, English Club, Kazakhstan, human intelligence, collective intelligence, artificial intelligence, EFL, high school students*

INTRODUCTION

In the context of modern education, intelligence is no longer solely defined as a person's cognitive ability as determined by their own performance. Three interrelated forms of intelligence are becoming more prevalent in language learning: human intelligence, which encompasses individual reasoning, memory, self-regulation, and communicative decision-making; collective intelligence, which arises when students collaborate, support one another, and co-create meaning; and artificial intelligence, which can increase access to rehearsal, feedback, and customized practice. This triadic approach is particularly pertinent to foreign language instruction since speaking progress depends not only on students' knowledge but also on how they communicate, negotiate meaning, and react to support structures both within and outside of the classroom.

In Kazakhstan, this framing is very crucial. English has been strategically linked to educational mobility, international involvement, and future career progression, and the nation has publicly committed to a multilingual language policy focusing on Kazakh, Russian, and English. However, current research indicates that there is still a significant disconnect between the goals of policy and the actual conditions of schools in Kazakhstan when it comes to teaching English. Speaking is still undervalued in many secondary school settings due to evaluation systems that continue to prioritize grammar and reading, and teachers report inadequate training, inconsistent resources, and limited target-language contexts. Speaking development in such a setting necessitates venues outside of the official classroom.

This essay makes the case that English Club activities provide one such area. More precisely, it suggests that English Clubs can function as a forward-thinking educational paradigm where students improve their speaking abilities by interacting with artificial, collective, and human intelligence. The article's three goals are to: (1) place English Club activities in the context of recent research on speaking instruction in Kazakhstan; (2) create a conceptual link between the conference theme and the author's research topic, Enhancing Speaking Skills among Kazakhstani High School Students through English Club Activities; and (3) provide a methodologically sound design for a school-based study along with preliminary findings and discussion.

LITERATURE REVIEW

SPEAKING INSTRUCTION IN KAZAKHSTAN: POLICY, PRESSURE, AND LIMITED ORAL SPACE

According to recent studies, English has a strong but precarious position in Kazakhstan. On the one hand, English is closely linked to internationalization and is part of the nation's multilingual educational mission. However, implementation is still uneven, especially in public school settings where top-down reforms don't necessarily align with classroom reality. According to Imanova et al. (2025), teachers in 17 different regions reported differences in personnel, training, resources, and teaching conditions. They

specifically mentioned target-language environments, like speaking and reading clubs, as one of the things that are most lacking in effective English education. According to the same study, teachers suggested extracurricular activities including reading clubs, speaking clubs, acting groups, and debates as useful strategies to enhance English instruction in Kazakhstan.

Speaking makes this policy-practice mismatch much more apparent. According to Tleuov (2025), assessment policies in Kazakhstani secondary schools promote grammar and reading competency, leaving speaking skills undervalued. The study also reveals that teachers frequently attempt to provide opportunities for local speaking, but they do so under pressure from class size, standardized testing, institutional standards, and variable student skill. To put it another way, there are communicative objectives, but the educational environment does not always support them.

This structural tension is mirrored in the learner experience. According to Yessenbekova's (2024) research on English-speaking difficulties in Kazakhstan, peer and teacher interactions can either help or impede speaking growth, and low proficiency is directly linked to psychological obstacles including stress and low confidence. Crucially, the study suggests that in order to foster a more encouraging and engaging atmosphere, additional speaking events and perhaps regular speaking clubs should be used. These results make English Clubs extremely pertinent as a pedagogical response to a recognized local demand rather than as optional pleasure.

ENGLISH CLUBS AS SPACES OF HUMAN AND COLLECTIVE INTELLIGENCE

When learning a language, human intelligence encompasses more than just vocabulary and grammar. It encompasses risk-taking, self-monitoring, planning, attentiveness, and the ability to deploy language resources under communicative pressure. Therefore, speaking is one of the most obvious ways that human intellect manifests itself. Speaking, however, hardly develops on its own. Through engagement, it grows.

This is the point at which communal intelligence becomes crucial. Peer-peer collaborative discourse, according to Swain (2002), facilitates second language acquisition because language serves as a cognitive and communicative tool at the same time when students work together to solve linguistic puzzles. Students who engage in productive peer contact are able to think through language with others in addition to having more opportunities to communicate. Knowledge is shared, negotiated, and improved cooperatively in these contexts.

This notion is supported by recent research on extracurricular speaking programs. Demiröz (2025) discovered that students participating in an extracurricular speaking program benefited from more chances to utilize language outside of the classroom. The results showed improvements in speaking performance, engagement, confidence, social interaction, and psychological well-being. The report also highlights how these programs create an environment that is open and encouraging, allowing students to express themselves more freely and develop relationships with others both within and outside of the classroom. Similar to this, Nabilla et al. (2025) report that while participants in an online English-speaking club still encountered psychological and linguistic challenges like anxiety, fear of making mistakes, and lack of fluency, the club helped with language development, psychological benefits, and opportunities for collaborative learning. All of these research point to the fact that clubs are important because they combine practice, emotion, and peer support.

This is particularly crucial for high school pupils in Kazakhstan. English Clubs can provide a lower-stakes, more dialogic setting where students practice spontaneous speaking, gain confidence in their ability to engage with others, and learn to co-create meaning when formal classrooms are still limited by curriculum requirements. In this way, an English Club is a small-scale community of collective intellect as well as an extracurricular activity.

ARTIFICIAL INTELLIGENCE AS AUGMENTATION, NOT REPLACEMENT

Artificial intelligence will play a part in spoken pedagogy in the future, but its role must be carefully considered. The concept that AI should take the place of instructor guidance or peer communication is not supported by current research. Rather, AI seems to be most helpful when it enhances practice.

The potential of conversational AI and chatbot-based aids for speaking development is demonstrated by an expanding body of literature. AI-powered chatbots can help with speaking outcomes, confidence, engagement, motivation, pronunciation, and decreased speaking anxiety, according to Du and Daniel's (2024) comprehensive evaluation of 24 studies. Conversational AI tools in ELT have demonstrated favorable affective and cognitive effects, according to Lai and Lee (2024). However, the literature is still primarily focused on Asian EFL contexts and still needs more thorough school-based research. According to Li et al. (2025), empirical research on generative AI in language acquisition expanded quickly

in 2023–2024, however the majority of studies concentrated on writing and higher education, leaving K–12 and speaking relatively unexplored.

More specifically, Hou and Min (2025) discovered that dialogue-based CALL systems had a moderate overall impact on the development of second-language speaking, with higher effects in certain goal-oriented and out-of-class circumstances. AI-powered speaking tasks can also greatly enhance speaking performance and lessen speaking anxiety, according to Ebadi et al. (2025), although they also caution against a potential trade-off between automation and autonomy. Similarly, studies on collaborative conversational agents indicate that AI can assist in scaling dialogic coaching across several groups, particularly in situations where educators are unable to keep an eye on every encounter in real time. However, this field of study also demonstrates that, absent adequately thought-out AI support, increased dialogue productivity does not necessarily translate into deeper learning.

This implies that AI should be ethically and modestly incorporated into the current topic. Artificial intelligence can be used as an optional speaking partner in a high school English Club for practice, idea generation, pronunciation checks, reflective feedback, or micro-practice outside of class. Nonetheless, teaching students to communicate with and on behalf of others should continue to be the fundamental component of speaking development.

METHODOLOGY

RESEARCH DESIGN

A small-scale mixed-methods intervention study with a qualitative focus is suggested in this work. The design is based on Braun and Clarke's (2006, 2021) approach to theme analysis for finding patterns in learner experience, as well as Creswell and Creswell's (2018) view of mixed methods as appropriate for combining quantifiable change with interpretive depth. Because the study examines a useful intervention implemented by a teacher-researcher in an actual school environment, it is also pedagogically consistent with action-oriented classroom research.

RESEARCH SITE AND PARTICIPANTS

A high school in Kazakhstan where English is taught as a foreign language is the suggested study location. About twenty to thirty pupils from grades nine through eleven who willingly join an English club would make up the participants. This group is suitable because teenagers at this stage frequently have sufficient language skills to take part in guided speaking exercises, but they still need a lot of assistance with fluency, self-assurance, and impromptu communication.

INTERVENTION

1. One 80-90 minute English Club session each week would be held during the eight-week intervention. Communicative speaking exercises such role plays, conversations, games, problem-solving exercises, mini-debates, storytelling, interview circles, and group presentations will be included in every session. Three guiding principles would form the club's structure:

2. Planning, speaking, reflecting, self-correcting, and developing confidence are all examples of human intelligence.

3. Students that possess collective intelligence collaborate in groups and pairs, support one another, and jointly create meaning.

4. Artificial intelligence: Students can choose to employ AI technologies for rehearsal, vocabulary assistance, pronunciation practice, or reflective speaking feedback outside of club time.

DATA COLLECTION

Data collection would combine quantitative and qualitative sources in order to capture both performance change and learner experience.

A pre- and post-speaking task would be given first. An analytical rubric emphasizing fluency, vocabulary, grammatical control, pronunciation, and interactional efficacy would be used to grade students on a brief solo speaking exercise. Second, following every club meeting, the teacher-researcher would record organized observation notes, concentrating on participation trends, self-assurance, peer cooperation, and noteworthy speaking behaviors. Third, students would fill out departure cards or brief reflective notebooks to document how each session went, what they found challenging, and what gave them the confidence to speak. Fourth, after the conclusion of the intervention, a smaller group of participants would participate in focus groups or semi-structured interviews. Finally, if AI tools are used, student self-reports and selected interaction logs could be collected to understand how artificial intelligence supported or constrained speaking practice.

This approach is consistent with recent studies on extracurricular speaking programs and speaking clubs, which have successfully combined interviews, observations, reflective reports, and performance measures to understand the value of out-of-class speaking practice.

PRELIMINARY FINDINGS AND DISCUSSION

Because no raw dataset is supplied in this draft, the following findings are presented as preliminary and analytically grounded expectations based on the proposed design and the existing literature.

FINDING 1: ENGLISH CLUB PARTICIPATION IS LIKELY TO IMPROVE SPEAKING CONFIDENCE AND WILLINGNESS TO COMMUNICATE

The first anticipated result is that frequent attendance at English Club sessions will boost students' self-esteem, lessen their fear of speaking, and raise their willingness to interact. A lower-stakes club style is likely to encourage students to take oral risks more voluntarily in the Kazakhstani context, where speaking anxiety and judgmental classroom environments have already been identified as impediments. In contrast to a standard test-oriented classroom, the club would offer regular exposure to spontaneous speaking in a more encouraging social setting. This anticipated result is consistent with the findings of Yessenbekova (2024), Demiröz (2025), and Nabilla et al. (2025), who all stress the significance of practice-rich surroundings, supportive interaction, and decreased anxiety.

FINDING 2: THE STRONGEST MECHANISM OF CHANGE IS EXPECTED TO BE COLLECTIVE RATHER THAN PURELY INDIVIDUAL

The second anticipated result is that peer-supported interaction, in addition to individual work, would propel students' advancement. Collaborative problem-solving, pair work, and group projects would probably assist students come up with ideas, borrow structures, negotiate meaning, and carry on lengthier conversations. According to this viewpoint, the English Club becomes a place of collective intelligence where dialogic engagement fosters the development of speaking skills. This is experimentally backed by research demonstrating that extracurricular activities promote interpersonal skills, group belonging, and active involvement, and it is theoretically consistent with Swain's understanding of collaborative discussion. As a result, the club's primary contribution can be a distinct ecology of speaking practice rather than just "more speaking practice."

FINDING 3: ARTIFICIAL INTELLIGENCE IS LIKELY TO BE USEFUL ONLY WHEN SUBORDINATED TO HUMAN GOALS

The third anticipated result is that speaking practice aided by AI might be advantageous, but only if it is utilized as an addition rather than a replacement. Particularly after school hours, some students would probably like AI for practice, immediate feedback, vocabulary prompts, or pronunciation assistance. When learners don't have enough exposure to the target language, this could be really helpful. But an over-reliance on AI can also limit original thought, decrease peer engagement, or lead to an over-reliance on automated recommendations. AI can increase speaking performance and lessen anxiety, but it also raises concerns about autonomy, critical involvement, and striking a balance between dependence and support, according to recent studies. In the present study, the most educationally sound outcome would therefore be a complementary model: AI for rehearsal, humans for communication, and the group for meaning-making.

OVERALL DISCUSSION

When considered collectively, these early results point to the need to avoid framing the future of intelligence in language instruction as a contest between people and machines. The relational model is more effective for speaking pedagogy. Because students must think, make decisions, exercise self-control, and speak for themselves, human intellect is still crucial. Collective intelligence remains indispensable because language is learned in interaction and through shared meaning-making. Artificial intelligence has significant educational usefulness, but mostly when it increases practice and feedback availability without taking the place of human communication. For Kazakhstani high school students, English Club activities may therefore represent a particularly strong model of future-oriented language education: socially grounded, psychologically supportive, and selectively technology-enhanced.

CONCLUSION

Enhancing Speaking Skills among Kazakhstani High School Students through English Club Activities is linked to the conference theme The Future of Intelligence: Human, Artificial, Collective. This correlation is not merely surface-level, according to the findings. Speaking is still limited in Kazakhstani schools due to gaps in policy implementation, unequal access to resources, evaluation washback, and a lack of oral practice settings. By providing a more adaptable and interactive environment for oral development, English Clubs directly address these issues.

According to the article, English Clubs stimulate human intelligence through introspection, self-control, and communication; collective intelligence through group discussions, peer support, and cooperative problem-solving; and artificial intelligence through carefully chosen rehearsal and feedback tools.

The suggested methodology further shows that a small-scale mixed-methods intervention in a Kazakhstani high school can be used to study this subject in a rigorous, APA-compatible manner.

In this way, intelligence in language education is not just going to be artificial in the future. It is dialogic, hybrid, and morally sound for education. For high school students in Kazakhstan, the English Club can serve as a useful location where these three types of intelligence converge and where speaking development becomes more self-assured, cooperative, and long-lasting.

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GAMIFICATION IN RUSSIAN LANGUAGE LEARNING

Zhakipova Mira Nurzadinovna

Senior Lecturer of the Department of «State and Foreign Languages», Almaty Technological University,
Almaty, Republic of Kazakhstan

ГЕЙМИФИКАЦИЯ В ОБУЧЕНИИ РУССКОМУ ЯЗЫКУ

Жакипова Мира Нурзадиновна

сеньор-лектор кафедры «Государственный и иностранные языки», Алматинский
технологический университет, г. Алматы, Республика Казахстан

Abstract

The article examines the possibilities of applying gamification in teaching Russian as a foreign language at levels A2-B1. Special attention is paid to the author's practical experience gained in the process of teaching in a national audience. The results of a pedagogical experiment aimed at identifying the impact of game elements on students' motivation and academic performance are described. A conclusion is drawn about the feasibility of systematic use of gamification in teaching Russian at the intermediate stage.

Аннотация

В статье рассматриваются возможности применения геймификации в обучении русскому языку как неродному на уровнях А2-В1. Особое внимание уделяется практическому опыту автора, полученному в процессе преподавания в национальной аудитории. Описываются результаты педагогического эксперимента, направленного на выявление влияния игровых элементов на мотивацию и успеваемость обучающихся. Делается вывод о целесообразности системного использования геймификации при обучении русскому языку на среднем этапе.

Keywords: gamification, learning Russian, motivation, game technologies, pedagogical experiment, digital education.

Ключевые слова: геймификация, обучение русскому языку, мотивация, игровые технологии, педагогический эксперимент, цифровое образование.

В последние годы преподавание русского языка как иностранного всё чаще выходит за рамки традиционных методик, ориентированных преимущественно на объяснение и закрепление грамматических правил. Это связано не только с цифровизацией образования, но и с изменением самих обучающихся: их ожидания, когнитивные привычки и формы вовлечения в учебный процесс существенно отличаются от предыдущих поколений. Поэтому педагоги ищут новые приёмы, методы, чтобы сделать уроки более интересными и результативными. Одним из таких методов является геймификация, которая используется на занятиях не только как вспомогательный элемент, но и как самостоятельный методический инструмент.

Под геймификацией в педагогике подразумевается применение игровых механик (баллы, уровни, рейтинги, награды) для повышения вовлеченности в учебный процесс и эффективности обучения. Как подчеркивает ученый и эксперт в области конвергенции игр К.Капп, через игровые механики происходит переосмысление учебного процесса, содействие обучению и решение проблем. В этом смысле геймификация хорошо вписывается в деятельностный подход: студент перестает быть пассивным получателем знаний и становится участником процесса. Если говорить менее формально, геймификация работает потому, что она апеллирует к естественным человеческим реакциям – интересу, азарту, желанию прогресса. Именно этого часто не хватает на традиционных занятиях по русскому языку, где большое количество правил и исключений может быстро утомлять.

Теоретические исследования подтверждают, что внедрение игровых элементов способствует усилению внутренней мотивации и вовлеченности обучающихся, а также облегчают усвоение сложного материала. Например, Позднякова М.Н. отмечает, что геймификация снижает когнитивную нагрузку при работе с грамматикой и лексикой. В свою очередь, а Ерофеева А.А. подчеркивает ее роль в формировании коммуникативных навыков.

Однако особенно важен не сам факт использования игровых элементов, а то, как именно они встроены в учебный процесс. Простое добавление «баллов за ответы» редко дает

устойчивый эффект. Гораздо более результативными оказываются сценарные формы – квесты, ролевые игры, симуляции. Например, в практике обучения русскому языку можно использовать модель «городского квеста»: студентам предлагается серия заданий – от покупки билета до общения в кафе. Каждое выполненное задание открывает следующий уровень. В таком формате грамматические конструкции (падежи, глагольные формы) осваиваются не изолированно, а в контексте реальной коммуникации.

Особую значимость геймификация приобретает в аудиториях, где русский язык не является родным. В подобных группах часто наблюдается повышенная языковая тревожность: студенты опасаются ошибок, избегают устных высказываний, предпочитают занимать пассивную позицию. Включение игровых моментов позволяет частично снять это напряжение, создавая более безопасное коммуникативное пространство.

Эффективность данного подхода была апробирована мной в ходе практического исследования. В течение одного учебного модуля была проведена индивидуальная работа с двумя параллельными группами, владеющих русским языком в одинаковой степени. На начальном этапе курса наблюдалась типичная динамика: достаточно высокая активность на первых занятиях и постепенное снижение вовлеченности по мере усложнения материала, особенно при изучении глагольной системы.

С целью изменения данной ситуации был организован педагогический эксперимент продолжительностью 6 недель (18 практических занятий). В исследовании приняли 2 учебные группы первокурсников одной специальности. Одна группа (контрольная) из 28 студентов обучалась по традиционной модели, а во второй (экспериментальной – 30 студентов) проводилась геймификация. При этом принципиально важным было сохранить учебную направленность экспериментальной группы и не превратить занятия в игру в буквальном смысле.

Во второй группе использовались следующие элементы:

1) Система накопительных баллов. Студенты получали их не только за правильные ответы, но и за участие в обсуждении, попытки сформулировать мысль, инициативу в диалоге. Этот подход позволил изменить отношение к ошибке: она перестала восприниматься исключительно как отрицательный результат и стала частью процесса обучения.

2) Ролевые задания. Например, при изучении темы «Покупки» моделировалась ситуация общения в магазине, однако с небольшим усложнением: студентам предлагались скрытые коммуникативные задачи. Так, один из участников должен был «обязательно получить скидку», другой – «не уступать в цене», третий – «купить как можно быстрее». Интересно, что в процессе выполнения задания студенты нередко отходили от заученных моделей и пытались импровизировать. В одном из случаев студент, испытывающий трудности с грамматикой, сумел достаточно убедительно выстроить аргументацию, используя ограниченный набор средств, но с явной коммуникативной целью. Подобные задания вызвали заметно более живую реакцию по сравнению с традиционными диалогами по образцу.

3) Также применялись задания квестового типа, предполагающие последовательное выполнение этапов. Например, при повторении лексики студенты должны были «пройти маршрут», выполняя небольшие задания, каждое из которых открывало следующий этап. Важно отметить, что ошибки не блокировали продвижение, а обсуждались коллективно, что способствовало формированию более доверительной атмосферы. По моим наблюдениям, именно в таких ситуациях чаще возникали спонтанные реплики, не предусмотренные заранее.

4) Цифровые инструменты. Например, при изучении лексики онлайн-викторины, интерактивные упражнения позволяли не только закрепить новые слова, но и активизировать их использование в речи. Однако они использовались эпизодически и выполняли скорее функцию оперативной обратной связи. Основной акцент сохранялся на устной коммуникации.

Наблюдения показали, что к середине эксперимента во второй группе значительно увеличилось количество студентов, регулярно участвующих в устной работе. Если ранее активность проявляла примерно треть группы, то в конце – большинство обучающихся. Особенно показательно, что в коммуникацию включились студенты, ранее занимавшие пассивную позицию. В первой же группе ситуация осталась без изменений.

Для оценки эффективности были выбраны 3 показателя:

- усвоение лексики (по итоговому тесту);
- речевая активность (количество устных высказываний на занятии);
- уровень мотивации (по шкале самооценки от 1 до 10).

Таблица 1. Результаты эксперимента

Показатель	Контрольная группа	Экспериментальная группа
Средний балл за лексический тест	68/100	80/100
Среднее число высказываний	9	14
Средний уровень мотивации	6.1	8.3

Для дополнительной проверки различий был проведён упрощённый статистический анализ (t-критерий Стьюдента). Различия по всем трём показателям оказались статистически значимыми ($p < 0.05$), что позволяет говорить о достоверном влиянии геймификации на результаты обучения.

Особенно заметным оказалось увеличение речевой активности: студенты экспериментальной группы чаще вступали в диалог, реже избегали ответов и демонстрировали большую инициативу. Это можно объяснить снижением психологического барьера – игровые элементы создают более безопасную среду для ошибок.

Анкетирование показало, что 82% студентов экспериментальной группы оценили занятия как «более интересные», а 76% отметили, что «стало легче запоминать слова». При этом более значимым представляется не столько количественный результат, сколько качественные изменения в поведении студентов.

Устная обратная связь показала, что обучающиеся стали воспринимать занятия как менее формальные и более «доступные». В их высказываниях регулярно повторялись формулировки, указывающие на снижение страха ошибки и повышение уверенности в использовании языка. Студенты чаще использовали изучаемую лексику спонтанно, а не только в рамках заданий. Кроме того, усилилась внутренняя конкуренция и вовлеченность в процесс. Подобные изменения трудно измерить количественно, однако именно они часто определяют успешность обучения на данном этапе.

Вместе с тем следует отметить, что геймификация не является универсальным решением. Ее эффективность напрямую зависит от методической целесообразности. Чрезмерное увлечение игровыми элементами может привести к снижению дисциплины или к смещению внимания с содержания на форму. В этой связи представляется оправданным говорить о необходимости «умеренной геймификации», встроенной в общую логику курса.

Таким образом, проведенный эксперимент позволяет сделать вывод о том, что геймификация при обучении русскому языку как иностранному на уровнях А2-В1 способствует повышению учебной мотивации, активизации речевой деятельности и созданию более благоприятной психологической атмосферы. Наиболее продуктивным является ее использование в сочетании с коммуникативным подходом и при условии четкой ориентации на учебные цели.

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MODERN MENTORING MODELS PROPOSED FOR IMPLEMENTATION IN UNIVERSITIES OF THE REPUBLIC OF ARMENIA**Sargsyan I.R.***Doctor of Sciences (Pedagogy), Professor
Russian-Armenian University
Republic of Armenia, Yerevan***Tatkalo N.I.***Doctor of Sciences (Pedagogy), Professor
Russian-Armenian University
Republic of Armenia, Yerevan***СОВРЕМЕННЫЕ МОДЕЛИ НАСТАВНИЧЕСТВА, ПРЕДЛАГАЕМЫЕ ДЛЯ РЕАЛИЗАЦИИ В ВУЗАХ РА****Саркисян И.Р.***Доктор педагогических наук, профессор
Российско-Армянский университет
Республика Армения, г. Ереван***Таткало Н.И.***Доктор педагогических наук, профессор
Российско-Армянский университет
Республика Армения, г. Ереван***Abstract**

The article examines modern mentoring models applicable in the higher education system of the Republic of Armenia, with an emphasis on their use in the process of language education and teaching Russian as a foreign language. Both traditional (one-on-one individual mentoring, situational mentoring) and innovative models (short-term and goal-setting mentoring, high-speed, flash mentoring, virtual, self-regulated, reverse and team mentoring) are analyzed. Special attention is paid to their organizational features, pedagogical potential, as well as possible psychological and professional barriers to implementation. The advantages and limitations of each model are identified, and options for combining them are proposed, depending on the level of professional training of young specialists. The necessity of a flexible approach to the choice of mentoring models is substantiated, taking into account the goals of the educational organization, the specifics of the university environment and the requirements for teacher training. The conclusion is made about the expediency of introducing variable and integrative mentoring models as an effective tool for improving the quality of professional training and developing the human resources potential of the Universities of the Republic of Armenia.

Аннотация

В статье рассматриваются современные модели наставничества, применимые в системе высшего образования Республики Армения, с акцентом на их использование в процессе языкового образования и преподавания русского как иностранного. Анализируются как традиционные (индивидуальное наставничество «один на один», ситуационное наставничество), так и инновационные модели (краткосрочное и целеполагающее наставничество, скоростное, флэш-наставничество, виртуальное, саморегулируемое, реверсивное и командное наставничество). Особое внимание уделяется их организационным особенностям, педагогическому потенциалу, а также возможным психологическим и профессиональным барьерам при реализации. Выявляются преимущества и ограничения каждой модели, предлагаются варианты их комбинирования в зависимости от уровня профессиональной подготовки молодых специалистов. Обосновывается необходимость гибкого подхода к выбору моделей наставничества с учетом целей образовательной организации, специфики вузовской среды и требований к подготовке преподавателей. Делается вывод о целесообразности внедрения вариативных и интегративных моделей наставничества как эффективного инструмента повышения качества профессиональной подготовки и развития кадрового потенциала вузов РА.

Keywords: mentoring, mentoring, higher education, Republic of Armenia, language education, RFL, mentoring models, flash mentoring, virtual mentoring, reverse mentoring, team mentoring, professional development, young professionals, pedagogical activity

Ключевые слова: наставничество, менторство, высшее образование, Республика Армения, языковое образование, РКИ, модели наставничества, флэш-наставничество, виртуальное наставничество, реверсивное наставничество, командное наставничество, профессиональное развитие, молодые специалисты, педагогическая деятельность

Введение

Для грамотной разработки методики осуществления наставничества в процессе языкового образования следует подробно изучить модели наставничества и выбрать наиболее оптимальную. Ведь в настоящее время совершенно справедливо менторство считается элементом методики работы преподавателя в системе высшего профессионального образования [1]. В первую очередь обратимся к **традиционной модели наставничества** – так называемое наставничество «один на один». Это взаимодействие между коллегами, а именно: опытным высококвалифицированным специалистом и начинающим методистом. При этом время наставничества может варьироваться от 3 месяцев до года. Для отбора наставника, равно как и его «подопечного» следует определить соответствующие критерии с учетом, в первую очередь, опыта, а также навыков преподавания и наставничества. Считаем, что следует также обязательно учитывать положительные личностные характеристики наставника и пр.

На наш взгляд, для обеспечения заинтересованного индивидуально-ориентированного подхода к подопечному, между ним и наставником должны сложиться гармоничные и тесные отношения. Только в этом случае может быть создана комфортная обстановка для осуществления всего процесса наставничества.

Следует оговорить, у наставника в группе может быть от одного до пяти молодых специалистов. А наставник должен немедленно и грамотно реагировать на определенные отклонения в ходе подготовки. Не менее важным представляется нам поощрение достижений молодых специалистов. Такой подход реально позволяет успешно раскрыть способности молодых специалистов. Более того, в команде могут быть сформированы лидеры, что представляется нам весьма позитивным явлением. Данную форму наставничества можно определить как своеобразный курс повышения квалификации молодого специалиста.

Традиционная модель наставничества / ситуативное наставничество

Отметим, что традиционная модель наставничества имеет разновидность – это так называемое ситуационное наставничество (**Situational Mentoring**). Данная разновидность актуальна, поскольку подразумевает немедленное предоставление наставником необходимой квалифицированной помощи молодому специалисту каждый раз, когда он остро нуждается в соответствующих советах, рекомендациях, указаниях. В данном случае роль наставника заключается в обеспечении быстрой помощи, выявлении ошибок и недочетов в деятельности подопечного, активного реагирования на сложившуюся затруднительную ситуацию (в некоторых случаях конфликтную). В данном случае могут возникнуть определенные психологические и педагогические трудности (барьеры), а именно:

- наставник – это опытный высококвалифицированный специалист, который, естественно, занимает более высокое положение в вузе, поэтому молодые специалисты могут испытывать заметные и психологически оправданные трудности в налаживании гармоничных дружеских взаимоотношений как из-за различий в статусе, так и из-за логичной принадлежности к разным поколениям;

- нередко наставники болезненно воспринимают своего подопечного/подопечных, воспринимая их как конкурентов в карьерном развитии.

Исходя из всего вышесказанного, считаем, что данная модель может быть успешно реализована в двух формах: взаимодействие в парах молодых специалистов, один из которых имеет определенный опыт работы в вузе и поэтому логично становится наставником более малоопытного специалиста, который, возможно, только приступает к преподавательской деятельности. Представленная модель весьма актуальна в ракурсе привлечения и закрепления выпускников вузов к педагогической деятельности. При этом оговорим, что, как правило, опыта работы в аудитории, а также профессиональной компетентности начинающего наставника для более грамотного и эффективного развития своего подопечного практически недостаточно. Это наводит на мысль, что программу рассматриваемой модели наставничества (точнее, ее разновидности) необходимо дополнять новыми активными формами.

Второй вариант представленной модели основан на взаимодействии нескольких молодых специалистов (группа до 12 человек), которые занимают практически одинаковые позиции

(должности) в вузе. При этом, логично, наставником становится специалист, имеющий большой опыт преподавательской деятельности, обладает более глубокими знаниями или умениями/навыками в профессиональной области и может поделиться с другим менее опытным специалистом. В практика наставничества следует стремиться к достижению наибольшего эффекта. Иначе наставничество теряет смысл. Поэтому при использовании данной модели мы рекомендуем варьировать представленную модель группового наставничества с другими формами, при этом умело преодолевая возникающие проблемы (которые неизбежны).

Краткосрочное/целеполагающее наставничество

Очень эффективную модель наставничества являет собой так называемое краткосрочное/целеполагающее наставничество (**Short-Term or Goal-Oriented Mentoring**). Для сегодняшнего дня при огромном дефиците времени данная модель представляется весьма актуальной. Здесь наставник и его подопечный организуют менторские встречи по предварительно установленному графику и определяют конкретные цели работы, которая должна быть ориентирована на весьма краткосрочные и при этом очень эффективные результаты. В данном случае требуются большие усилия непосредственно для подопечного, поскольку именно он/она должен позитивно и активно проявить себя в обозначенный период между рабочими встречами. А достижение поставленных целей - это уже совместная работа наставника и подопечного. Ведь не только подопечный является активным участником данного процесса. Наставник работает наравне с ним, прослушивает уроки, дает ценные советы, помогает с научно-методической литературой и пр.

Однако предлагаемая модель не лишена определенных недостатков, а именно: нехватка личного общения из-за намеченных коротких сроков достижения целей. По этой причине данную модель мы не можем рекомендовать начинающим специалистам, поскольку им требуется более тесное и интенсивное взаимодействие со своим наставником. Успех перманента обеспечивается при условии, что непосредственно подопечный имеет определенный опыт работы. В данном случае его профессиональное развитие может быть успешно направлено в область саморазвития.

Похожая модель наставничества - скоростное наставничество (**Speed Mentoring**). Скоростное наставничество представляет собой однократные встречи специалистов со своим наставником - более квалифицированным специалистом. Подобные «разовые» встречи дают реальную возможность грамотно формулировать/устанавливать непосредственно цель/цели научно-методического развития, а также карьерного роста. Встречи основываются на получении необходимой информации, обмене мнениями, равно как и личного опыта наставника. При этом рабочие отношения наставник – подопечный должны непременно складываться по принципу «равный – равному». И только в этом случае можно достигнуть желаемого результата.

Флэш-наставничество

В настоящее время актуальной и востребованной формой наставничества можно назвать так называемое флэш-наставничество (**Flash Mentoring**), которая являет собой новую концепцию, а именно: специалисты, высказавшие добровольное желание стать наставником, должны принимать участие в очень короткой встрече с потенциальными подопечными (не более получаса). Во время подобных коротких встреч наставники должны поделиться опытом проведения занятий и давать ценные научно-методические рекомендации начинающим сотрудникам. Возможны также советы и рекомендации по карьерному росту. При этом молодые сотрудники вольны самостоятельно принять решение – продолжать подобные встречи с наставником или нет, нужен ли им наставник. Если да, то какой именно. Они вольны поменять наставника, иметь несколько наставников для краткосрочных встреч. Отметим, что в данном случае подбор наставников и подопечных не имеет определенных строгих критериев. Критерии устанавливают сами подопечные. Таким образом, обе стороны этого процесса общения должны непременно видеть перспективу своего сотрудничества. Это основное условие реализации программы флэш-наставничества. Следует непременно оговорить, что представленная модель также имеет ряд модификаций. Стандартная разновидность флэш-наставничества – это всего лишь одноразовая встреча (возможно также онлайн общение), квалифицированного специалиста с начинающим коллегой. Продолжительность данной одноразовой встречи может быть от нескольких минут до часа.

Другой вид флэш-наставничества – **последовательное**, что подразумевает работу молодого специалиста с двумя, тремя и более наставниками. Причем с каждым из наставников подопечный имеет несколько встреч

Скоростное наставничество

Представляем скоростное наставничество. Это определенная разновидность последовательного флэш-наставничества. Само название этого подвида говорит о том, что менторы встречаются с начинающими специалистами всего на несколько минут, после чего подопечные переходят к другому наставнику.

Групповое флэш-наставничество

Весьма эффективно, на наш взгляд, групповое флэш-наставничество. В этой модели квалифицированный опытный ментор наставляет уже группу молодых специалистов. Причем данный формат может быть эффективно реализован в аспекте группового скоростного наставничества.

Виртуальное наставничество

В настоящее время все активнее используются информационно-коммуникационные технологии. Это могут быть различные вебинары, туториумы, видеоконференции, равно как и специальные платформы для дистанционного (онлайн) обучения и пр. [1]. Представляется естественным, что активно развивающиеся ИКТ способствовали появлению виртуального наставничества (**Virtual Mentoring**). Отметим, что в течение двух лет проводилась виртуальная программа наставничества [4]. Анализ результатов исследования данной программы выявил позитивные изменения в сознании подопечных, которые стали проявлять большую готовность к обмену информацией. Более того, молодые специалисты – участники виртуальной программы единогласно отметили полезность этого процесса в ракурсе карьерного роста, что также представляется нам весьма актуальным. Немаловажное значение при виртуальном общении имеет и возможность использования значительного объема учебных ресурсов, обеспечение регулярного коллегиального общения. Более того, виртуальная среда делает программу наставничества доступной для широкого круга молодых специалистов. Это очень мобильная и эффективная, а также востребованная на сегодняшний день модель.

Саморегулируемое наставничество

Интересна модель саморегулируемого наставничества (**Self-Directed Mentoring**). Данная модель работает несколько по-иному. В данном случае наставников в лице опытных специалистов, равно как и молодых специалистов-их подопечных подпират не вуз (кафедра, факультет). Наоборот, квалифицированные энтузиасты сами предлагают свои наставнические услуги. Рассматриваемая модель импонирует тем, что работает наставником именно тот специалист, который самовольно решил посвятить себя этому делу и не боится трудностей и ответственности. А молодой специалист также самостоятельно, без посторонней помощи/вмешательства имеет реальную возможность выбирать себе адекватного его запросам наставника.

Реверсивное наставничество

Заслуживает внимания новая модель реверсивного наставничества (**Reverse Mentoring**). Здесь в процесс наставничества вовлекается практически весь преподавательский коллектив без учета должности, звания и возраста. Здесь на корректном уровне учитывается очевидный факт: нередко опытные специалисты старшего возраста затрудняются при работе с новейшими технологиями, в то время как для молодых специалистов эта работа представляется легкой и простой. Оговорим, что данная эта модель основана на активном взаимодействии между двумя сотрудниками: опытный и высококвалифицированный специалист, который старше по возрасту, становится наставляемым. Отметим, что при реализации этой модели может быть успешно решена серьезная проблема недостаточной информированности опытных специалистов старших возрастов в области новых технологий. При этом значительно повысится мотивация подопечных и нейтрализуются опасения по поводу своего будущего в вузе, взявшем курс на компьютеризацию и информатизацию учебного процесса.

Командное наставничество

Самый сложный, на наш взгляд, вид наставничества – командное (**Team Mentoring**). С помощью реализации данной модели можно в короткие сроки подготовить преемников руководителей. Предполагается, что два или более опытных наставников работают с группой молодых специалистов, помогая им в достижении целей. Применение данной модели для решения задач подготовки будущих руководителей (зав. кафедрой, декан, проректор, ректор), как правило, обеспечивает хорошие результаты.

Выводы

Таким образом, нами проанализированы актуальные модели менторства, выделенные из различных публикаций [2, 3, 4, 5, 6, 7, 8 и т.д.] и представлены наиболее приемлемые для образовательного пространства РА. На основе существующего опыта, выделив весь его позитив, мы можем рекомендовать эти модели менторства, отвечающие условиям обучения РКИ в Республике Армения.

Подводя итоги, следует отметить, что каждый вуз, факультет или кафедра должны выбрать свою модель наставничества, исходя из поставленных целей и задач развития своего учебного заведения.

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Philological sciences

INTERNET SLANG AND ITS INFLUENCE ON THE CONTEMPORARY RUSSIAN LANGUAGE AMONG THE YOUTH

Dauletbay Akbota

student of the Faculty of Information Technology

Scientific Supervisor: **Mukasheva Raushana Nurbaevna**

Master of Science, Senior Lecturer

JSC Almaty Technological University

Almaty, Kazakhstan

ИНТЕРНЕТ-СЛЕНГ И ЕГО ВЛИЯНИЕ НА СОВРЕМЕННЫЙ РУССКИЙ ЯЗЫК У МОЛОДЕЖИ

Даулетбай Ақбота

студент факультета информационных технологий

Научный руководитель: **Мукашева Раушана Нурбаевна**

магистр наук, сеньор-лектор

АО «Алматинский технологический университет»

Алматы, Казахстан

Abstract

The study explores the influence of the Internet on the contemporary Russian language. It examines changes in vocabulary, grammar, and modes of emotional expression. Internet slang, memes, and emojis are analyzed. The research concludes that the language is flexible and capable of adapting to digital communication.

Аннотация

Исследование посвящено влиянию интернета на современный русский язык. Рассматриваются изменения в лексике, грамматике и способах выражения эмоций. Анализируются интернет-сленг, мемы и эмодзи. Делается вывод о гибкости языка и его способности адаптироваться к цифровой коммуникации.

Keywords: Internet language, Russian language, slang, memes, emojis, digital communication, language adaptation

Ключевые слова: интернет-язык, русский язык, сленг, мемы, эмодзи, цифровая коммуникация, адаптация языка

Введение

За последние годы интернет стал не просто частью жизни, а одной из её основ [1]. Люди постоянно общаются в социальных сетях, переписываются в мессенджерах, смотрят видео и участвуют в онлайн-сообществах. Особенно сильно это влияет на молодёжь, так как именно она проводит в сети больше всего времени [2]. В результате меняется не только способ общения, но и сам язык.

Современный русский язык всё чаще взаимодействует с интернет-средой. В него активно входят новые слова, появляются необычные формы выражения мыслей, а также меняется способ передачи эмоций [3]. Теперь, чтобы выразить настроение, люди используют не только слова, но и эмодзи, мемы и даже особенности написания текста. Всё это делает язык более гибким и адаптированным к быстрому общению.

Теоретические основы

Лексика, то есть словарный состав языка, реагирует на изменения быстрее всего. Интернет буквально «создаёт» новые слова, которые быстро распространяются среди пользователей [4]. Можно сказать, что язык в сети напоминает моду: одни выражения становятся популярными, затем исчезают, а на их месте появляются новые. Но пока такие слова используются, они играют важную роль и помогают людям чувствовать себя частью определённой группы.

Сегодня можно выделить множество популярных интернет-слов, которые часто встречаются в речи молодёжи. Например: «кринж», «рофл», «краш», «имба», «флексить», «забайтить», «задизить» и другие. Эти слова удобны тем, что позволяют коротко и точно

передать эмоции или отношение к ситуации. Вместо длинного объяснения достаточно одного слова, чтобы собеседник понял смысл [3].

Интересно, что русский язык довольно легко «приспосабливает» такие заимствования. Они начинают изменяться по правилам русского языка, приобретая новые формы. Например, от слова «кринж» появляются варианты вроде «кринжик» или «кринжануть», а от других слов — «видосик», «имбовый» и так далее. Это показывает, что даже новые и заимствованные слова быстро становятся частью языка [5].

Отдельное место в интернет-коммуникации занимают мемы. Это не просто шутки, а целые смысловые конструкции, которые помогают быстро передать эмоцию или ситуацию. Часто достаточно одной фразы, чтобы человек сразу понял, о чём идёт речь. Например: «это фиаско», «а что так можно было», «я в шоке». Такие выражения можно сравнить с современными пословицами — короткими, но ёмкими по смыслу [6].

Кроме отдельных слов и мемов, интернет создаёт и целые модели общения. В определённых ситуациях люди используют уже готовые реакции. Например, если что-то неловкое — говорят «кринж», если смешно — «я ору» или «рофл», если кто-то нравится — «у меня краш». Это упрощает общение и делает его быстрее, потому что не нужно долго объяснять свои эмоции [3].

Сеть влияет не только на лексику, но и на грамматику. В онлайне люди нередко отступают от строгих норм языка, и делают это намеренно. Это не всегда недочёт — порой это метод передать чувства или акцентировать интонацию. Такой подход можно сопоставить с творчеством: нормы нарушаются не хаотично, а с целью сделать речь более живой. [3].

Имеется несколько отличительных черт интернет-общения. К примеру, нередко растягивают буквы, дабы передать чувства: «дааа», «нууу», «лооол». Это служит для отображения того, как именно звучит фраза в беседе. Ещё многие набирают текст без прописных букв, что формирует ощущение лёгкой и свободной речи.

Временами применяются специальные ошибки, например: «превед», «кросавчег», «пичьялка». Подобные слова обычно применяются в шутливом ключе и вошли в состав интернет-культуры [4]. Также распространены краткие выражения вроде «я не могу», «это вообще что», «ну как так». Они выражают чувства оперативно и без ненужных уточнений.

Отдельно следует упомянуть применение пунктуации. В сети она выполняет не только грамматическую, но и эмоциональную функцию. К примеру, точка способна обозначать отстранённость или неодобрение: «хорошо.» или «ясно.». Многоточие нередко выражает неуверенность или смущение: «ну вот...», «вероятно...». А обилие восклицательных знаков передаёт сильные чувства: «ты где!!!» [2]. Порой люди совершенно не применяют знаки препинания, что создаёт ощущение скорой, «потокowej» речи. Всё это содействует сделать текст более оживлённым и схожим на устное общение.

Ещё одним значимым компонентом интернет-языка являются эмодзи. Они замещают мимику, жесты и интонацию, которые имеются в обычной беседе. Посредством их можно показать чувства, отношение к высказываниям или даже внести шутку. К примеру, «😂» демонстрирует сильный хохот, «😞» — небольшую печаль, а «😐» — равнодушие [2]. Смайлики способствуют точнее передать смысл послания. Одна и та же фраза способна звучать по-разному в зависимости от присоединённого значка. К примеру, «благодарю» — это просто учтивость, а «спасибо 😊» уже звучит душевнее и радушнее. Таким образом, эмодзи делают текст более ясным и чувственным.

Можно утверждать, что интернет оказывает значительное воздействие на современный русский язык. Он преобразует лексику, грамматику и манеры выражения чувств. Язык становится более подвижным, оперативным и приспособленным к свежим условиям взаимодействия. Вопреки некоторым отступлениям от канонов, эти метаморфозы демонстрируют не упадок языка, а его прогресс и умение подстраиваться под текущую действительность [1].

Можно сказать, что сеть оказывает большое влияние на современный русский язык. Она меняет лексику, грамматику и методы выражения эмоций. Язык становится более гибким, оперативным и приспособленным к новым условиям общения. Несмотря на некоторые отклонения от норм, эти перемены показывают не упадок языка, а его рост и умение подстраиваться под нынешнюю действительность.

Результаты исследования

На основе изученной информации мы провели исследование о важности использования интернет-сленга в разговорной речи: как часто студенты ими пользуются и насколько они хорошо понимают значение сленгов. В исследовании приняли участие 103 студента Алматинского технологического университета.

Как всем известно, в наши дни интернет играет огромную роль в жизни людей, особенно молодёжи. Общение в социальных сетях, мессенджерах и на различных онлайн-площадках влияет не только на образ жизни, но и на язык. Одним из ярких проявлений этого влияния является интернет-жаргон — особые слова и выражения, которые возникли в сети и постепенно стали частью повседневной речи. В данном исследовании рассматривается, как студенты применяют интернет-жаргон, насколько хорошо его постигают и какую функцию он выполняет в их общении.

В первую очередь, можно констатировать, что интернет-жаргон довольно живо применяется среди обучающихся. Для многих он сделался обычным методом передачи эмоций и откликов. Подобные слова дают возможность оперативнее и легче донести дух или позицию к положению. При этом существенно, что жаргон уже не замыкается лишь на переписке: он плавно переходит и в разговорную речь. Это свидетельствует о том, что черты между онлайн-общением и действительной жизнью становятся менее явными.

Коль скоро говорить о постижении интернет-сленга, то большинство учащихся неплохо разбирается в его смысле. Распространенные слова и фразы известны почти любому, поскольку они нередко попадают в сети. Впрочем, порой появляются затруднения с новыми или нечастыми словами. Это вполне понятно, ведь интернет-речь всегда трансформируется: какие-то слова стремительно обретают известность, а иные так же быстро пропадают. Следовательно, не всегда выходит сходу уловить значение неведомого оборота. Было интересно то, как обучающиеся держатся в подобных моментах. Многие стремятся не оставлять неясные слова без внимания и стараются уяснить их смысл. Довольно часто для этого задействуют интернет — поисковики или специализированные ресурсы. Также популярен способ спросить у друзей или приятелей. Это демонстрирует, что диалог и передача сведений остаются существенной составляющей учебного процесса, даже когда затрагивается неофициальный язык. Отдельные студенты пытаются постичь значение слова сами, опираясь на окружение, что также считается ценным умением.

Отдельно стоит отметить, где именно применяется интернет-сленг. Как уже говорилось, он широко распространен в переписке, так как именно там он возник изначально. Однако многие обучающиеся отмечают, что употребляют такие слова и в обычном разговоре. Особенно часто это случается в беседе с друзьями. Таким образом, интернет-сленг становится частью будничного языка и перестает мыслиться как нечто исключительно «онлайн».

Также в процессе изыскания изучалась осведомлённость обучающихся о конкретных жаргонных словах. Такие выражения, как «лол», «кринж» и «краш», знакомы большей части респондентов. При этом можно отметить, что знание значения слова не всегда подразумевает его активное применение. Кто-то пользуется такими словами постоянно, а кто-то отдаёт предпочтение более нейтральной лексике. Это обусловлено личными склонностями и манерой общения индивида.

Занимательным оказался вопрос о том, насколько важен интернет-жаргон в беседе. Взгляды обучающихся по этому поводу разошлись. Одни полагают, что он делает речь более оживленной и содействует лучшему взаимодействию со сверстниками. Другие придерживаются суждения, что без жаргона вполне можно обойтись, поскольку есть множество обычных слов, которые ясны всем. Таким образом, интернет-жаргон расценивается скорее как вспомогательное средство, а не как неотъемлемая часть общения.

Несмотря на широкое распространение, интернет-жаргон не всегда упрощает общение. В некоторых случаях он, напротив, способен порождать недопонимание. Такое случается, когда собеседник не ведаёт значения применяемого слова. Подобные случаи встречаются нечасто, но всё же имеют место. Это демонстрирует, что уровень владения сленгом у разных людей может различаться, даже если они относятся к одной возрастной группе.

Ещё одной значимой чертой является многоязычие интернет-жаргона. В речи обучающихся нередко можно заметить слияние слов из различных языков — русского, казахского и английского. Это обусловлено тем, что сеть объединяет индивидов из разных государств, и языки начинают переплетаться. В итоге возникает новый способ взаимодействия, в котором без

труда гармонируют различные языковые компоненты. При этом ряд обучающихся всё же склоняются к использованию жаргона лишь на одном языке или вообще уклоняются от него.

Заключение

Результаты исследования среди студентов выявили значимый социолингвистический феномен: молодёжь не только демонстрирует активное употребление сленга, но и рассматривает его как неотъемлемый компонент своей групповой идентичности. Специфический лексикон выступает в роли маркера принадлежности к определённому поколению или социальной группе. Тем не менее, часть опрошенных студентов акцентирует внимание на том, что сленг не является обязательным условием для эффективного общения, а скорее служит удобным средством для выражения эмоционального состояния и оптимизации коммуникативных процессов.

Резюмируя вышеизложенное, возможно утверждать, что интернет-сленг занимает видное место в жизни нынешней молодежи. Он живо применяется, отчетливо осознается и неспешно делается компонентом обывденной речи. В то же время его воздействие нельзя назвать безусловным: с одной стороны, он делает общение более легким и экспрессивным, а с другой — порой вызывает неясности. Невзирая на это, интернет-сленг являет собой отражение сдвигов, случающихся в языке, и демонстрирует, как он приспосабливается к новым обстоятельствам.

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WAYS TO LEARN WORD FORMATION IN MODERN GERMAN

Muslimova Ofelya Surkhay

Ganja State University

Candidate of Philological Sciences,

Associate Professor, Senior Lecturer Azerbaijan, Ganja

MÜASİR ALMAN DİLİNDƏ SÖZ ƏMƏLƏ GƏLMƏSİNİN ÖYRƏNİLMƏ YOLLARI

Muslimova Ofelya Surkhay

Gəncə Dövlət Universiteti

Filologiya üzrə fəlsəfə doktoru,

dosent, baş müəllim

Azərbaycan, Gəncə

Abstract

The German language uses a variety of ways to form words, reflecting its rich linguistic heritage and dynamic evolution. Compounding is a common strategy for combining two or more existing words to form a new word, such as *Fernseher* (television) from *Fern* (far) and *Seher* (viewer). Derivation involves adding prefixes or suffixes to existing words to change the meaning or create new words, as seen in the words *"unmöglich"* (impossible) or *"Schönheit"* (beauty). Borrowing from other languages, especially English and French, contributes to lexical enrichment. In addition, blending and the formation of acronyms represent innovative approaches to linguistic innovation, demonstrating the adaptation and creativity inherent in German word-formation processes.

Xülasə

Alman dili söz yaratmaq üçün onun zəngin dil irsini və dinamik təkamülünü əks etdirən müxtəlif üsullardan istifadə edir. Mürəkkəbləşdirmə iki və ya daha çox mövcud sözü birləşdirərək yeni söz yaratmaq üçün geniş yayılmış strategiyadır, məsələn, *"Fern"* (uzaq) və *"Seher"* (tamaşaçı) sözlərindən *"Fernseher"* (televiziya). Törəmə, *"unmöglich"* (mümkünsüz) və ya *"Schönheit"* (gözəllik) sözlərində göründüyü kimi, mənanı dəyişdirmək və ya yeni sözlər yaratmaq üçün mövcud sözlərə prefikslər və ya şəkilçilər əlavə etməyi əhatə edir. Digər dillərdən, xüsusən də ingilis və fransız dillərindən borc götürmək leksik zənginləşməyə kömək edir. Bundan əlavə, qarışdırma və akronimlərin formalaşması alman dilinin söz əmələ gəlməsi proseslərinə xas olan uyğunlaşma və yaradıcılığı nümayiş etdirərək lingvistik innovasiyaya innovativ yanaşmaları təmsil edir.

Keywords: German language, word creation, modern linguistics, linguistic solutions.

Açar sözlər: Alman dili, söz yaradıcılığı, müasir dilçilik, lingvistik həll yolları.

İnsanlar arasında ünsiyyət şifahi və ya yazılı şəkildə baş verə bilər. Danışarkən hissləri və düşüncələri ardıcıl şəkildə ifadə etmək, əlbəttə ki, idealdir, lakin buna ehtiyac yoxdur. Şifahi ifadədə danışanla dinləyici arasında qarşılıqlı əlaqə yaranır; Danışan öz hiss və düşüncələrini qarşı tərəfə birbaşa, onun köməyi ilə, çatışmayan hissələri tamamlamaqla və ya bədən dilinin köməyi ilə ifadə edir. Yazmaqla özünü ifadə etmək danışmaqla müqayisədə olduqca çətinidir. Yazıçı ilə oxucunun qarşılıqlı əlaqəsini müəyyən edən zaman, məkan və s. Bu kimi şərtlər mesajın ötürülməsinə və qavranılmasına təsir göstərir. Çünki yazılı ifadədə bədən dilinin heç bir təsiri yoxdur; Mesajını yazılı şəkildə çatdırmaq istəyən insan hiss və düşüncələrini aydın və başa düşülən şəkildə sözə çevirməlidir. Bunun üçün sisteməlik təfəkkür və yazı vərdişi və uşaqlıqdan əldə edilməli olan bilik lazımdır. Yazı mədəniyyəti ənənəsi olmayan, şifahi mədəniyyətə əsaslanan cəmiyyətimizdə yazı vərdişinə yiyələnmək son dərəcə çətin və məhduddur. Anasında, atasında, yaxın çevrəsində oxuyub-yazmaq vərdişi olmayan uşaq həvəsləndirmədən oxumaq və yazmaq vərdişi və bacarığına necə yiyələne bilər? Üstəlik, dəyişikliklərin çox sürətlə baş verdiyi cəmiyyətimizdə hələ yazılı mədəniyyət tam formalaşmamış, müasir kütləvi informasiya vasitələrinin təsiri altında uşaqlarımız, gənclərimiz hələ oxuyub-yazmağı öyrənməmiş televiziya, kompüter, mobil telefonlarla tanış olurlar. Gündəlik qəzetlərin ümumi tirajının və kitab istehlakının bu qədər az olması, xüsusən də qəzetlərimizin Avropa qəzetləri ilə müqayisədə məndən daha çox şəkilli olması mədəniyyətimizdə vizual ünsiyyətin son dərəcə yaygın olmasına baxmayaraq, yazılı ünsiyyətin

olmasının göstəricisidir, çox az istifadə olunur. Bundan əlavə, məktəblərimizdə ibtidai sinifdən başlayaraq uşaqlarımızın yazılı ifadə yox, çox seçimli testlərlə bombalanması onların yazılı ifadə bacarıqlarının inkişafına mane olur.[4]

Alman dilinin qeydə alınmış tarixi, onun danışanlarının romalılarla ilk təması ilə, yəni eramızdan əvvəl 1-ci əsrdə başlayır. O dövrdə və ondan sonrakı bir neçə əsr ərzində cüzi dialekt fərqlərindən bir qədər çox olmayan tək bir "german dili" mövcud idi. Yalnız təxminən eramızın 6-cı əsrindən sonra "alman" (yəni, yüksək alman) dilindən danışmaq olar.

Dilçilik sahəsində müəyyən bir üslub daxilində həlledici element əsas terminin əhəmiyyətidir. İstənilən dildə fikrin məqsəduyğunluğunun ifadəsi həmin dildə sözlərin məntiqi tərifindən və istifadəsindən irəli gəlir.

Müzakirə zamanı sözlərdən istifadə olunur və onların mənası dərk edilir. Belə bir prosedur zamanı sözlər bir neçə şəkildə istifadə edilə bilər. Beləliklə, sözləri bir neçə mənə ifadə edən fərdi varlıqlar kimi istifadə etmək həyati əhəmiyyət kəsb edir. Dəmirçizadə qeyd edir ki, sözlər təkə bir mənə ifadə etmək üçün deyil, daha çox bir neçə mənə ifadə edə bilən vahidlər kimi işlənir. Nəticə etibarlı ilə dilin lüğət tərkibini təşkil edən və çoxsaylı mənalar daşıyan sözlər müxtəlif gözəl mənalar daşıyan leksik vahidlərə çevrilir. [7]

Bu sözlərin məcazi mənaları da ola bilər. Alman alimi H.Paul sözlərin mənalarına görə necə dəyişdiyini izah edir. Bu dəyişikliklər müxtəlif yollarla müşahidə oluna bilər: a) Sözlərin metafora və metonimiya vasitəsilə çevrilməsi. b) Sözlərdə həm geniş, həm də dar mənaların əhəmiyyəti. c) Sözlərdə mənənin inkişafı və ya azalması. d) Hiperbol və litotalardan istifadə etməklə sözlərin gücləndirilməsi və ya zəiflədilməsi. e) Evfemizm prosesi ilə mənə dəyişikliyi.

Təkamül dərəcəsindən asılı olaraq, bir söz yaradıcılar tərəfindən müəyyən edilmiş bir çox mənaya malik ola bilər. Bəzən termin həm hərfi, həm də metaforik şərhə malik ola bilər. Obrazlı dil sözlərdən qeyri-hərfi mənada istifadə etməklə mətnin ifadəliliyini və obrazlılığını artırır. Metafora həm danışq dilində, həm də ədəbi əsərlərdə tez-tez rast gəlinən bir növdür. Metafora iki fərqli kateqoriyaya bölünür: poetik metafora və leksik metafora [1].

Alman dili Hind-Avropa dillərinin german qoluna aiddir. Dünyada təxminən 120 milyon insan alman dilində danışır. Bundan əlavə, Almaniya iqtisadiyyat, ticarət, sənaye və bir çox başqa sahələrdə beynəlxalq miqyasda mühüm mövqeyə malikdir. Bu səbəbdən alman dili çox geniş istifadə olunur. Lakin dilin geniş yayılması bu sahədə biometrik məlumatlarda təhlükəsizlik problemləri yaradır. Bu, təhlükəsiz, sürətli avtomatik səs və dinamik tanınması ehtiyacını tələb edir. Alman dilinin xüsusiyyətlərinə nəzər salsaq; Alman dili kök və şəkildə ibarətdir və flektiv dillər qrupuna aiddir. Latin hərflərindən istifadə olunur və əlifbada 26 hərflər var. Alman dilində artıq hər ismin qarşısında işlədilir. Tələffüz baxımından sözlər yazıldığı kimi tələffüz olunur. O, həm də müxtəlif səs dəyişikliyi və intonasiyaları ilə digər dillərdən fərqlənir [2].

Alman dilində "Deutsch" olaraq adlandırılan alman dili, əsasən Almaniya, Avstriya, İsveçrə, Lixtenşteyn, Lüksemburq və Belçika və İtaliyanın bəzi bölgələrində danışılan Qərbi Alman dilidir. Avropada ən çox danışılan dillərdən biridir və əhəmiyyətli mədəni, tarixi və iqtisadi əhəmiyyətə malikdir.

Alman dili öz köklərini təxminən 2000 il əvvəl Mərkəzi Avropada məskunlaşmış erkən german tayfalarına götürür. Zamanla german dilləri proto-german dilindən təkamül edərək müxtəlif dialektlərə şaxələnmiş və nəticədə fərqli dillər meydana gətirmişdir. Köhnə yüksək alman, orta yüksək alman və erkən yeni yüksək alman dili 16-cı əsrdə Martin Lüterin Müqəddəs Kitab tərcüməsinin çapı ilə ortaya çıxan Müasir Standart Alman dilindən əvvəlki tarixi mərhələlərdir.

Alman dili mürəkkəb qrammatikası ilə tanınır, o cümlədən isim təftişləri sistemi, fərl birləşmələri və dörd qrammatik hal mövcuddur. O, həmçinin üç cinsi (kişi, qadın, neytral) və çevik söz sırasına malikdir. Alman dilində mürəkkəb sözlər üstünlük təşkil edir ki, bu da natiqlərə yeni, çox vaxt uzun terminlər yaratmaq üçün bir neçə sözü birləşdirməyə imkan verir.[8]

Alman dili hər birinin özünəməxsus xüsusiyyətləri olan müxtəlif regional dialektləri və çeşidləri əhatə edir. Əsasən Almaniyanın mərkəzi və cənubunda danışılan yüksək alman dialektləri Standart Alman dilinin əsasını təşkil edir. Şimali Almaniya və Hollandiyada danışılan aşağı alman ləhcələri tələffüz, lüğət və qrammatika baxımından yüksək alman dilindən əhəmiyyətli dərəcədə fərqlənir.

Alman dili Avropanın mədəni və intellektual tarixində mərkəzi rol oynamışdır. İohan Volfqanq fon Höte, Fridrix Nitsşe və Albert Eynşteyn də daxil olmaqla, çoxlu nüfuzlu yazıçılar, filosoflar və elm adamları yetişdirmişdir. Alman ədəbiyyatı, musiqisi, fəlsəfəsi və elmi tədqiqatları global mədəniyyət və biliyə mühüm töhfələr verib.

Alman dili Almaniya, Avstriya və Lixtenşteynin rəsmi dili, İsveçrə və Lüksemburqun rəsmi dillərindən biridir. Qonşu ölkələrdə və bütün dünyada immiqrant icmaları arasında da geniş danışılır. Alman dili beynəlxalq diplomatiya, ticarət və akademiya mühüm dil olaraq qalır və milyonlarla insan onu ikinci dil kimi öyrənir.[11]

Alman təhsil sistemi dil öyrənilməsinə böyük diqqət yetirir, alman dili məktəblərdə məcburi fənn kimi tədris olunur. Alman dilli ölkələrin bir çox universitetləri yüksək keyfiyyətli təhsil almaq istəyən beynəlxalq tələbələrə cəlb edən alman dilində tədris proqramları təklif edir. Alman dilində dil biliyi Avropada və onun həudlarından kənarda iş, təhsil və mədəni mübadilə imkanları açır [14].

Zəngin tarixi, mürəkkəb quruluşu və müxtəlif mədəni təsirləri ilə alman dili global dil mənzərəsində mühüm yer tutur. Qədim german qəbilələrindəki mənşəyindən tutmuş müasir beynəlxalq dil roluna qədər alman dili inkişaf etməyə və danışanların və öyrənənlərin dəyişən ehtiyaclarına uyğunlaşmağa davam edir. İstər ünsiyyət vasitəsi, istər mədəniyyətə giriş qapısı, istərsə də bilik vasitəsi kimi alman dili getdikcə bir-birinə bağlı olan dünyada dəyərli varlıq olaraq qalır.

Müasir dilçilik, dilin elmi tədqiqini və onun quruluşunu, istifadəsini və mənimsənilməsini əhatə edən dinamik bir sahədir. Müasir dilçiliyin kökləri Hindistanda Panini və Yunanıstanda Aristotel kimi alimlərin dil quruluşu və qrammatikasını tədqiq etdiyi qədim sivilizasiyalara gedib çıxır. Bununla belə, dilçiliyin elmi bir elm kimi formal şəkildə öyrənilməsi 19-cu əsrin sonu və 20-ci əsrin əvvəllərində Ferdinand de Sossure, Leonard Bloomfield və Noam Chomsky kimi alimlərin işi ilə başlamışdır. Saussure-nin strukturalist yanaşması dil sistemlərinin sinxron təhlilini vurğulayaraq, zamanın konkret məqamında verilmiş dil daxilində linqvistik elementlər arasındakı əlaqələrə diqqət yetirirdi. Blumfildin davranışçı baxışı isə müşahidə olunan dil davranışını və dilin stimula-cavab sistemi kimi təhlilini vurğulayırdı.[3]

Xomskinin transformasiya-generativ qrammatikası 20-ci əsrin ortalarında universal qrammatika və anadangəlmə dil strukturları anlayışını təqdim etməklə dilçilikdə inqilab etdi. Onun işi linqvistik tədqiqatın diqqətini təsviri təhlildən əsas linqvistik mexanizmlərin və koqnitiv proseslərin öyrənilməsinə çevirdi.

Müasir dilçilik dilin strukturunu, funksiyasını və mənimsənilməsini izah etməyə çalışan müxtəlif nəzəri yanaşmaları əhatə edir. Əsas nəzəri cərəyənlərdən bəzilərinə aşağıdakılar daxildir:

Generativ qrammatika: Xomskinin universal qrammatika nəzəriyyəsinə əsaslanan generativ qrammatika insan dilinin əsasını təşkil edən fitri qaydaları və strukturları üzə çıxarmağa çalışır. O, bütün insan dillərinin ümumi əsas strukturu paylaşdığını və linqvistik səriştənin bir sıra mücərrəd qrammatik qaydalarla idarə olunduğunu irəli sürür.

Funksional dilçilik dilə onun sosial və mədəni konteksti ilə formalaşan ünsiyyət sistemi kimi yanaşır. O, dilin funksional aspektlərini, məsələn, kommunikativ məqsədlərə nail olmaq və sosial mənalara ifadə etmək üçün dilin necə istifadə edildiyini vurğulayır.

Koqnitiv dilçilik: Koqnitiv dilçilik dil və idrak arasındakı əlaqəni araşdırır, dilin dərk edilməsində, istehsalında və mənimsənilməsində psixi proseslərin rolunu vurğulayır. O, dilə koqnitiv strukturların və konseptual sistemlərin əksi kimi baxır.

Sosiolinqvistika sosial sinif, etnik mənsubiyyət, cins və coğrafi bölgə kimi amillərin dil istifadəsinə və münasibətinə necə təsir etdiyini araşdıraraq, dil dəyişkənliyi və dəyişməsinin sosial ölçülərini araşdırır. O, dil və cəmiyyət arasındakı əlaqəni və dilin sosial kimlikləri əks etdirmə və gücləndirmə yollarını anlamağa çalışır. [12]

Müasir dilçilik fənlərarası xarakterini və onun müxtəlif akademik fənlərə və real dünya tətbiqlərinə uyğunluğunu əks etdirən geniş tədqiqat sahələrini əhatə edir. Dilçilikdə müasir tədqiqat sahələrindən bəziləri bunlardır:

Tədqiqatçılar dil öyrənmə prosesində iştirak edən idrak, sosial və linqvistik prosesləri araşdıraraq, uşaqların dili necə mənimsədiyini öyrənirlər. Bu tədqiqatın təhsil, dil pedaqogikası və inkişaf psixologiyasına təsiri var.

Hesablama dilçilik təbii dilin emalı, maşın tərcüməsi və mətn təhlili üçün alqoritmlər və modellər hazırlamaq üçün linqvistik nəzəriyyəni kompüter elmləri ilə birləşdirir. Onun süni intellekt, məlumat axtarışı və insan-kompüter qarşılıqlı əlaqəsində tətbiqləri var.

Tədqiqatçılar dialektologiya, dil təması və dilin təkamülü kimi faktorları araşdıraraq, müxtəlif nitq icmalarında və zamanla dil dəyişkənliyi və dəyişmə nümunələrini öyrənirlər. Bu tədqiqat linqvistik müxtəlifliyi və dil dəyişikliyinə səbəb olan mexanizmləri dərk etməyimizə kömək edir.[10]

Müasir dilçilik çoxlu nəzəri yanaşmaları və tədqiqat sahələrini əhatə edən canlı və fənlərarası bir sahədir. Dilin quruluşu və idrakının öyrənilməsindən tutmuş dilin variasiyası və texnologiyasının tədqiqinə qədər dilçilik insan ünsiyyətinin təbiəti və onun cəmiyyətdəki rolu haqqında dəyərli fikirlər təklif

edir. Dil anlayışımız təkamül etməyə davam etdikcə, dilçilik elmi araşdırmaların önündə qalaraq insan dilinin mürəkkəb və çoxşaxəli təbiətinə işıq salır [5].

Mürəkkəbliyi və dəqiqliyi ilə tanınan alman dili zəngin dil tarixini və mədəni müxtəlifliyini əks etdirən söz yaratmaq üçün müxtəlif mexanizmlərdən istifadə edir. Bu esse alman sözlərini formalaşdıran müxtəlif üsulları araşdırır, onun leksik proseslərinə xas olan yaradıcılığı və çevikliyi vurğulayır.

Alman dilinin ən fərqli xüsusiyyətlərindən biri onun birləşməyə meyilli olmasıdır, bunun sayəsində iki və ya daha çox mövcud söz birləşərək yeni söz əmələ gətirir. Bu proses mürəkkəb anlayışları lakonik şəkildə ifadə edən mürəkkəb isimlərin yaradılmasına imkan verir. Mürəkkəbləşdirmə alman dilində danışanlara dilin ifadə gücünə töhfə verərək dəqiq mənalı şəmərəli şəkildə çatdırmağa imkan verir. Törəmə, yeni sözlər yaratmaq və ya mənalılarını dəyişdirmək üçün mövcud sözlərə prefikslər və ya şəkilçilər əlavə etməyi əhatə edir. Bu proses sözləri müxtəlif kontekstlərə uyğunlaşdırmaq və ya nüansları çatdırmaq üçün dəyişdirməklə alman dilinin lüğətini genişləndirməyə imkan verir. Məsələn, "un-" prefiksi "möglich"ə (mümkün) əlavə olunaraq "unmöglich" (mümkün deyil) meydana gətirə bilər ki, bu da inkarı göstərir. Eynilə, "-heit" şəkilçisi "schön"ə (gözəl) qoşularaq "Schönheit" (güzəllik) yaratmaq, sifəti keyfiyyət və ya hal bildirən ismə çevirmək olar. Derivasiya alman dilində danışanlara dili müxtəlif kommunikativ ehtiyacları uyğunlaşdırmağa imkan verən çox yönlü mexanizmdir.[13]

Törəmə üsulları mövcud sözlərdən - bəzi hallarda məhdud morfemlərdən və ya formal strukturlardan - kökə fiqlər əlavə etməklə yaranan sözlərdən istifadə etməkdən ibarətdir. Beləliklə, xəyali pandle sözümdən, məsələn, pandler, pandlette, depandle və repandlize sözləri alın bilər. Belə şəkilçilər aktiv şəkilçilər adlanır. Bütün yerli danışanlar onların mənasını bilirlər və ingilis törəmə qaydaları və ya bənzətmə ilə onları müxtəlif köklərə ahəngdar şəkildə əlavə edə bilərlər. Bu üsulla hər hansı yeni söz, mənşəyindən asılı olmayaraq, tez bir zamanda törəmələr toplusunun əsasına çevrilir. Bundan əvvəl emplane və deplane sözləri fransız dilindən götürülmüş entrain və detrain sözləri ilə bənzətmə yolu ilə, bu sözlərin özü isə embark və debark sözləri ilə bənzətmə yolu ilə əmələ gəlmişdir. Bunların hamısı öz-özünə törəməni izah edir. Məhsuldar şəkilçilərdən söz formalarının alınma yolları o qədər aydındır ki, yəqin ki, hamımız bunu təsəvvür etdiyimizdən daha tez-tez edirik. Bir çox hallarda bu şəkildə əmələ gələn sözlər biz onları tez-tez istifadə etməmişdən əvvəl lüğətlərdə qeyd olunur, lakin biz onları bilmirik. Bu üsullar xüsusi olaraq yeni sözləri əzbərləmədən öz lüğətimizi genişləndirməyə imkan verir. Lakin bu etimad bizi lazımsız yeni sözlər yaratmaqda çətin hala sala bilər, çünki istifadə etdiyimiz sözlər artıq başqa vasitələrlə icad edilmiş ola bilər. [9]

Alman dili, bir çox dillər kimi, tarixi boyu digər dillərdən, xüsusən də ingilis, fransız və latın dillərindən geniş şəkildə borc almışdır. Alınmış sözlər lüğəti zənginləşdirir və mədəni mübadilə və globallaşmanı əks etdirir. Məsələn, "Kompüter" (kompüter) və "Otel" (otel) ingilis dilindən, "Restoran" (restoran) və "Kafe" (kafe) isə fransız dilindən götürülüb. "Universität" (universitet) və "Medizin" (tibb) kimi latın dilindən alınma sözlər akademik və elmi diskursda üstünlük təşkil edir. Borc alma alman danışanlara xarici anlayışları və texnologiyaları dillərinə daxil etmək imkanı verir, ünsiyyət və mədəni mübadilələri asanlaşdırır.

Qarışdırma, əridilmiş məna ilə yeni bir söz yaratmaq üçün iki və ya daha çox sözün hissələrini birləşdirməyi əhatə edir. Bu proses tez-tez texnoloji irəliləyişlərə və ya sosial hadisələrə cavab olaraq baş verir. Məsələn, "Handy" (mobil telefon) "handlich" (əlverişli) və "Telefon" (telefon) birləşməsidir və cihazın daşınma qabiliyyətini və faydalılığını əks etdirir. Eynilə, "Smog" (smog) hava çirklənməsinin bir növünü təsvir edən "Tüstü" (tüstü) və "Duman" (duman) qarışığıdır. Qarışıq alman dilində danışanlara cəmiyyətdə yaranan konsepsiyaları və tendensiyləri əks etdirən innovativ terminlər yaratmağa imkan verir. [8]

Akronimlər bir ifadənin ilk hərflərini götürərək yeni söz yaratmaq üçün onları birləşdirərək əmələ gəlir. Bu proses alman dilində, xüsusən texniki və bürokratik kontekstlərdə geniş yayılmışdır. Məsələn, "CDU" (Xristian Demokratik Birlik) və "BMW" (Bayerische Motoren Werke) müvafiq olaraq Alman siyasətində və sənayesində akronimlərin görkəmli nümunələridir. Akronim formalaşması şəmərəli ünsiyyəti asanlaşdırır və mürəkkəb təşkilati strukturlar və ya konsepsiyalar üçün mnemonik cihaz kimi xidmət edir. [6]

Alman dili söz yaratmaq üçün mürəkkəbləşdirmə və törəmədən tutmuş borc alma, qarışdırma və akronim formalaşmasına qədər müxtəlif üsullardan istifadə edir. Bu mexanizmlər dilin uyğunlaşma qabiliyyətini, yaradıcılığını və mürəkkəb fikirləri ifadə etmək qabiliyyətini əks etdirir. Alman dili lingvistik irsini qoruyaraq innovasiyaları qəbul etməklə, dinamik və ifadəli ünsiyyət vasitəsi kimi inkişaf etməyə davam edir.

Dillər öz strukturuna, qrammatikasına, lüğətinə və mədəni kontekstinə görə əhəmiyyətli dərəcədə fərqlənir, öz nitq icmalarının unikal tarixlərini, təsirlərini və inkişaflarını əks etdirir. Alman dilini bir çox başqa dillərdən fərqləndirən mürəkkəb qrammatikası və çevik söz sırası ilə tanınır. Ümumiyyətlə subyekt-fel-obyekt (SVO) söz sırasına əməl edən ingilis dilindən fərqli olaraq, alman dili hal sistemi və çevik cümlə quruluşu sayəsində söz sırasında daha çox dəyişikliyə imkan verir. Məsələn, ingilis dili adətən sözlər arasındakı əlaqələri (məsələn, "evdə") göstərmək üçün ön sözlərdən istifadə etdiyi halda, alman dili qrammatik əlaqələri çatdırmaq üçün dörd haldan (nominativ, ittihamedic, dativ və cinsiyyət) bir hal sistemindən istifadə edir. Bu, "Ich gebe dem Hund den Ball" (topu itə verirəm) kimi cümlələrlə nəticələnir, burada söz sırası isimlərdəki hal işarələrinə görə mənasını dəyişmədən dəyişə bilər.[5]

Alman fonologiyası digər dillərdən fərqli səslər və fonetik nümunələri ilə fərqlənir. Diqqəti çəkən xüsusiyyətlərdən biri saitlərin tələffüzünü dəyişdirən "umlautların" (ä, ö, ü) olmasıdır. Bundan əlavə, alman dilində /p/, /t/, /k/ kimi səssiz dayanmalar və /v/, /z/ və /ʃ/ kimi səsləli frikativlər də daxil olmaqla, samit səslərin nisbətən böyük inventarına malikdir. Bu fonetik fərqlər alman dilinin unikal səslənməsinə kömək edir və onun fonoloji sistemi ilə tanış olmayan öyrənənlər üçün problemlər yarada bilər. Alman lüğəti müxtəlif mənbələrdən, o cümlədən yerli german köklərindən, Latın dilindən alınmalardan və digər dillərdən alınma sözlərdən ibarətdir. Alman dili mürəkkəb sözlərə meyli ilə tanınır, burada çoxlu sözlər birləşərək tək, çox vaxt uzun söz əmələ gətirir. Məsələn, "Donaudampfschiffahrtsgesellschaftskapitän" (Dunay buxar gəmisi şirkətinin kapitanı) alman dilində mürəkkəb sözün məşhur nümunəsidir. Digər dillər də birləşmələrdən istifadə etsə də, alman dili bu baxımdan xüsusilə məhsuldar və bir çox unikal və təsviri terminlərin yaranmasına səbəb olur. [[2]

Dil mədəniyyətlə dərinə bağlıdır və mədəni normalar, dəyərlər və sosial strukturlardakı fərqlər dil ifadəsinə təsir göstərə bilər. Alman mədəniyyəti dilin qrammatikasında, söz ehtiyatında və ünsiyyət tərzində əks olunan dəqiqliyə, nizama və səmərəliliyə, əlamətlərə güclü diqqət yetirir. Bundan əlavə, alman dili müxtəlif səviyyələrdə formallıq və nəzakət nümayiş etdirir, müxtəlif vəzifələr və fel formaları sosial statusuna və danışanla münasibətinə görə fərdlərə müraciət etmək üçün istifadə olunur. Dilin tarixi və coğrafi konteksti də onun inkişafını və xüsusiyyətlərini formalaşdırır. Alman dili german dillərinin ortaq əcdadı olan proto-german dilindən təkamül yolu ilə inkişaf etmiş və qonşu dillərin və tarixi hadisələrin təsiri nəticəsində zamanla əhəmiyyətli dəyişikliklərə məruz qalmışdır. Məsələn, alman dilində dialektlərin və regional variasiyaların olması tarixi köçlər, siyasi bölünmələr və almandilli dünya daxilində mədəni qarşılıqlı əlaqələrlə əlaqələndirilə bilər. Alman dili digər dillərlə bir çox dil xüsusiyyətlərini bölüşsə də, onu fərqləndirən fərqli xüsusiyyətlərə malikdir. Mürəkkəb qrammatikası və çevik söz sırasından tutmuş unikal fonologiyasına və geniş lüğət ehtiyatına qədər Alman dili kəşfiyyat üçün zəngin və müxtəlif linqvistik mənzərə təqdim edir. Alman dili ilə digər dillər arasındakı fərqləri dərk etməklə biz dil müxtəlifliyini formalaşdırıran və insan ünsiyyətinin zənginliyinə töhfə verən mədəni, tarixi və sosial-linqvistik amillər haqqında fikir əldə edirik [7].

Zəngin tarixi və mürəkkəb qrammatikası ilə alman dili həm german dilləri ailəsində, həm də ondan kənarda olan digər dillərlə çoxsaylı oxşarlıqları bölüşür. Alman dili german dil ailəsinə aiddir, digərləri arasında ingilis, holland, İsveç və Danimarka dillərini də əhatə edir. Bu dillər ortaq əcdadı olan proto-german dilini bölüşür və lüğət, qrammatika və fonologiya baxımından bir çox oxşarlıqlar nümayiş etdirir. Məsələn, "Haus" (Alman), "ev" (İngilis), "huis" (Holland) və "hus" (İsveç) soydaşları "ev" mənasını verir və bu dillərin ortaq linqvistik irsini nümayiş etdirir.

Tarix boyu alman dili də fransızlardan, xüsusən də Orta əsrlər və İntibah dövründə borclar və sitəsilə təsirlənmişdir. Alman dilində fransız dilinə tərcümə olunan sözlər çox vaxt mədəniyyət, mətbəx, moda və hökumətə aiddir. Məsələn, "Restoran" (restoran), "Büro" (ofis) və "Parfüm" (ətir) fransız dilindən götürülmüşdür və alman dilli ölkələrdə geniş istifadə olunur.[2]

Müasir globallaşan dünyada alman dilində danışanların çoxu çoxdillidir və ingilis, fransız və ya ispan dilləri kimi digər dilləri mükəmməl bilir. Bu çoxdillilik mədəniyyətlərarası ünsiyyəti və mübadiləni təşviq edir, alman və digər dillər arasında daha çox linqvistik borclanma və təsirə səbəb olur. Bundan əlavə, almandilli ölkələrdə dil öyrənmə və ikidilli təhsilin yayılması dil müxtəlifliyini və mədəniyyətlərarası anlaşmanı təşviq edir.

Alman dili həm german dilləri ailəsində, həm də ondan kənarda digər dillərlə çoxlu oxşarlıqları bölüşür. Ortaq lüğət, qrammatik strukturlar və tarixi təsirlər vasitəsilə alman dili linqvistik təkamülün mürəkkəb və bir-biri ilə əlaqəli təbiətini əks etdirən müxtəlif dillər toplusuna bağlanır. Bu linqvistik əlaqələri tədqiq etməklə biz almandilli dünyanın zəngin irsi və mədəni müxtəlifliyi, eləcə də Avropa və onun hüduqlarından kənarda daha geniş linqvistik mənzərə haqqında fikir əldə edirik [3].

Nəticə

Müasir dilçilik sahəsində alman dilində söz əmələ gəlməsinin tədqiqi dillərin inkişaf etdiyi və danışanların kommunikativ ehtiyaclarını ödəmək üçün uyğunlaşdığı mürəkkəb proseslər haqqında heyranedicə fikir təklif edir. Alman dilində söz yaratmağın müxtəlif üsullarını, o cümlədən mürəkkəbləşdirmə, törəmə, borc alma, qarışdırma və geri formalaşdırmanı araşdırmaqla biz bu zəngin və canlı dilə xas olan linqvistik yaradıcılıq və mürəkkəbliyi daha dərinlən dərk edirik.

Alman dilində söz əmələ gəlməsinin ən təəccüblü xüsusiyyətlərindən biri, yeni birləşmələr yaratmaq üçün çoxlu sözlərin birləşdirildiyi birləşmənin yayılmasıdır. Bu proses yüksək təsviri və dəqiq terminlər yaratmağa imkan verir ki, bu da natiqlərə mürəkkəb anlayışları diqqətəlayiq səmərəliliklə çatdırmağa imkan verir. "Schadenfreude" (zərər sevinci) və "Fernweh" (məsafə ağrısı) kimi birləşmələr alman söz yaradıcılığının ixtiraçılıq və ifadəliliyini nümayiş etdirir.

Alman dilində söz yaratmağın başqa bir görkəmli üsulu olan törəmə, mənalarını dəyişdirmək və ya yeni sözlər yaratmaq üçün mövcud sözlərə prefikslər və ya şəkilçilər əlavə etməyi nəzərdə tutur. Bu proses alman lüğətinin genişlənməsinə və zənginləşməsinə imkan verir, natiqlərə dili müxtəlif kontekstlərə uyğunlaşdırmağa və geniş anlayışları ifadə etməyə imkan verir. "unglücklich" (bədbəxt) və "Gesundheit" (sağlamlıq) kimi törəmələr almanca söz əmələ gəlməsinin çox yönlüliyünü və uyğunlaşma qabiliyyətini nümayiş etdirir.

Başqa dildən götürmə, qarışdırma və geri formalaşdırma alman dilinin linqvistik müxtəlifliyinə və zənginliyinə daha çox kömək edir. "Kompüter" (kompüter) və "Restoran" (restoran) kimi digər dillərdən götürülmüş sözlər mədəni mübadilə və qloballaşmanı əks etdirir, "Handy" (mobil telefon) kimi qarışıqlar isə cəmiyyətdə yaranan anlayışları və tendensiyaları əks etdirir. Backformasiya daha az yayılmış olsa da, mövcud sözlərin sadələşdirilməsi və ya yenidən qurulması yolu ilə yeni sözlərin yaradılmasına imkan verir, alman leksikonunun dinamizmini artırır.

Alman dilində söz əmələ gəlməsinin öyrənilməsi linqvistik quruluş, yaradıcılıq və mədəni kontekst arasında mürəkkəb qarşılıqlı əlaqəni vurğulayır. Alman dilində sözlərin yaradılmasının müxtəlif üsullarını tədqiq etməklə biz dilin təkamülü və uyğunlaşmasının əsas mexanizmləri haqqında fikir əldə edirik. Mürəkkəbləşdirmə və törəmədən tutmuş borc alma və qarışdırmağa qədər hər bir üsul dil istifadəçilərinin effektiv və ifadəli ünsiyyət axtarışında ixtiraçılıq və bacarıqlarını əks etdirir. Alman dili dəyişən sosial, mədəni və texnoloji dinamika cavab olaraq təkamül etməyə davam etdikcə, söz yaradıcılığının tədqiqi dilçilik sahəsində maraqlı və səmərəli araşdırma sahəsi olaraq qalır.

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ORCHESTRATING HUMAN, ARTIFICIAL, AND COLLECTIVE INTELLIGENCE IN THE B1 EFL CLASSROOM

Ayauly Nussipakyn

2nd year Master's degree student

Abai Kazakh National Pedagogical University

Abstract

Recent advances in artificial intelligence (AI) have brought powerful language technologies directly into the hands of secondary school learners, yet pedagogical frameworks for integrating these tools into English as a Foreign Language (EFL) instruction remain underdeveloped. This article presents an empirical study of a structured AI-EFL Integration Framework (AIEF) designed to orchestrate human, artificial, and collective intelligence in the B1 EFL classroom. The study employed a quasi-experimental pre-test–post-test design with 40 upper-secondary learners divided into an experimental group receiving AI-enhanced instruction and a control group receiving conventional teaching. Both groups followed the same curriculum topics over eight weeks. The AIEF model mapped four AI tools—ChatGPT, Grammarly, ELSA Speak, and Quizlet AI—onto CEFR B1 descriptors and task-based lesson stages, explicitly defining their roles in input, interaction, and output phases while maintaining the teacher as the primary pedagogical decision-maker. Results showed that the experimental group achieved substantially larger gains in writing and speaking, with medium improvements in reading and listening compared to the control group. Learners reported increased motivation and heightened awareness of their errors, but also expressed concerns about potential over-reliance on AI and data privacy. These findings suggest that AI can meaningfully augment human intelligence in the classroom when embedded within a coherent pedagogical framework that also develops learners' critical and collaborative abilities. The article argues that the future of intelligence in language education should be conceptualised as an ecology of human, artificial, and collective processes, rather than as a competition between human and machine.

Keywords: English as a Foreign Language; B1 level; AI integration; human–AI collaboration; collective intelligence; task-based learning; feedback; secondary education

Introduction

The growing availability of artificial intelligence (AI) tools for language learning has created both new opportunities and new risks for secondary English as a Foreign Language (EFL) classrooms. Learners now have access to conversational agents, automated writing evaluators, pronunciation trainers, and adaptive vocabulary platforms that can provide immediate, individualised feedback at scale. However, in many school systems, AI is entering classrooms faster than appropriately grounded pedagogical models for integrating it into everyday instruction. Teachers face difficult questions about which tools to use, how to position them in relation to existing methods, and how to preserve learners' autonomy and critical thinking.

At the B1 level, these questions are especially urgent. Upper-secondary learners at B1 can already communicate in familiar situations, but they often show persistent grammatical errors, limited lexical range, and uneven spoken fluency. This “intermediate plateau” is difficult to overcome in typical school conditions, where class sizes are large and contact time is limited. AI tools promise a way to intensify feedback and practice without adding teaching hours, yet they can also encourage superficial engagement (for example, accepting corrections without reflection) or replace productive struggle with automatic solutions.

This article addresses these challenges by conceptualising the B1 classroom as an “intelligence ecology” in which human, artificial, and collective intelligence play complementary roles. It reports on a quasi-experimental study that implemented an AI-EFL Integration Framework (AIEF) in one upper-secondary EFL class and compared outcomes with a parallel class receiving conventional instruction. The main research questions were: (1) How does an AI-enhanced intelligence ecology affect B1 learners' development in the four language skills? (2) How do learners perceive AI-assisted learning when it is embedded in structured classroom practice? and (3) What do these findings imply for the future design of intelligence in language education?

Methods**Participants and design**

The study involved 40 upper-secondary EFL learners at B1 level, divided into an experimental group (EG, $n = 20$) and a control group (CG, $n = 20$). Both groups were taught by the same experienced teacher,

followed the same curriculum topics, and had three 45-minute English lessons per week over an eight-week period. A quasi-experimental pre-test–post-test design was chosen due to the use of intact classes rather than random assignment. Pre-test scores on a CEFR-aligned four-skill test confirmed that the groups were statistically equivalent in reading, writing, speaking, and listening at the outset.

AI-EFL Integration Framework (AIEF)

The AIEF model guided the design of the experimental condition. It integrates several strands of theory:

- SLA perspectives on input, interaction, and output, drawing on Krashen, Long, and Swain;
- sociocultural notions of scaffolding and the Zone of Proximal Development;
- the Technological Pedagogical Content Knowledge (TPACK) framework for teacher expertise;
- task-based language teaching (TBLT); and
- CEFR B1 descriptors as the primary learning targets.

In practical terms, AIEF required the teacher to start from specific B1 can-do statements (for example, “Can write personal letters describing experiences and impressions”) and then design tasks in which AI tools support, but do not replace, learners’ own production. ChatGPT was used to generate B1-level texts and to provide limited writing feedback under carefully constrained prompts. Grammarly offered sentence-level suggestions on drafts written independently by learners. ELSA Speak provided phoneme-level feedback on pronunciation practice that preceded communicative speaking activities. Quizlet AI delivered spaced-repetition vocabulary practice linked to weekly topics. The teacher mediated all tool use, including prompt design, sequencing, and classroom discussion of AI outputs.

Instruments and data collection

Language outcomes were measured with a four-skill test aligned to CEFR B1 descriptors. Each skill (reading, listening, writing, speaking) was scored out of 50 points, giving a total possible score of 200. Reading and listening were assessed through multiple-choice and short-answer items, while writing and speaking were rated analytically across four criteria: task achievement, coherence and cohesion, lexical resource, and grammatical range and accuracy.

Learner perceptions were investigated using a Technology Acceptance Model (TAM)-based questionnaire administered to the experimental group at the end of the programme. The instrument included Likert-scale items on perceived usefulness, ease of use, motivation, and perceived learning effectiveness, as well as items on concerns such as over-reliance and privacy.

Classroom processes were captured through a structured observation checklist completed by the researcher during regular visits and a weekly teacher reflection diary. These qualitative sources documented how AI tools were actually used in lessons, how learners reacted, and how human, artificial, and collective intelligence interacted in practice.

Procedure

Both groups took the pre-test in Week 1 under identical conditions. In Weeks 2–7, the experimental group followed AI-integrated lessons in which the four tools were embedded at different stages of the task cycle, while the control group completed analogous activities using only teacher input, coursebook materials, and peer interaction. In Week 8, both groups took the post-test, and the experimental group completed the attitude questionnaire. Observation and diary data were collected throughout the intervention. Quantitative data were analysed with descriptive statistics and effect sizes (Cohen’s *d*), while qualitative data were subjected to thematic analysis to identify recurring patterns related to engagement, scaffolding, and learner agency.

Results

Language outcomes

Pre-test results showed no statistically significant differences between the experimental and control groups in any skill, with mean scores in the mid-30s out of 50 in each area. After eight weeks, both groups improved, but the experimental group improved substantially more.

In writing, the experimental group’s mean score rose from 33.5 to 41.5, while the control group increased from 34.0 to 35.8. The difference in post-test means corresponded to a large effect size ($d \approx 0.9$). Speaking displayed a similar pattern: the experimental group improved from 32.8 to 40.2, and the control group from 33.2 to 35.1, again with a large effect size ($d \approx 0.8$). Gains in reading and listening were smaller but still meaningful. Reading scores increased from 35.6 to 39.8 in the experimental group and from 35.1 to 36.7 in the control group, while listening scores rose from 34.2 to 38.6 and from 33.8 to 35.4 respectively, with medium effect sizes in both skills.

These results indicate that AI-enhanced instruction, as structured by the AIEF framework, accelerated learners' progress across all four skills, with the strongest impact in productive areas directly supported by AI feedback tools.

Learner attitudes

The attitude questionnaire revealed generally positive perceptions of AI-assisted learning in the experimental group. Most students agreed or strongly agreed that AI tools helped them improve their English, made lessons more interesting, and increased their motivation to practise outside class. Many reported that AI feedback helped them notice and understand their recurrent errors more clearly than before.

At the same time, a substantial minority expressed concerns. Around half of respondents indicated that they sometimes worried about relying too much on AI and losing their own problem-solving abilities. A smaller but notable proportion mentioned anxiety about how their data might be stored or used by AI platforms, and frustration when connectivity problems limited access. These responses suggest that learners are already engaging in critical reflection about AI, not only consuming its benefits.

Classroom processes

Observation and diary data showed that AI tools influenced classroom dynamics in several ways. During writing lessons, students initially tended to accept most Grammarly suggestions automatically, but under the teacher's requirement to note and justify each accepted change, they gradually became more selective and reflective. In speaking lessons, ELSA Speak provided an effective warm-up that allowed learners to practise difficult sounds privately before pair work, reducing visible embarrassment and increasing willingness to participate. Quizlet AI homework logs indicated steady vocabulary practice across the eight weeks, and students often referred to newly learned words spontaneously in subsequent tasks.

Collective intelligence emerged when learners and teacher jointly evaluated AI-generated texts or responses, discussing appropriateness of register, clarity, and cultural references. In these episodes, AI outputs served as shared artefacts that supported deeper conversation about language use rather than as unquestioned authorities.

Discussion

The findings support the view that AI can play a productive role in the B1 EFL classroom when embedded in a carefully designed intelligence ecology. The experimental group's larger gains in writing and speaking suggest that AI tools are particularly effective in domains where frequent, individualised feedback is difficult to provide through human teaching alone. Automated suggestions from Grammarly and ELSA Speak addressed fossilised patterns in grammar and pronunciation that had previously gone uncorrected, while ChatGPT's model texts and explanations offered additional input tailored to learners' current topics.

However, these benefits depended heavily on the teacher's mediation. Without tasks that require learners to draft independently, explain their choices, and critically compare AI proposals with communicative goals, feedback tools risk reducing effortful learning to superficial correction. The AIEF framework mitigated this risk by making independent production and metacognitive reflection explicit phases in each lesson.

The medium gains in reading and listening point to both potential and limits. While AI-generated texts and adaptive vocabulary support certainly contributed to improved reading, the absence of a dedicated listening tool in the intervention may explain the smaller effect size in that skill. This suggests that future research should explore AI systems designed specifically for interactive listening practice, such as adaptive audio platforms that combine automatic speech recognition with comprehension tasks.

Learner attitudes highlight the importance of AI literacy as a component of collective intelligence. Students' concerns about over-reliance and privacy indicate that they are not passive adopters of AI, but active agents negotiating its role in their learning. Integrating explicit discussion of ethical, cognitive, and practical issues into the curriculum can help transform these individual reflections into shared classroom norms, strengthening the collective's capacity to use AI responsibly.

Taken together, the results support a shift in how educators think about the "future of intelligence" in the language classroom: from a narrative of replacement (AI versus teacher) to one of orchestration (teacher plus AI plus learners as a collaborative system).

Conclusion

This study has shown that a structured AI-EFL Integration Framework can enhance B1 learners' progress across all four language skills, with particularly strong effects in writing and speaking, when human, artificial, and collective intelligence are deliberately combined. The experimental group, which

engaged with ChatGPT, Grammarly, ELSA Speak, and Quizlet AI under teacher guidance, outperformed a control group receiving traditional instruction on matched content, and reported high levels of motivation and perceived usefulness.

At the same time, learners' expressed concerns about dependence and data privacy, along with uneven gains across skills, demonstrate that AI integration is not a simple technical upgrade. It requires ongoing pedagogical design, critical reflection, and institutional support. Future research should replicate and extend this work in diverse contexts, explore additional tools for receptive skills, and examine long-term effects on learner autonomy and teacher roles.

The broader implication for the future of intelligence in education is that meaningful progress lies not in choosing between human and artificial intelligence, but in cultivating learning environments where both, together with the emergent intelligence of the learning community, can contribute their distinctive strengths.

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Technical sciences

THE IMPORTANCE AND CAPABILITIES OF THE GOOGLE SCHOLAR SERVICE IN SEARCHING AND EVALUATING SCIENTIFIC INFORMATION FOR STUDENTS OF UNIVERSITIES

Algozhaeva Raikhan

Senior-lecturer at ATU University

Turgynbaeva Aliza

Senior-lecturer at ATU University

Adilbekova Aizhan

Senior-lecturer at ATU University

Kerimbaeva Venera

Senior-lecturer at ATU University

ЗНАЧЕНИЕ И ВОЗМОЖНОСТИ СЕРВИСА GOOGLE SCHOLAR В ПОИСКЕ И ОЦЕНКЕ НАУЧНОЙ ИНФОРМАЦИИ ДЛЯ ОБУЧАЮЩИХСЯ ВУЗОВ

Алгожаева Райхан

Сеньор-лектор, АТУ

Тургынбаева Ализа

Сеньор-лектор, АТУ

Адилбекова Айжан

Сеньор-лектор, АТУ

Керимбаева Венера

Сеньор-лектор, АТУ

Abstract

This article examines the importance and capabilities of the Google Scholar service in searching for and evaluating scientific information for university students. The main functions of the platform are analyzed, including the search for academic publications and the assessment of their scientific significance using citation metrics and other indicators. Special attention is given to the role of the service in developing students' research skills, critical thinking, and digital literacy. The advantages and limitations of Google Scholar are also discussed, along with recommendations for its effective use in the higher education environment. The study concludes that this service is an essential tool for improving the quality of students' academic and research activities.

Аннотация

В данной статье рассматривается значение и возможности сервиса Google Scholar в процессе поиска и оценки научной информации студентами высших учебных заведений. Анализируются основные функции платформы, включая поиск академических публикаций, оценку их научной значимости с помощью цитируемости и других метрик. Особое внимание уделяется роли сервиса в развитии исследовательских навыков, критического мышления и цифровой грамотности обучающихся. Также раскрываются преимущества и ограничения Google Scholar, а также приводятся рекомендации по его эффективному использованию в образовательной среде. Сделан вывод о том, что данный сервис является важным инструментом для повышения качества учебной и научной деятельности студентов.

Keywords: *Google Scholar, scientific information, information search, university students, digital resources, academic publications, citation metrics, research, digital literacy, educational environment, critical thinking*

Ключевые слова: *Google Scholar, научная информация, поиск информации, студенты вузов, цифровые ресурсы, академические публикации, цитируемость, научные исследования, цифровая грамотность, образовательная среда, критическое мышление*

Актуальность использования цифровых ресурсов в высшем образовании постоянно растёт, и одной из ключевых задач современного студента становится эффективный поиск качественной научной информации. Google Scholar представляет собой один из самых доступных и

удобных инструментов, позволяющих обучающимся вузов быстро находить академические публикации, анализировать их значимость и формировать теоретическую базу для учебных и научных работ. Простота использования, широкий охват научных источников и наличие аналитических инструментов делают сервис важным элементом образовательной среды.

Отмечается, что сервис значительно расширяет информационные ресурсы, доступные студентам, облегчает подготовку дипломных и научно-исследовательских проектов. В статье также обозначены ограничения платформы и представлены рекомендации по ее эффективному применению в образовательной среде высшей школы. Полученные результаты подтверждают, что Google Scholar является важным цифровым инструментом, поддерживающим повышение уровня самостоятельной и научной деятельности обучающихся вузов.

В условиях цифровизации высшего образования доступ к качественной научной информации становится критически важным компонентом учебной и исследовательской деятельности студентов. Вузы активно внедряют электронные образовательные ресурсы, цифровые библиотеки и поисковые системы, которые позволяют будущим специалистам эффективно ориентироваться в огромных массивах научных данных. Среди этих инструментов особое место занимает сервис Google Scholar — универсальная поисково-аналитическая платформа, предоставляющая доступ к широкому спектру академических материалов: журналам, книгам, диссертациям, препринтам, конференционным публикациям и патентам.

Главным преимуществом Google Scholar является его доступность: сервис открыт для всех пользователей и не требует обязательной подписки, что делает его незаменимым в образовательной среде, особенно для студентов, не имеющих постоянного доступа к платным научным базам данных. Благодаря этому Google Scholar существенно расширяет горизонты самостоятельной исследовательской работы. Студенты могут находить актуальные научные публикации, изучать новейшие исследования, отслеживать развитие научных направлений и формировать собственные научные интересы.

Кроме того, Google Scholar обеспечивает высокий уровень интеграции с другими инструментами научной коммуникации, такими как Google Books, Google Patents, ResearchGate, Scopus и другие ресурсы. Это позволяет студентам не только выполнять поиск, но и анализировать междисциплинарные связи, сравнивать публикации, изучать теоретические подходы и использовать найденные данные в учебных проектах, рефератах и исследованиях.

Google Scholar предлагает многоуровневый механизм поиска, который включает простую строку поиска и расширенные параметры. Благодаря этому студент может находить информацию по ключевым словам, комбинациям терминов, именам авторов, названиям журналов и годам публикаций. Такой подход существенно упрощает отбор релевантных источников и способствует формированию навыков аналитического поиска.

Одной из наиболее полезных функций Google Scholar является система метрик: количество цитирований публикации, индекс Хирша автора, рейтинг журнала. Эти показатели позволяют студентам оценивать научную значимость материала и избегать использования нерелевантных или недостоверных источников. В процессе подготовки курсовых и дипломных работ такая оценка является обязательной частью академических стандартов.

Google Scholar представляет собой специализированную поисковую систему, ориентированную на научные публикации. Платформа охватывает различные виды источников: научные статьи, диссертации, книги, материалы конференций, патенты и отчёты. Основным преимуществом сервиса является его доступность и простота использования, что делает его востребованным среди студентов и преподавателей.

Сервис интегрируется с другими научными базами и платформами, что позволяет пользователям получать более широкий доступ к информации и отслеживать взаимосвязи между исследованиями.

Google Scholar предоставляет возможность изучать авторские профили, что позволяет студентам видеть вклад конкретного учёного в развитие научного направления. Инструмент раскрывает:

- основные публикации автора;
- динамику цитируемости;
- соавторов;
- тематические области исследований.

Это помогает формировать целостное понимание научной школы, ее направления и актуальных проблем.

1. Подготовка учебных и научных работ

Студенты активно используют Google Scholar при создании:

- рефератов,
- курсовых работ,
- проектов,
- научных статей,
- выпускных квалификационных работ.

Сервис помогает формировать теоретическую базу, подбирать актуальные исследования и использовать их в анализе.

2. Развитие навыков критического мышления

Работа с публикациями, цитированием и метриками помогает студентам:

- отличать качественные исследования от вторичных источников;
- анализировать научную достоверность информации;
- развивать умение критически подходить к литературе;
- оценивать научные аргументы.

3. Участие в научно-исследовательской деятельности

Google Scholar способствует формированию у студентов исследовательской культуры:

- выявление научных пробелов;
- выбор темы исследования;
- определение актуальности работы;
- поиск методов исследования;
- отслеживание современных научных дискуссий.

4. Поддержка самостоятельной работы и цифровой грамотности

Использование сервиса формирует:

- навыки библиографической грамотности;
- умение работать с цифровыми базами данных;
- способность анализировать большие объёмы информации;
- самостоятельность в обучении.

5. Использование в профессиональной подготовке

Во многих специальностях Google Scholar является необходимым инструментом:

- медицинские направления используют публикации о клинических исследованиях;
- педагоги анализируют современные методики обучения;
- экономисты изучают аналитические отчёты и исследования;
- инженеры — инновационные разработки и проекты.

6. Практическое применение в образовательном процессе

Google Scholar широко используется студентами при подготовке:

- рефератов;
- курсовых работ;
- дипломных проектов;
- научных статей.

Сервис помогает формировать теоретическую базу исследования, подбирать актуальные источники и проводить анализ научной литературы.

Таким образом, Google Scholar является важным инструментом в образовательной и научной деятельности студентов вузов. Он обеспечивает эффективный поиск и оценку научной информации, способствует развитию исследовательских навыков и повышению качества учебных работ. В условиях цифровизации образования данный сервис занимает значимое место в формировании современной академической среды.

Заключение. Google Scholar играет значимую роль в обучении студентов вузов, предоставляя им эффективные средства поиска, анализа и оценки научной информации. Благодаря широкому охвату научных публикаций, удобным инструментам навигации и метрикам цитируемости сервис способствует развитию академической грамотности и исследовательской культуры. В условиях цифровизации высшего образования Google Scholar становится важным элементом научной инфраструктуры, помогающим студентам формировать критическое мышление и повышать качество учебных и научных работ.

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CYBERSECURITY RISKS IN 5G TECHNOLOGY

Kanan Mammadhasanov

Azerbaijan State Oil and Industry University,
Department of Instrumentation Engineering, Master

Faxraddin Agayev

Azerbaijan State Oil and Industry University,
Department of Instrumentation Engineering, Prof.**Abstract**

The rapid deployment of fifth-generation (5G) mobile communication systems has led to significant advancements in terms of speed, latency, connectivity capabilities, and support for large-scale Internet of Things (IoT) ecosystems. However, this development has also expanded the attack surface of telecommunications networks. The aim of this study is to analyze the impact of 5G architecture on cybersecurity risks and to evaluate the main cyber threat vectors associated with next-generation networks.

The methodology is based on qualitative analysis of scientific literature, comparative analysis of security frameworks, and examination of key components of 5G network architecture, including Software-Defined Networking (SDN), Network Function Virtualization (NFV), and edge computing environments. The study investigates how the increased virtualization level, cloud integration, and distributed structure of 5G lead to new vulnerabilities. These vulnerabilities include Distributed Denial of Service (DDoS) attacks, signaling attacks, data interception, malware propagation, and unauthorized access to network slices.

Special attention is given to security challenges related to network slicing, IoT integration, and edge computing. These areas require the implementation of advanced authentication mechanisms, strong encryption techniques, and continuous monitoring systems.

The obtained results show that although 5G has more advanced security capabilities compared to previous generations, its complex and open ecosystem necessitates multi-layered protection strategies. These strategies include artificial intelligence-based intrusion detection systems, zero-trust architecture, strong encryption protocols, and proactive threat intelligence sharing.

Effective cybersecurity in 5G networks depends on the coordinated implementation of technical, organizational, and regulatory measures to ensure the confidentiality, integrity, and availability of data. Strengthening security management and applying adaptive defense mechanisms are essential to mitigate emerging threats and maintain trust in 5G services.

Xülasə

Beşinci nəsil (5G) mobil rabitə sistemlərinin sürətli tətbiqi sürət, gecikmə müddəti, bağlantı imkanları və geniş miqyaslı "Əşyaların İnterneti" ekosistemlərinin dəstəklənməsi baxımından mühüm inkişaflara səbəb olmuşdur. Bununla yanaşı, bu inkişaf telekommunikasiya şəbəkələrinin hücum səthini də genişləndirmişdir. Bu işin məqsədi 5G arxitekturasının kibertəhlükəsizlik risklərinə təsirini təhlil etmək və yeni nəsil şəbəkələrlə əlaqəli əsas kibercumə vektorlarını qiymətləndirməkdir.

İstifadə olunan metodologiya elmi ədəbiyyatın keyfiyyət analizinə, təhlükəsizlik çərçivələrinin müqayisəli təhlilinə və 5G şəbəkə arxitekturasının əsas komponentlərinin, o cümlədən proqram təminatı ilə idarə olunan şəbəkələr (SDN), şəbəkə funksiyalarının virtualizasiyası (NFV) və kənar hesablama mühitlərinin (edge computing) araşdırılmasına əsaslanır. Araşdırmada 5G-nin artan virtualizasiya səviyyəsi, bulud inteqrasiyası və paylanmış strukturunun necə yeni zəifliklərə səbəb olduğu tədqiq edilir. Bu zəifliklərə paylanmış xidmətin inkarı (DDoS) hücumları, siqnalizasiya hücumları, məlumatların ələ keçirilməsi, zərərli proqramların yayılması və şəbəkə dilimlərinə icazəsiz giriş kimi hallar daxildir.

Xüsusi diqqət şəbəkə dilimlənməsi, IoT inteqrasiyası və kənar hesablama ilə bağlı təhlükəsizlik problemlərinə yönəldilmişdir. Bu sahələr inkişaf etmiş autentifikasiya, güclü şifrələmə və davamlı monitoring mexanizmlərinin tətbiqini tələb edir.

Əldə olunan nəticələr göstərir ki, 5G əvvəlki nəsil şəbəkələrlə müqayisədə daha inkişaf etmiş təhlükəsizlik imkanlarına malik olsa da, onun mürəkkəb və açıq ekosistemi çoxsəviyyəli qoruma strategiyalarını zəruri edir. Bu strategiyalara süni intellektə əsaslanan müdaxilə aşkarlama sistemləri, "zero-trust" arxitekturası, güclü şifrələmə protokolları və qabaqlayıcı təhlükə məlumatlarının paylaşılması daxildir.

5G şəbəkələrində effektiv kibertəhlükəsizlik məlumatların məxfiliyini, bütövlüyünü və əlçatanlığını təmin etmək üçün texniki, təşkilati və tənzimləyici tədbirlərin koordinasiyalı şəkildə həyata

keçirilməsindən asılıdır. Təhlükəsizlik idarəetməsinin gücləndirilməsi və adaptiv müdafiə mexanizmlərinin tətbiqi yaranan yeni təhlükələrin qarşısını almaq və 5G xidmətlərinə olan etibarı qorumaq üçün vacibdir.

Аннотация

Быстрое внедрение мобильных коммуникационных систем пятого поколения (5G) привело к значительным достижениям в области скорости передачи данных, задержки, возможностей подключения и поддержки крупномасштабных экосистем Интернета вещей (IoT). Однако это развитие также расширило поверхность атак телекоммуникационных сетей. Цель данного исследования заключается в анализе влияния архитектуры 5G на риски кибербезопасности и оценке основных векторов киберугроз, связанных с сетями нового поколения.

Методология основана на качественном анализе научной литературы, сравнительном анализе структур безопасности и изучении ключевых компонентов архитектуры сети 5G, включая программно-определяемые сети (SDN), виртуализацию сетевых функций (NFV) и периферийные вычисления (edge computing). В исследовании рассматривается, как повышенный уровень виртуализации, интеграция облачных технологий и распределённая структура 5G приводят к появлению новых уязвимостей. К таким уязвимостям относятся атаки типа «отказ в обслуживании» (DDoS), атаки на сигнальные протоколы, перехват данных, распространение вредоносного программного обеспечения и несанкционированный доступ к сетевым срезам.

Особое внимание уделяется вопросам безопасности, связанным с сетевым слайсингом, интеграцией IoT и периферийными вычислениями. Эти области требуют внедрения расширенных механизмов аутентификации, надежных методов шифрования и систем непрерывного мониторинга.

Полученные результаты показывают, что хотя 5G обладает более развитыми возможностями безопасности по сравнению с предыдущими поколениями, его сложная и открытая экосистема требует многоуровневых стратегий защиты. Эти стратегии включают системы обнаружения вторжений на основе искусственного интеллекта, архитектуру нулевого доверия (zero-trust), надежные протоколы шифрования и проактивный обмен информацией об угрозах.

Эффективная кибербезопасность в сетях 5G зависит от согласованной реализации технических, организационных и нормативных мер для обеспечения конфиденциальности, целостности и доступности данных. Усиление управления безопасностью и применение адаптивных механизмов защиты являются ключевыми для противодействия возникающим угрозам и поддержания доверия к услугам 5G.

Keywords: 5G technology, cybersecurity, cyber threats, network security, network slicing, defense mechanisms

Açar sözlər: 5G texnologiyası, kibertəhlükəsizlik, kibercumələr, şəbəkə təhlükəsizliyi, şəbəkə dilimlənməsi, müdafiə mexanizmləri

Ключевые слова: технология 5G, кибербезопасность, киберугрозы, безопасность сетей, сетевой слайсинг, механизмы защиты

Introduction

In recent years, the deployment of 5G technology has led to significant transformations in the telecommunications sector. High data transmission speeds, ultra-low latency, and the ability to connect millions of devices simultaneously are among the key features that distinguish 5G from previous generations of networks. At the same time, alongside these technological advancements, the increasing complexity of 5G systems and their virtualization-based architecture have introduced new security challenges. Features such as software-defined networking, cloud integration, and network slicing create additional vulnerabilities that can be exploited by cybercriminals. Therefore, the implementation of 5G technology represents not only a technological innovation but also a field that requires comprehensive security analysis.

In the modern digital environment, the number and complexity of cyberattacks continue to grow. Traditional security mechanisms used in earlier-generation networks may not be sufficiently effective within 5G infrastructure. Ensuring data confidentiality, service availability, and network integrity has become a primary priority. In particular, network slicing, edge computing, and IoT integration expand the attack surface and require more advanced and adaptive security strategies.

The main objective of this study is to analyze cybersecurity risks associated with 5G technology and to examine the defense mechanisms used to mitigate these risks. It identifies potential vulnerabilities within the 5G architecture, evaluates possible attack scenarios, and explores modern protection approaches such as artificial intelligence-based intrusion detection systems, advanced encryption methods, and zero-trust security models. It is also emphasized that 5G security should be ensured not only through technical solutions but also through organizational and regulatory measures.

Based on existing scientific sources, this study systematically presents cybersecurity issues in 5G networks and aims to contribute to the development of future security strategies. The findings indicate that the secure and successful implementation of 5G technology depends on the integration of multi-layered defense mechanisms and proactive security management.

With the deployment of 5G technology, network infrastructures are becoming increasingly software-based and more tightly integrated with cloud environments. While these innovations improve flexibility and operational efficiency, they also increase system complexity. Unlike traditional hardware-based security approaches, security in a 5G environment must be dynamic and adaptive. The virtualization of network functions expands the potential attack surface and makes security monitoring more challenging.

One of the key features of 5G networks is network slicing. This technology allows the creation of separate virtual network segments for different services. Although this approach enables more efficient resource allocation, a security breach in one slice can affect others if proper isolation is not ensured. Additionally, edge computing allows data to be processed closer to users, reducing latency and improving performance. However, this distributed architecture introduces new vulnerabilities and requires stronger monitoring and protection mechanisms.

This study analyzes the main types of cyberattacks targeting 5G networks and their potential impacts. Threats such as Distributed Denial of Service (DDoS) attacks, data breaches, unauthorized access, and identity spoofing are examined. Furthermore, the application of artificial intelligence and machine learning-based security systems is evaluated. These technologies help detect anomalies in real time and enable proactive threat mitigation.

The significance of this study lies in the fact that 5G technology is not limited to the field of communications but is also widely used in critical infrastructure, healthcare systems, industrial automation, and smart city applications. Therefore, security is no longer an additional feature but a fundamental requirement. Ensuring the reliability of 5G networks requires the implementation of comprehensive and multi-layered defense strategies.

This study systematically evaluates existing cybersecurity challenges in the 5G environment and provides recommendations for strengthening network protection, thereby contributing to future research and practical applications.

Security Challenges in 5G Network Architecture

The architecture of 5G networks reflects significant changes compared to previous generations of mobile communication systems. Unlike traditional centralized infrastructures, 5G is based on a highly virtualized, software-defined, and distributed structure. This architecture incorporates modern technologies such as software-defined networking (SDN), network function virtualization (NFV), cloud computing, and edge computing. While these innovations provide advantages in terms of flexibility, scalability, and performance, they also introduce new and more complex security challenges that were not present in earlier generations. The increased reliance on virtualization and cloud services expands the potential attack surface and creates additional entry points for attackers.

One of the primary security challenges in 5G architecture is its high level of complexity. Although the division of network functions into virtual components improves operational efficiency, it requires more sophisticated coordination across different layers. Misconfigurations, software vulnerabilities, and insufficient isolation between virtual environments can lead to unauthorized access or service disruptions. Moreover, the implementation of many network functions through software increases the risk of remote exploitation of code-level vulnerabilities and the likelihood of large-scale attacks.

Another critical issue is related to network slicing. This technology enables the creation of multiple virtual networks on the same physical infrastructure. It allows the delivery of customized services for sectors such as healthcare, autonomous transportation, and industrial automation. However, if proper isolation between slices is not ensured, a security breach in one slice can affect others. In such cases, attackers may propagate within the system, causing damage to other services and disrupting critical processes.

Edge computing is another essential component of 5G networks. This approach enables data to be processed closer to the user, reducing latency and improving real-time performance. However, it also leads to the distribution of computing resources across multiple locations, making each edge node a potential attack target. Ensuring security in such a distributed environment requires continuous monitoring, strong authentication, and robust encryption mechanisms. The lack of centralized resources further complicates security management.

The integration of Internet of Things (IoT) devices within the 5G ecosystem further intensifies security challenges. The connection of a vast number of devices necessitates the use of equipment with varying technical capabilities and security levels. Many IoT devices have limited computational power, making it difficult to implement strong security mechanisms. As a result, these devices can become weak points that attackers exploit to gain access to the network.

In addition, signaling security and authentication mechanisms face new challenges in the 5G environment. Global connectivity and the requirement for interoperability across different systems make identity and access management more complex. Weak authentication or insufficient encryption mechanisms increase the risk of data interception or manipulation. Therefore, ensuring end-to-end security across all network components is considered a fundamental requirement.

The security challenges in 5G network architecture are mainly associated with virtualization, distributed structure, increased connectivity, and reliance on software. While 5G technology offers high-performance capabilities, it also requires the implementation of complex and adaptive security approaches. A proper understanding of these architectural vulnerabilities is essential for developing effective defense mechanisms and ensuring the reliable operation of next-generation communication systems.

Authentication and Signaling Attacks

In 5G network architecture, authentication and signaling mechanisms are more complex and multi-layered compared to previous generations of mobile networks. This complexity is mainly due to the transition to a fully software-defined, virtualized, and distributed structure. As interactions between users, devices, and network functions increase, the management and verification of identities become more critical. This situation, in turn, leads to the emergence of various security risks.

One of the main issues is weak or misconfigured authentication mechanisms. Although complex authentication protocols are used in 5G systems to enable devices and users to connect to the network, implementation flaws may allow attackers to gain access using fake identities. In such cases, spoofing or fake base station attacks may occur, resulting in the interception of user data.

Another serious problem is signaling attacks. In 5G networks, signaling processes are used for establishing communication between devices and the network, allocating resources, and managing services. Attackers can manipulate signaling messages to cause unnecessary consumption of network resources, service delays, or complete service disruption. These types of attacks are particularly dangerous in scenarios such as signaling storms and Denial of Service (DoS) attacks.

In addition, the numerous interfaces and APIs used in 5G introduce new vulnerabilities. Communication between network functions through APIs, if not properly secured, can lead to unauthorized access. Attackers may exploit weak API endpoints to interfere with network functions and partially gain control over the system.

Another important aspect of authentication-related issues arises during roaming. When connections are established between different operators, the compatibility and security of authentication mechanisms play a crucial role. Poorly implemented roaming protocols may allow third parties to intercept user data.

Addressing these security challenges requires a multi-layered and adaptive approach. First, the implementation of strong authentication systems is essential. Multi-Factor Authentication (MFA) and enhanced SIM-based authentication mechanisms are effective in preventing unauthorized access. Furthermore, improved versions of the Authentication and Key Agreement (AKA) protocol used in 5G provide higher levels of security.

Second, encryption and monitoring of signaling traffic are critical. All signaling messages within the network should be encrypted and analyzed in real time. Artificial intelligence-based intrusion detection systems (IDS) can be used to identify abnormal traffic behavior.

Third, API security must be strengthened. All network APIs should be protected with authentication, authorization, and auditing mechanisms, and should respond only to authorized requests. API gateways should be used to centrally manage access.

Fourth, the implementation of a zero-trust architecture is essential. In this model, no user or device, whether inside or outside the network, is automatically trusted. Every access request is continuously verified and validated.

Finally, to enhance roaming security between operators, standardized and encrypted protocols should be used. Mutual security certifications and real-time verification systems should be implemented for international connections.

Cloud Infrastructure and Centralized Risks

The architecture of 5G networks is considered the most advanced form of modern telecommunications systems, and one of its key features is deep integration with cloud technologies. While previous-generation networks primarily relied on centralized physical servers, 5G systems deploy network functions in virtual environments and cloud platforms, managed through software. Although this approach provides high flexibility, rapid scalability, and more efficient resource utilization, it also introduces significant security risks.

One of the main issues is that cloud infrastructure represents a highly concentrated target. Large volumes of user data, network management functions, and services are aggregated within a limited number of cloud centers. This creates an attractive target for attackers, as a single successful breach can result in large-scale data leaks or service disruptions. The risk is further increased in multi-tenant cloud environments, where multiple organizations share the same physical infrastructure.

Another critical concern is vulnerabilities related to virtualization. Technologies such as Network Function Virtualization (NFV) and Software-Defined Networking (SDN) are widely used in 5G networks. While these technologies enhance flexibility by transforming network functions into software-based components, they also introduce potential software-level vulnerabilities. For instance, a security flaw in one virtual machine may impact other virtual services, enabling lateral movement attacks.

API security is also a major issue in cloud environments. 5G network functions communicate with each other through APIs, and if these interfaces are not properly secured, they can lead to unauthorized access, data theft, or service manipulation. Attackers may exploit weak API endpoints to control cloud resources and partially compromise the system.

Data confidentiality and leakage risks are additional major concerns. In cloud systems, data is continuously transmitted and stored across the network. If encryption is not properly implemented or if key management is weak, user data may be intercepted by third parties. This poses a serious threat, particularly for the protection of personal data and critical industrial information.

Service availability is another area at risk. Distributed Denial of Service (DDoS) attacks targeting cloud infrastructure can overload servers, leading to delays or complete outages in 5G services. This is especially critical for real-time applications such as autonomous transportation, healthcare systems, and industrial automation.

To mitigate the security risks associated with cloud infrastructure in 5G networks, a comprehensive and multi-layered defense strategy must be implemented. First, the Zero Trust Security model is one of the most effective approaches. According to this model, no user or device is automatically trusted, regardless of whether it is inside or outside the network. Every access request must undergo continuous authentication and authorization, significantly reducing the risk of unauthorized access in cloud environments.

Second, strong data encryption is essential. All data stored and transmitted within the cloud environment should be encrypted both at rest and in transit. The use of robust encryption standards such as AES-256 minimizes the risk of data leakage. Additionally, cryptographic keys should be managed using dedicated Key Management System (KMS) platforms.

Third, API security requires special attention. APIs, which serve as the primary communication channels for 5G network functions, must be centrally secured. By using API gateways, all incoming and outgoing traffic can be controlled, and only authenticated requests should be allowed. Furthermore, techniques such as rate limiting and behavioral analysis should be applied to detect abnormal activities at an early stage.

Fourth, virtualization security must be strengthened. In NFV and SDN environments, each virtual component should be properly isolated. Security controls must be enforced at the hypervisor level, and communication between virtual machines should be restricted. This plays a crucial role in preventing lateral movement attacks.

Fifth, real-time monitoring and AI-based threat detection are essential. All activities within the cloud infrastructure should be continuously analyzed, and anomalies should be identified using machine

learning algorithms. This approach enables early detection of threats such as DDoS attacks, API abuse, and data breaches.

Sixth, the adoption of multi-cloud and hybrid-cloud strategies helps distribute risks. Instead of concentrating all resources within a single cloud provider, distributing them across multiple providers increases system resilience and reduces the risk of a single point of failure.

The security of 5G cloud infrastructure cannot be ensured solely through technical solutions; it also requires proper management, continuous monitoring, and well-defined security policies. When combined, Zero Trust approaches, strong encryption, API security, and AI-based defense systems significantly enhance the overall security level of 5G networks in cloud environments.

Risk Index Model

• Formula:

$$\text{Risk Score (R)} = P \times I \times V$$

Where:

- *P (Probability)* → likelihood of attack occurrence (0–1)
- *I (Impact)* → impact level (1–10)
- *V (Vulnerability)* → vulnerability level (1–10)

• Example:

- *P = 0.7* (high likelihood of attack)
- *I = 9* (very severe impact)
- *V = 8* (system is highly vulnerable)

• Calculation:

$$R = 0.7 \times 9 \times 8 = 50.4$$

• Interpretation:

- 0–20 → low risk
- 20–50 → medium risk
- 50+ → high risk

→ **Result: HIGH RISK**

Conclusion

The implementation of 5G technology has brought revolutionary changes to modern telecommunications systems. High-speed data transmission, ultra-low latency, and the ability to connect billions of devices simultaneously distinguish 5G from previous-generation technologies. However, alongside these advantages, the increased complexity and virtualization-based nature of the system have also introduced new security risks. In particular, while cloud infrastructure and centralized management models enhance network flexibility, they also expand the attack surface and create new vulnerabilities.

Cloud infrastructure is one of the core components of 5G networks. It provides operators with capabilities such as more efficient resource management, flexible service scalability, and cost reduction. However, the centralized storage and processing of data in cloud-based systems create significant security weaknesses. If a cloud platform is compromised, it may lead not only to the disruption of a single service but also to the failure of the entire network ecosystem. Therefore, cloud security is considered one of the most critical elements of 5G infrastructure.

Centralized risks are of particular importance in 5G networks. Unlike traditional networks, 5G relies heavily on virtual functions and software-based management. This increases the risk of a "single point of failure," where an issue in one central component can affect the entire network. In addition, centralized management systems are attractive targets for cyberattacks, as attackers can achieve large-scale impact by compromising a single point. For this reason, distributed architecture approaches and additional protection mechanisms are essential.

Authentication systems play a key role in ensuring the security of 5G networks. The increasing number of connected devices and the integration of the Internet of Things (IoT) make the authentication process more complex and sensitive. Weak or poorly secured authentication mechanisms can lead to unauthorized access, data theft, and service disruption. In particular, vulnerabilities in SIM-based authentication or key-based systems may be exploited by attackers. Therefore, multi-factor authentication (MFA), encryption technologies, and AI-based anomaly detection systems should be more widely implemented.

At the same time, it should be noted that security in the 5G ecosystem is not only a technical issue but also a matter of governance and policy. Without proper coordination between operators, service

providers, and users, full security cannot be achieved. Improved standards, international cooperation, and continuous monitoring systems contribute to making 5G networks more secure.

The analysis shows that while 5G technology offers significant opportunities, it also introduces serious security challenges. Cloud infrastructure, centralized risks, and authentication issues constitute the main part of these challenges. Effective management of these risks requires the combined application of both technological solutions and strategic approaches. In the future, the role of artificial intelligence, automated security systems, and distributed architectures will further increase in ensuring more resilient and secure 5G networks.

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AUTOMATION OF ACADEMIC TIMETABLING: A COMPARATIVE STUDY AND APPLIED IMPLICATIONS FOR COLLEGES**G.N. Kazbekova¹****A.Zh. Ongar²***Khoja Akhmet Yassawi International Kazakh-Turkish University, Turkestan, Kazakhstan***Abstract**

This article examines the automation of academic timetabling through a comparative scientific analysis. The relevance of the study stems from the fact that manual timetable construction is time-consuming, often leads to conflicts, and complicates the simultaneous coordination of teachers, student groups, classrooms, and other interdependent resources. The aim of the study is to compare the main approaches used in educational timetabling, determine their effectiveness in the college context, and propose the most appropriate organizational and algorithmic model. The research methods include a literature review, comparative analysis, systematization, and applied synthesis. The results show that although manual planning remains manageable, it is inferior to automated solutions in terms of speed and quality, whereas fully automated and hybrid models ensure higher accuracy and greater resilience to change. For colleges, the most effective solution is the combination of a hybrid solver and an interactive decision support system. The scientific novelty lies in adapting the comparative evaluation of classical and modern algorithmic approaches to the specific management needs of colleges. The practical significance of the study is that its conclusions can be used to improve planning quality, optimize resource allocation, and support the stable organization of the educational process.

Keywords: *academic timetable, automation, educational timetabling, comparative analysis, metaheuristics, constraint programming, hybrid model, decision support system, college.*

INTRODUCTION

In contemporary colleges, the construction of academic timetables remains one of the central organizational tasks. A timetable determines the rhythm of the educational process, coordinates teachers' workloads, allocates classroom resources, and structures students' learning time. However, when this process is performed manually, it requires substantial effort, depends heavily on human accuracy, and makes it difficult to take into account a large number of constraints simultaneously. For this reason, in the broader context of educational digitalization, the automation of academic timetabling has become a particularly important problem [1, 2].

The significance of timetable automation is not limited to saving time. Automated systems make it possible to distribute educational resources more rationally, reduce the number of conflicts, improve the convenience of work for teachers and students, and maintain a more stable organization of the educational process. In the literature, educational timetabling is usually treated as a complex combinatorial optimization problem that combines a large number of hard and soft constraints. Hard constraints determine whether a timetable is feasible at all, for example, whether one teacher, one student group, or one classroom is assigned to more than one class at the same time. Soft constraints influence timetable quality, including compact schedules, minimized idle periods, balanced workloads, and the accommodation of institutional preferences [3, 4].

From a theoretical perspective, academic timetabling belongs to a class of NP-hard optimization problems for which the search space grows extremely rapidly with every additional rule, class, or resource. This difficulty is even more pronounced in colleges, where the calendar is often affected by laboratory classes, workshops, practice periods, block teaching, specialized rooms, shift-based study modes, and abrupt administrative changes. Therefore, the central issue is not only how to generate a feasible timetable, but also how to build a model that remains interpretable, correctable, and operationally useful for administrative staff.

Another important theoretical consideration is that many published studies focus primarily on university-scale benchmarks and algorithmic performance, whereas college management requires a more applied perspective. In colleges, timetable planners often work with smaller administrative teams, limited technical support, and a stronger need for transparent intervention in the scheduling process. As a result, the best practical solution is not always the most mathematically sophisticated one, but the one

that achieves an effective balance between optimization quality, explainability, and the capacity for rapid rescheduling [5].

This article provides a comparative analysis of the main scientific approaches to timetable automation and clarifies their applied potential in the college context. The purpose of the study is to systematize the classical and modern methods used in educational timetabling, compare them, and justify the most effective organizational and algorithmic solution for colleges. The object of the study is the process of academic timetable construction, and the subject of the study is the set of algorithmic and system-based approaches used to automate it.

MATERIALS AND METHODS

The present study was conducted using a comparative analytical methodology based on authoritative scholarly publications in the field of educational timetabling. The methodological foundation of the research was formed through a systematic examination of academic works devoted to the theory, modeling, optimization, and practical implementation of timetable construction in educational institutions. The source base included peer-reviewed journal articles, review papers, benchmark-oriented studies, and conference proceedings published on major academic platforms such as Elsevier, Springer, IEEE Access, and the PATAT conference series. These sources were selected because they represent the most influential and methodologically significant body of research on timetabling problems in contemporary educational management. Particular attention was paid to classical surveys and recent state-of-the-art studies that summarize the development of educational timetabling, identify dominant algorithmic trends, and evaluate the strengths and limitations of different solution strategies in real institutional contexts [6, 7].

The choice of a comparative analytical approach was determined by the nature of the research problem. Academic timetabling cannot be reduced to a purely technical procedure of assigning classes to available time slots. It is a multidimensional organizational and computational task that requires simultaneous consideration of pedagogical priorities, institutional regulations, teacher workloads, classroom availability, student group structures, and numerous hard and soft constraints. For this reason, a simple descriptive review of the literature would not have been sufficient. Instead, the study required a structured comparison of existing approaches in order to determine which of them are most effective, flexible, and applicable in the specific context of college administration. The selected methodology made it possible not only to describe the main concepts and models used in the field, but also to assess their practical relevance in terms of feasibility, manageability, adaptability, and decision-support capacity.

The comparative analysis was carried out at two interrelated levels. At the first level, the study examined the main organizational formats of timetable construction. These included manual scheduling, semi-automated planning, fully automated planning, and hybrid planning supported by an interactive decision support system. Manual scheduling was considered as the traditional administrative approach in which timetable construction depends almost entirely on the experience, intuition, and operational judgment of scheduling staff. Semi-automated planning was analyzed as an intermediate format in which software tools are used to process data, verify conflicts, and generate partial scheduling alternatives, while the final structure of the timetable remains under substantial human control. Fully automated planning was examined as a model in which the timetable is generated primarily through algorithmic procedures with minimal direct intervention during the main scheduling phase. Hybrid planning was treated as a more advanced organizational model that combines computational optimization with interactive managerial supervision, thus allowing administrators to review alternatives, adjust priorities, refine constraints, and respond to changes without losing the efficiency advantages of automated methods [8].

At the second level, the research focused on the main algorithmic paradigms used in educational timetabling. These included rule-based approaches, heuristic and metaheuristic methods, genetic algorithms, constraint programming, integer programming, and hybrid algorithmic solutions. Rule-based approaches were included because of their relative simplicity, interpretability, and practical usefulness in cases where institutional scheduling logic can be expressed in the form of explicit administrative rules. Heuristic and metaheuristic methods were considered due to their wide application in large-scale combinatorial optimization problems, particularly when exact optimization becomes computationally expensive or impractical. Genetic algorithms were analyzed as evolutionary search methods capable of exploring multiple solution candidates simultaneously and improving timetable quality through iterative selection, crossover, and mutation. Constraint programming and integer programming were examined as formal optimization frameworks particularly suitable for modeling strict operational requirements and producing highly feasible solutions under complex institutional conditions. Hybrid algorithmic

solutions were studied as integrated models that combine several techniques in order to balance feasibility, solution quality, search efficiency, robustness, and adaptability in real educational environments.

The methodological logic of the study was based on the assumption that timetable quality should not be assessed solely in terms of the existence of a technically feasible solution. A timetable may satisfy all formal hard constraints and still remain inconvenient, unstable, or suboptimal from an institutional point of view. Therefore, the analytical framework of the research distinguished between two interrelated dimensions of quality: operational feasibility and managerial usefulness. Operational feasibility refers to the absence of direct scheduling conflicts, such as assigning the same teacher, student group, or classroom to more than one class in the same time period. Managerial usefulness, by contrast, concerns the extent to which the resulting timetable supports the stable organization of the educational process, reflects administrative priorities, remains understandable to scheduling personnel, and can be modified without excessive disruption when institutional conditions change. This perspective made it possible to evaluate scheduling approaches not merely as abstract computational procedures, but as instruments embedded in the real management practices of colleges [9].

In accordance with this analytical framework, a set of evaluation criteria was defined. These criteria were selected on the basis of their frequent use in the literature and their direct relevance to the needs of college administration. The first and most important criterion was conflict-freeness and accuracy, since any timetable must first ensure the absence of basic contradictions in the allocation of teachers, student groups, and rooms. The second criterion was timetable generation speed, because educational institutions often operate under strict administrative deadlines, especially at the beginning of semesters or when emergency changes must be introduced. The third criterion was flexibility with respect to new constraints, understood as the ability of a scheduling approach to adapt when additional requirements emerge, such as new teacher availability conditions, classroom restrictions, subject-specific demands, or institutional policy changes. The fourth criterion was robustness during rescheduling, which reflects the degree to which an existing timetable can absorb modifications without requiring complete reconstruction. The fifth criterion was managerial transparency, that is, the extent to which the logic of the schedule and the principles of its generation remain understandable and controllable for administrative users. The sixth criterion was the ability to reduce teacher-group-room conflicts and to distribute institutional resources in a balanced and rational manner. Finally, the overall applicability of each approach to the college context was taken into account, since some algorithmically powerful methods may be difficult to implement effectively in institutions with limited technical resources or strong requirements for user interaction [10].

A further methodological issue concerned the heterogeneity of the empirical indicators reported in the literature. Studies on educational timetabling differ significantly in their objectives, datasets, benchmark structures, institutional settings, optimization goals, and performance metrics. Some publications focus mainly on algorithmic competitiveness in standardized benchmark environments, while others emphasize implementation in real universities or colleges with institution-specific constraints. As a consequence, direct quantitative comparison across all studies is not always possible. To address this limitation, the present research used a qualitative comparative synthesis supported by scenario-based interpretation. This means that the findings reported by different authors were not mechanically aggregated; rather, they were interpreted through a common analytical framework oriented toward the practical conditions of college scheduling. Such an approach made it possible to compare conceptually different methods in a consistent way, even when the original studies employed different evaluation procedures or reported results in non-uniform formats [3, 7, 8].

To increase the clarity and practical value of the comparison, a scenario-based weighted assessment using a 1-5 scale was applied. This assessment model should not be interpreted as an absolute empirical measurement or as a substitute for direct institutional testing. Instead, it was used as a structured comparative tool that allowed the conclusions of the reviewed literature to be translated into a common evaluative format. Each organizational and algorithmic approach was assessed according to the selected criteria, and weighted scores were assigned to reflect the relative importance of each criterion for college administration. The weighting scheme was constructed in accordance with priorities that are especially relevant in the college context: conflict-freeness and accuracy were assigned the highest weight of 0.25; timetable generation speed was assigned a weight of 0.20; flexibility with respect to new constraints, robustness during rescheduling, and the ability to balance resources were each assigned a weight of 0.15; and managerial transparency was assigned a weight of 0.10 [3, 8]. This

weighting structure made it possible to move beyond purely narrative comparison and to formulate a more systematic basis for identifying the most appropriate scheduling model for colleges.

An important feature of the methodology is that the study was oriented not only toward idealized algorithmic performance, but also toward actual implementation conditions in educational organizations. In real college practice, timetable construction is influenced by factors that are not always fully captured in abstract mathematical formulations. These factors include uneven teacher workloads, limited room capacity, subject-specific classroom requirements, the coexistence of general and specialized disciplines, administrative preferences regarding lesson distribution, and the need to react quickly to unexpected changes in the academic process. Consequently, the analysis did not evaluate methods exclusively in terms of theoretical optimization power. It also examined the extent to which each method can be integrated into everyday institutional workflows, support administrative personnel, and maintain a workable balance between formal rigor and practical usability. This applied orientation is especially important because a method that is mathematically sophisticated but operationally opaque may be less valuable in practice than a method that offers slightly lower optimization performance but significantly greater interpretability, controllability, and adaptability.

The research process itself consisted of several successive stages. At the initial stage, relevant scientific publications were selected and reviewed in order to establish the theoretical background of the study and identify the major approaches used in educational timetabling. At the second stage, the collected sources were classified according to organizational models and algorithmic paradigms. At the third stage, a comparative analysis was performed using the selected criteria in order to determine the relative strengths, weaknesses, and practical limitations of each approach. At the final stage, the results of the comparison were synthesized in relation to the specific needs of colleges, where timetable quality depends not only on technical correctness but also on administrative manageability, flexibility, and sustainability in the face of operational changes. Through this sequence of steps, the study was able to connect theoretical knowledge from the academic literature with practical conclusions relevant to real educational management.

RESULTS AND DISCUSSION

The analysis of the scientific literature shows that manual scheduling, although familiar and organizationally controllable, is weak in terms of time efficiency and quality when applied in larger educational settings. Manual planning allows the schedule manager to rely on experience, tacit knowledge, and contextual judgment. However, as the number of groups, teachers, rooms, and special cases increases, the probability of hidden conflicts rises, the time required for timetable construction becomes longer, and even a small change may lead to a cascade of corrections [1, 8]. For this reason, manual scheduling is generally appropriate only for small-scale or structurally simple educational environments.

Semi-automated approaches preserve the planner's control while delegating data processing and conflict checking to the system. In such models, the role of an interactive decision support system is especially important: it allows the scheduler to inspect intermediate solutions, clarify constraints, and introduce corrections quickly. From a practical standpoint, this format can be seen as a compromise between full automation and manual control. It is particularly suitable where administrative trust, transparency, and gradual adoption are as important as technical optimization [8, 9].

Fully automated approaches, especially those supported by constraint programming, integer programming, and metaheuristic optimization, are capable of reducing conflicts more systematically and improving overall solution quality. Their strength lies in formalizing institutional rules and exploring a wider solution space than a human planner can manage manually. At the same time, the effectiveness of such approaches depends directly on the completeness of the input data, the correctness of the formal rule set, and the adequacy with which local educational policies are modeled [3-5, 7]. An automated solver may be computationally powerful, but if the institutional logic is represented incompletely, the resulting timetable may still be difficult to implement in practice.

From a theoretical standpoint, the major algorithmic families differ in the way they balance feasibility search, optimization depth, and interpretability. Rule-based systems are strong at quickly generating a transparent initial timetable, but they are less effective at deeply optimizing numerous competing soft constraints. Heuristic and metaheuristic approaches improve timetable quality by searching larger solution spaces, although they tend to be sensitive to parameter settings and to the structure of particular instances. Genetic algorithms are useful for multi-scenario exploration and often perform better when combined with repair operators or local search. Constraint programming and closely related formal models are particularly valuable when many complex institutional constraints must be represented explicitly.

Hybrid architectures are theoretically the most attractive because they combine a formal feasibility core, adaptive optimization procedures, and a user-oriented management layer [2, 10].

Since quantitative indicators in the literature are reported in different formats, a weighted scenario-based assessment was used to clarify the comparison. The scale ranges from 1 to 5 and integrates the criteria described above. Within this model, the weighted scores do not replace empirical benchmarking; instead, they offer a structured way to compare organizational formats from the perspective of college administration.

Table 1 – Weighted scenario-based assessment of organizational approaches

Criterion	Weight	Manual scheduling	Semi-automated scheduling	Full automation	Hybrid DSS
Conflict-freeness and accuracy	0.25	2	4	5	5
Planning time	0.20	1	3	5	4
Flexibility to new constraints	0.15	3	4	3	5
Rescheduling robustness	0.15	2	4	3	5
Managerial transparency	0.10	4	5	3	5
Resource balancing	0.15	2	4	4	4
Total score	1.00	2.15	3.90	4.05	4.55

The results presented in Table 1 show that manual scheduling, although familiar from a managerial point of view, performs weakly in terms of time expenditure and conflict reduction. Full automation achieves high scores in accuracy and speed, but managerial transparency and flexibility during rescheduling are not always equally strong. By contrast, the hybrid DSS format provides a more stable balance between conflict-freeness, user intervention, and adaptability to change.

This outcome is theoretically significant because it confirms that colleges require not only high-quality optimization, but also a controllable operating environment. An administrator must be able to understand why a schedule was produced, identify which rule caused a conflict, and modify particular assignments without destroying the global structure of the timetable. The hybrid format is therefore advantageous precisely because it combines algorithmic rigor with institutional interpretability.

Table 2 – Matrix of algorithmic approaches for application in the college context

Algorithmic approach	Main advantage	Main limitation	Appropriate use case in colleges
Rule-based	Fast generation of an initial timetable and high explainability	Weak deep optimization of soft constraints	When simple rules dominate and a rapid prototype is required
Heuristic / metaheuristic	Effective for improving solution quality and exploring a large search space	Sensitive to parameters; results depend on the instance	When timetable quality must be improved and idle periods should be reduced
Genetic algorithms	Support multi-scenario search and perform well in hybrid models	Stability may decrease without repair or local search	When several scenarios must be tested on large and complex data
Constraint programming	Well suited to the formal modeling of complex constraints	Modeling is complex and harder to explain to non-technical users	When there are many hard constraints, specialized rooms, or block classes
Hybrid model	High balance between feasibility, quality, and rescheduling	Relatively higher design and implementation cost	In a full production scenario for a college, especially together with a DSS

Table 2 clarifies the comparison at the algorithmic level. In the college environment, not only solution quality but also explainability, the ability to reschedule, and the formal representation of complex constraints are of decisive importance. This means that algorithm selection should be guided by institutional priorities rather than by raw optimization performance alone.

The visual summaries in Figures 1 and 2 make this conclusion more explicit. The first figure shows the aggregate advantage of the hybrid DSS format over the other organizational approaches. The second figure demonstrates that hybrid models preserve strong positions across nearly all key dimensions, especially feasibility, quality improvement, complex constraints, and rescheduling capacity.

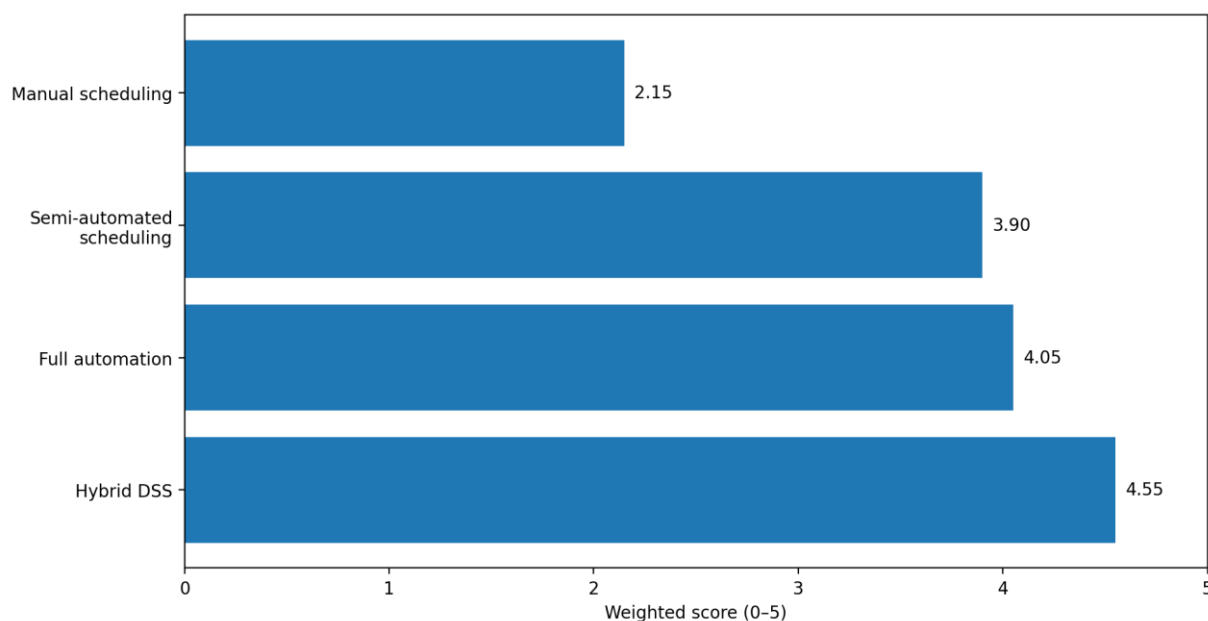


Figure 1 – Weighted scenario-based assessment of organizational approaches

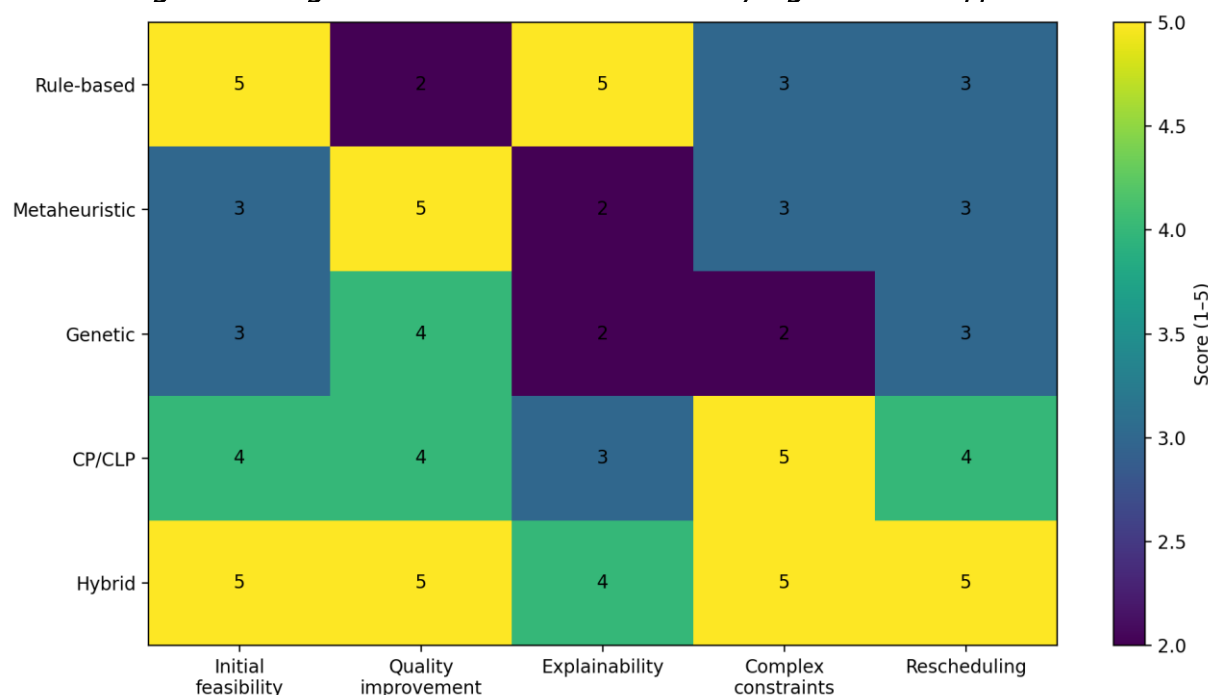


Figure 2 – Heat map of algorithmic approaches by college application profile

The figures indicate that, in the college context, the main issue is not simply selecting the most accurate algorithm, but constructing the right interaction between algorithmic power and management practice. While full automation increases computational efficiency, an interactive DSS preserves controllability and explainability for the user. For this reason, the most stable model for colleges is a hybrid architecture that includes a formal constraint-solving core, optimization mechanisms for solution improvement, and an interactive layer for administrators.

This conclusion is also consistent with applied work that proposes a hybrid model based on OR-Tools/ILP and an LLM assistant for vocational college timetabling. Such a model is promising because it combines rigorous feasibility control with a natural-language support layer that can help explain conflicts, suggest corrections, and support human decision-making. Thus, the comparative analysis confirms that the future of timetable automation in colleges lies not in replacing administrators, but in strengthening their planning capacity through intelligent and transparent tools [11].

Conclusion

The comparative analysis conducted in this study shows that the automation of academic timetabling is a complex and multifaceted problem. Each of the major approaches used to solve timetabling

problems—rule-based methods, heuristics and metaheuristics, genetic algorithms, constraint programming, and hybrid models—has its own strengths and limitations. No single method is equally effective in all situations, which means that the choice of a scheduling solution should always be adapted to the structure, rules, and management needs of a particular educational institution.

The results of the study make it possible to identify the most effective direction for colleges as a model that combines a hybrid solver with an interactive decision support system. This approach preserves hard constraints, supports the satisfaction of soft requirements to the greatest possible extent, enables rapid adaptation to changes, and increases the transparency of the system for administrative users. As a result, it contributes to higher timetable quality, shorter planning time, and more rational use of educational resources.

Thus, the introduction of academic timetable automation in colleges should be viewed as an important instrument for improving the organization of the educational process. Future research should focus on empirical testing within real colleges, the refinement of evaluation indicators, and the broader implementation of interactive automation systems in administrative practice.

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INTERNATIONAL QUALITY MANAGEMENT STANDARDS (ISO) 9000

Hacıyev Rafiq

PhD, Associate Professor, Department of Instrument Engineering,
Azerbaijan State Oil and Industry University

Punhan Shahmuradli

Master's Student, Department of Instrument Engineering,
Azerbaijan State Oil and Industry University

KEYFİYYƏTİ İDARƏETMƏ ÜZRƏ BEYNƏLXALQ STANDARTLAR (İSO) 9000

Hacıyev Rafiq¹,¹T.ü.f.d., dosent, "Cihaz mühəndisliyi" kafedrası, Azərbaycan Dövlət Neft və Sənaye UniversitetiPünhan Şahmuradlı²²Magistr tələbəsi, "Cihaz mühəndisliyi" kafedrası, Azərbaycan Dövlət Neft və Sənaye Universiteti**Abstract**

The International Standards for Quality Management (ISO) 9000 represent the fundamental framework of internationally recognized standards designed to guide organizations in establishing, implementing, and maintaining effective quality management systems. Rather than being limited to a specific industrial sector or type of organization, these standards provide universally applicable principles that assist enterprises of all sizes — from small businesses to large multinational corporations — in achieving consistent quality across their operations and processes. ISO 9000 encompasses a family of standards developed and maintained by the International Organization for Standardization through its Technical Committee ISO/TC 176. The core of this framework rests on seven fundamental quality management principles: customer focus, leadership, engagement of people, process approach, improvement, evidence-based decision making, and relationship management. Each of these principles is supported by a rationale, a set of key benefits, and actionable steps for implementation within any organizational context. In today's highly competitive global market, ISO 9000 serves as a critical strategic tool for companies striving to meet customer requirements, comply with stringent regulatory demands, and foster a culture of continuous improvement. Organizations that adopt these standards gain a structured, universally understood language for quality assurance — one that bridges the gap between different countries, industries, and engineering disciplines. This enables enterprises to transition from reactive problem-solving to proactive quality management, significantly reducing errors and optimizing the use of available resources. The primary objective of this article is to examine how the ISO 9000 framework enhances an organization's operational effectiveness, strengthens its commitment to exceeding customer expectations, and ensures consistent satisfaction with the products and services it delivers. The study analyzes the seven core principles in depth, explores the application of the framework's requirements, and discusses both the certification process and its associated costs based on international and local practice. Furthermore, the article addresses the specific application of ISO 9000 standards within the Azerbaijani business environment. As Azerbaijan deepens its integration into the global economy, the adoption of international quality standards has become a strategic priority for local enterprises. The Azerbaijan Standardization Institute (AZSTAND) serves as the national body responsible for adopting ISO standards for the local market, while the Small and Medium Business Development Agency (KOBIA) provides financial support to enterprises pursuing certification. The findings confirm that ISO 9000 certification yields substantial long-term benefits including enhanced operational efficiency, improved competitiveness, and consistently higher-quality products and services.

Xülasə

Keyfiyyəti idarəetmə üzrə Beynəlxalq Standartlar (İSO) 9000 keyfiyyətin idarə edilməsi və keyfiyyətin təminatı üçün nəzərdə tutulmuş beynəlxalq standartların əsas çərçivəsini təmsil edir. Bu standartlar müəyyən bir sənaye sahəsi ilə məhdudlaşmaq əvəzinə, bütün ölçülərdəki təşkilatlara — kiçik müəssisələrdən tutmuş iri çoxmillətli korporasiyalara qədər — yüksək səmərəli keyfiyyət sistemlərini sənədləşdirməyə, tətbiq etməyə və qoruyub saxlamağa kömək edən universal şəkildə tətbiq edilə bilən təlimatlar təqdim edir. İSO 9000 standartlar ailəsi Beynəlxalq Standartlaşdırma Təşkilatının ISO/TC 176 Texniki Komitəsi tərəfindən işlənib hazırlanır və mütəmadi olaraq yenilənir. Bu çərçivənin əsasını yeddi fundamental keyfiyyəti idarəetmə prinsipi təşkil edir: müştəri yönümlülük, liderlik, insanların cəlb edilməsi, proses yanaşması, təkmilləşdirmə, sübutlara əsaslanan qərar qəbulətmə və

münasibətlərin idarə edilməsi. Hər bir prinsip üçün əsaslandırma, əsas faydalar toplusu və hər hansı bir təşkilatı kontekstdə tətbiq üçün konkret addımlar müəyyən edilmişdir. Bu prinsiplər birlikdə təşkilatın bütün fəaliyyət istiqamətlərini əhatə edən vahid keyfiyyət idarəetmə sistemi yaradır. İndiki yüksək rəqabətli global bazarda ISO 9000 müştəri tələblərini ödəməyə, ciddi normativ tələblərə riayət etməyə və davamlı inkişaf mədəniyyətini təşviq etməyə çalışan şirkətlər üçün mühüm ilk addım kimi çıxış edir. Bu standartları mənimsəyən təşkilatlar fərqli ölkələr, sənaye sahələri və mühəndislik intizamı arasındakı uçurumu aradan qaldıran, hamı tərəfindən anlaşılan keyfiyyət təminatı dili əldə edirlər. Bu iş müəssisələrə reaktiv problem həllindən proaktiv keyfiyyət idarəetməsinə keçid etməyə, səhvləri əhəmiyyətli dərəcədə azaltmağa və mövcud resurslardan istifadəni optimallaşdırmağa imkan verir. Bu məqalənin əsas məqsədi ISO 9000 çərçivəsinin təşkilatın əməliyyat məlumatlılığını necə artırdığını, müştəri gözləntilərini aşmaq öhdəliyini necə möhkəmləndirdiyini və təqdim olunan məhsul və xidmətlərlə ardıcıl məmnuniyyəti necə təmin etdiyini araşdırmaqdır. Tədqiqat yeddi əsas prinsipi dərindən təhlil edir, çərçivənin tələblərinin tətbiqini araşdırır və beynəlxalq həmçinin yerli təcrübə əsasında sertifikatlaşdırma prosesini və onunla bağlı xərcləri müzakirə edir. Bundan əlavə, məqalədə ISO 9000 standartlarının Azərbaycan biznes mühitindəki tətbiqinin spesifik xüsusiyyətləri araşdırılır. Azərbaycan global iqtisadiyyata integrasiyasını dərinləşdirdikcə, beynəlxalq keyfiyyət standartlarının mənimsənilməsi yerli müəssisələr üçün strateji əhəmiyyət kəsb edir. Azərbaycan Standartlaşdırma İnstitutu (AZSTAND) bu standartları yerli bazara uyğunlaşdıran milli qurum kimi fəaliyyət göstərdiyi halda, Kiçik və Orta Biznesin İnkişafı Agentliyi (KOBİA) sertifikat alan müəssisələrə maliyyə dəstəyi göstərir. Tədqiqatın nəticələri təsdiqləyir ki, ISO 9000 sertifikatlaşdırması əhəmiyyətli uzunmüddətli faydalar — əməliyyat səmərəliliyinin artırılması, global bazarda rəqabət qabiliyyətinin gücləndirilməsi və ardıcıl olaraq daha yüksək keyfiyyətli məhsul və xidmətlər — əldə etməyə imkan yaradır.

Keywords: Quality Management System, ISO 9000, Quality Assurance, Continuous Improvement, Standardization, Customer Satisfaction.

Açar sözlər: Keyfiyyəti İdarəetmə Sistemi, ISO 9000, Keyfiyyətin Təminatı, Davamlı İnkişaf, Standartlaşdırma, Müştəri Məmnuniyyəti.

MÖVZUNUN AKTUALLIĞI

Qloballaşmanın və sürətli sənaye inkişafının müasir dövründə məhsul və xidmət keyfiyyətinin davamlılığının təmin edilməsi bütün dünyada təşkilatlar üçün mühüm problemə çevrilmişdir. Beynəlxalq Standartlaşdırma Təşkilatı (ISO) beynəlxalq ticarəti asanlaşdırmağa və hamı tərəfindən qəbul edilmiş əməliyyat meyarlarını müəyyən etməyə həsr olunmuş əsas global standartlar müəyyən edən orqan kimi fəaliyyət göstərir [1], [2]. ISO-nun tarixi kökləri 20-ci əsrin ortalarına [5] gedib çıxsada, onun müasir aktuallığı heç vaxt bu qədər yüksək olmamışdır. Bu gün şirkətlər gərgin global rəqabət və getdikcə sərtləşən tənzimləyici mühitlərlə üzləşirlər. Nəticədə, ənənəvi xüsusi keyfiyyətə nəzarət üsulları uzunmüddətli əməliyyat uğuruna zəmanət vermək üçün artıq kifayət etmir.

Məhz bu nöqtədə ISO 9000 standartlar ailəsi özünün dərin aktuallığını nümayiş etdirir. Əsas keyfiyyəti idarəetmə sistemi (KİS) olaraq, ISO 9000 fərqli ölkələr, sənayelər və mühəndislik intizamı arasındakı boşluğu aradan qaldıran keyfiyyət təminatı üçün strukturlaşdırılmış, hamı tərəfindən anlaşılan bir dil təmin edir. O, təşkilatlara reaktiv problem həllindən proaktiv keyfiyyət idarəetməsinə keçid etməyə imkan verir. Bu standartları tətbiq etməklə müəssisələr səhvləri əhəmiyyətli dərəcədə azalda, resurslardan istifadəni optimallaşdırır və beynəlxalq tərəfdaşları və istehlakçıları ilə davamlı inam yarada bilirlər.

İŞİN ƏSAS MƏQSƏDİ

Bu tədqiqat işinin əsas məqsədi ISO 9000 beynəlxalq standartlarının keyfiyyəti idarəetmə sistemindeki rolunu, onun yeddi əsas prinsipini təhlil etmək və bu standartların həm global, həm də yerli (Azərbaycan) bazarda tətbiqi xüsusiyyətlərini araşdırmaqdır. Eyni zamanda, məqalədə ISO 9000 çərçivəsinin müəssisələrin əməliyyat səmərəliliyini, rəqabət qabiliyyətini və müştəri məmnuniyyətini necə artırdığı elmi-nəzəri baxımdan əsaslandırılır. Keyfiyyəti idarəetmə sistemi qurmaq niyyətində olan hər hansı bir təşkilat üçün bu standartların başlanğıc nöqtəsi kimi əhəmiyyəti xüsusi vurğulanır [6], [7].

ƏSAS DƏYƏRLƏR, PRİNSİPLƏR VƏ KONSEPSİYALAR

ISO 9000 üçün yeddi keyfiyyəti idarəetmə prinsipi mövcuddur. "Prinsip" in tərfi ondan ibarətdir ki, o, bir işin görülmə tərzinə böyük təsir göstərən əsas inanc, nəzəriyyə və ya qaydadır. Keyfiyyəti idarəetmə prinsipləri (KİP) doğru olaraq qəbul edilən və keyfiyyətin idarə edilməsi üçün əsas kimi istifadə edilə bilən fundamental inanclar, normalar, qaydalar və dəyərlər toplusudur [13], [14].

KİP-lər təşkilatın fəaliyyətinin yaxşılaşdırılmasını istiqamətləndirmək üçün əsas kimi istifadə edilə bilər. Onlar ISO-nun keyfiyyəti idarəetmə standartlarının işlənilib hazırlanması və saxlanması cavabdeh olan ISO/TC 176-nın beynəlxalq ekspertləri tərəfindən işlənilib hazırlanmış və yenilənmişdir [6], [15].

Prinsip 1 – Müştəri yönümlülük

Təşkilatlar öz müştərilərindən asılıdır və buna görə də müştərilərin cari və gələcək ehtiyaclarını anlamalı, müştəri tələblərinə cavab verməli və müştəri gözləntilərini aşmağa çalışmalıdırlar.

Prinsip 2 – Liderlik

Liderlər təşkilatın məqsəd və istiqamət vəhdətini qururlar. Onlar insanların təşkilatın məqsədlərinə çatmaqda tam iştirak edə biləcəyi daxili mühit yaratmalı və qorumaqdadırlar.

Prinsip 3 – İnsanların cəlb edilməsi

Bütün səviyyələrdə olan insanlar təşkilatın mahiyyətidir və onların tam cəlb olunması onların bacarıqlarından təşkilatın xeyrinə istifadə etməyə imkan verir. İnsanlar əsas resursdur və təşkilatın fəaliyyəti təşkilatdakı insanların necə davranmasından asılıdır. İnsanlar təşkilatların keyfiyyət siyasətləri və arzu olunan nəticələr haqqında ümumi anlayış inkişaf etdirmək yolu ilə proseslərə cəlb olunurlar.

Prinsip 4 – Proses yanaşması

Fəaliyyətlər və əlaqədar resurslar bir proses kimi idarə edildikdə istənilən nəticəyə daha səmərəli şəkildə nail olunur.

Prinsip 5 – Təkmilləşdirmə

Təşkilatın ümumi fəaliyyətinin təkmilləşdirilməsi təşkilatın daimi məqsədi olmalıdır.

Prinsip 6 – Sübutlara əsaslanan qərar qəbulətmə

Effektiv qərarlar məlumat və informasiyanın təhlilinə əsaslanır.

Prinsip 7 – Münasibətlərin idarə edilməsi

Təşkilat və onun xarici təchizatçıları (tədarükçülər, podratçılar, xidmət təminatçıları) bir-birindən asılıdır və qarşılıqlı faydalı münasibət hər ikisinin dəyər yaratmaq imkanlarını artırır.

ÇƏRÇİVƏ

Yeddi prinsipin hər biri üçün təşkilatın niyə həmin prinsipə müraciət edəcəyini izah edən əsaslandırma, habelə Əsas Faydalar və prinsipi həyata keçirmək üçün atıla biləcək Tədbirlər (addımlar) verilmişdir.

Müştəri Yönümlülük

Keyfiyyətin idarə edilməsinin əsas diqqət mərkəzi müştəri tələblər qarşılamaq və müştəri gözləntilərini aşmağa çalışmaqdır.

• **Əsaslandırma:** Təşkilat müştərilərin və digər maraqlı tərəflərin etibarını cəlb etdikdə və qoruduqda davamlı uğur əldə edilir. Müştəri ilə qarşılıqlı əlaqənin hər bir aspekti müştəri üçün daha çox dəyər yaratmaq fürsəti təqdim edir. Müştərilərin və digər maraqlı tərəflərin cari və gələcək ehtiyaclarını anlamaq təşkilatın davamlı uğuruna töhfə verir.

• **Əsas faydalar:**

- Artan müştəri dəyəri
- Artan müştəri məmnuniyyəti
- Təkmilləşdirilmiş müştəri sadıqlığı
- Artan təkrar biznes əlaqələri
- Təşkilatın reputasiyasının yüksəlməsi
- Genişləndirilmiş müştəri bazası
- Gəlir və bazar payının artması

• **Atıla biləcək addımlar:**

- Birbaşa və dolaylı müştəriləri təşkilatdan dəyər alan şəxslər kimi tanımaq.
- Müştərilərin cari və gələcək ehtiyac və gözləntilərini anlamaq.
- Təşkilatın məqsədlərini müştəri ehtiyacları və gözləntiləri ilə əlaqələndirmək.
- Müştəri ehtiyaclarını və gözləntilərini təşkilat daxilində çatdırmaq.
- Müştəri ehtiyaclarını və gözləntilərini qarşılamaq üçün mal və xidmətləri planlaşdırmaq, dizayn etmək, inkişaf etdirmək, istehsal etmək, çatdırmaq və dəstəkləmək.
- Müştəri məmnuniyyətini ölçmək, izləmək və müvafiq tədbirlər görmək.
- Müştəri məmnuniyyətinə təsir edə biləcək maraqlı tərəflərin ehtiyac və gözləntilərini müəyyən etmək və tədbirlər görmək.
- Davamlı uğur əldə etmək üçün müştərilərlə münasibətləri fəal şəkildə idarə etmək.

Liderlik

Bütün səviyyələrdəki liderlər məqsəd və istiqamət vəhdətini qurur və insanların təşkilatın keyfiyyət məqsədlərinə çatmağa cəlb olunduğu şərait yaradır.

• **Əsaslandırma:** Məqsəd və istiqamət vəhdətinin yaradılması və insanların cəlb edilməsi təşkilata öz məqsədlərinə çatmaq üçün strategiyalarını, siyasətlərini, proseslərini və resurslarını uyğunlaşdırmağa imkan verir.

- **Əsas faydalar:**

- Təşkilatın keyfiyyət məqsədlərinə çatmaqda artan effektivlik və səmərəlilik
- Təşkilat proseslərinin daha yaxşı əlaqələndirilməsi
- Təşkilatın səviyyələri və funksiyaları arasında təkmilləşdirilmiş ünsiyyət
- Təşkilatın və onun işçilərinin arzu olunan nəticələri əldə etmək qabiliyyətinin inkişafı və təkmilləşdirilməsi

- **Atıla biləcək addımlar:**

- Təşkilatın missiyasını, vizyonunu, strategiyasını, siyasətlərini və proseslərini bütün təşkilat daxilində çatdırmaq.
- Təşkilatın bütün səviyyələrində davranış üçün ortaq dəyərlər, ədalət və etik modellər yaratmaq və qorumaq.
- İnam və dürüstlük mədəniyyəti qurmaq.
- Təşkilat miqyasında keyfiyyətə sadıqlığı təşviq etmək.
- Bütün səviyyələrdəki liderlərin təşkilatdakı insanlar üçün müsbət nümunə olmasını təmin etmək.
- İnsanları hesabatlılıqla hərəkət etmək üçün tələb olunan resurslar, təlim və səlahiyyətlərlə təmin etmək.
- İnsanların töhfəsini ilhamlandırmaq, təşviq etmək və tanımaq.

- **İnsanların cəlb edilməsi**

Təşkilatın bütün səviyyələrində səriştəli, səlahiyyətli və cəlb olunmuş insanlar onun dəyər yaratmaq və təqdim etmək qabiliyyətini artırmaq üçün vacibdir.

• **Əsaslandırma:** Təşkilatı effektiv və səmərəli idarə etmək üçün bütün səviyyələrdəki insanları cəlb etmək və onlara fərd kimi hörmət etmək vacibdir. Tanınma, səlahiyyətləndirmə və səriştənin artırılması təşkilatın keyfiyyət məqsədlərinə çatmaqda insanların iştirakını asanlaşdırır.

- **Əsas faydalar:**

- Təşkilatdakı insanlar tərəfindən təşkilatın keyfiyyət məqsədlərinin daha yaxşı başa düşülməsi və onlara nail olmaq üçün artan motivasiya
- İnsanların təkmilləşdirmə fəaliyyətlərinə geniş cəlb olunması
- Şəxsi inkişaf, təşəbbüslər və yaradıcılığın artması
- İnsan məmnuniyyətinin artması
- Təşkilat daxilində gücləndirilmiş etibar və əməkdaşlıq
- Təşkilat daxilində ortaq dəyərlərə və mədəniyyətə artan diqqət

- **Atıla biləcək addımlar:**

- Fərdi töhfənin vacibliyini başa düşmək üçün insanlarla ünsiyyət qurmaq.
- Təşkilat daxilində əməkdaşlığı təşviq etmək.
- Açıq müzakirələr, bilik və təcrübə mübadiləsini asanlaşdırmaq.
- İnsanlara performansla mane olan amilləri müəyyən etmək və qorxmada təşəbbüslər etmək səlahiyyəti vermək.
- İnsanların töhfəsini, öyrənməsini və inkişafını tanımaq və etiraf etmək.
- Şəxsi məqsədlərə qarşı performansın özünü qiymətləndirməsinə imkan yaratmaq.
- İnsanların məmnuniyyətini qiymətləndirmək üçün sorğular keçirmək, nəticələri bildirmək və müvafiq tədbirlər görmək.

- **Proses Yanaşması**

Fəaliyyətlər vahid bir sistem kimi fəaliyyət göstərən, bir-biri ilə əlaqəli proseslər kimi anlaşıldıqda və idarə edildikdə davamlı və proqnozlaşdırıla bilən nəticələr daha effektiv və səmərəli şəkildə əldə edilir.

• **Əsaslandırma:** Keyfiyyəti idarəetmə sistemi bir-biri ilə əlaqəli proseslərdən ibarətdir. Nəticələrin bu sistem tərəfindən necə istehsal edildiyini anlamaq təşkilata sistemi və onun fəaliyyətini optimallaşdırmağa imkan verir.

- **Əsas faydalar:**

- Səyləri əsas proseslərə və təkmilləşdirmə imkanlarına yönəltmək qabiliyyətinin artması
- Uyğunlaşdırılmış proseslər sistemi vasitəsilə ardıcıl və proqnozlaşdırıla bilən nəticələr
- Effektiv proses idarəçiliyi, resurslardan səmərəli istifadə və çarpaz funksional maneələrin azaldılması vasitəsilə optimallaşdırılmış performans
- Təşkilata onun tutarlılığı, effektivliyi və səmərəliliyi ilə bağlı maraqlı tərəflərə inam verməyə imkan yaratmaq

• **Atıla biləcək addımlar:**

- Sistemin məqsədlərini və onlara nail olmaq üçün zəruri olan prosesləri müəyyən etmək.
- Proseslərin idarə edilməsi üçün səlahiyyət, məsuliyyət və hesabatlılıq müəyyən etmək.
- Təşkilatın imkanlarını anlamaq və hərəkətə keçməzdən əvvəl resurs məhdudiyyətlərini müəyyən etmək.
- Proseslərin qarşılıqlı asılılığını müəyyən etmək və fərdi proseslərə edilən dəyişikliklərin sistemə təsirini təhlil etmək.
- Təşkilatın keyfiyyət məqsədlərinə effektiv və səmərəli nail olmaq üçün prosesləri və onların qarşılıqlı əlaqələrini bir sistem kimi idarə etmək.
- Prosesləri idarə etmək və təkmilləşdirmək, həmçinin ümumi sistemin fəaliyyətini izləmək, təhlil etmək və qiymətləndirmək üçün lazımi məlumatların mövcudluğunu təmin etmək.
- Proseslərin nəticələrinə və keyfiyyəti idarəetmə sisteminin ümumi nəticələrinə təsir edə biləcək riskləri idarə etmək.

Təkmilləşdirmə

Uğurlu təşkilatlar davamlı olaraq təkmilləşdirməyə diqqət yetirirlər.

• **Əsaslandırma:** Təkmilləşdirmə təşkilatın cari performans səviyyəsini qorumaq, daxili və xarici şəraitindəki dəyişikliklərə reaksiya vermək və yeni imkanlar yaratmaq üçün mütləqdir.

• **Əsas faydalar:**

- Təkmilləşdirilmiş proses performansı, təşkilati imkanlar, müştəri məmnuniyyəti
- Kök-səbəb araşdırılmasına və müəyyən edilməsinə, ardınca profilaktika və düzəldici hərəkətlərə yönəldilmiş diqqət
- Daxili və xarici riskləri və imkanları təxmin etmək və onlara reaksiya vermək qabiliyyətinin artması

○ Həm artan, həm də sıçrayışlı inkişafın nəzərə alınmasının gücləndirilməsi

○ Təkmilləşdirmə üçün öyrənmədən istifadənin yaxşılaşdırılması

○ İnnovasiya üçün artan motivasiya

• **Atıla biləcək addımlar:**

- Təşkilatın bütün səviyyələrində təkmilləşdirmə məqsədlərinin qurulmasını təşviq etmək.
- Bütün səviyyələrdəki insanları təkmilləşdirmə məqsədlərinə çatmaq üçün əsas alətlər və metodologiyaları necə tətbiq etmək barədə maarifləndirmək və öyrətmək.
- İnsanların təkmilləşdirmə layihələrini uğurla təşviq etmək və tamamlamaq üçün səriştəli olmasını təmin etmək.
- Bütün təşkilat daxilində təkmilləşdirmə layihələrini həyata keçirmək üçün prosesləri inkişaf etdirmək və tətbiq etmək.
- Təkmilləşdirmə layihələrinin planlaşdırılmasını, həyata keçirilməsini, tamamlanmasını və nəticələrini izləmək, nəzərdən keçirmək və audit etmək.
- Təkmilləşdirmə mülahizələrini yeni və ya dəyişdirilmiş mal, xidmət və proseslərin inkişafına integrasiya etmək.
- Təkmilləşdirməni tanımaq və etiraf etmək.

Sübutlara əsaslanan qərar qəbul etmə

Məlumat və informasiyanın təhlili və qiymətləndirilməsinə əsaslanan qərarların arzu olunan nəticələri vermə ehtimalı daha yüksəkdir.

• **Əsaslandırma:** Qərar qəbul etmə mürəkkəb bir proses ola bilər və bu həmişə müəyyən dərəcədə qeyri-müəyyənliyi ehtiva edir. O, çox vaxt subyektiv ola bilən çoxsaylı daxilolma növləri və mənbələri, eləcə də onların təfsirini əhatə edir. Səbəb-nəticə əlaqələrini və potensial gözlənilməz nəticələri anlamaq vacibdir. Faktlar, sübutlar və məlumatların təhlili qərarların qəbul edilməsində daha çox obyektivliyə və inama gətirib çıxarır.

• **Əsas faydalar:**

- Təkmilləşdirilmiş qərar qəbul etmə prosesləri

- o Prosesin performansının və məqsədlərə çatma qabiliyyətinin təkmilləşdirilmiş qiymətləndirilməsi

- o Təkmilləşdirilmiş əməliyyat effektivliyi və səmərəliliyi
- o Fikir və qərarları nəzərdən keçirmək, şübhə altına almaq və dəyişdirmək qabiliyyətinin artması
- o Keçmiş qərarların effektivliyini nümayiş etdirmək qabiliyyətinin artması

- **Atıla biləcək addımlar:**

- o Təşkilatın fəaliyyətini nümayiş etdirmək üçün əsas göstəriciləri müəyyən etmək, ölçmək və izləmək.

- o Bütün lazımi məlumatları müvafiq insanlar üçün əlçatan etmək.

- o Məlumat və informasiyanın kifayət qədər dəqiq, etibarlı və təhlükəsiz olmasını təmin etmək.

- o Müvafiq üsullardan istifadə edərək məlumat və informasiyanı təhlil etmək və qiymətləndirmək.

- o İnsanların lazım olduqda məlumatları təhlil etmək və qiymətləndirmək üçün səriştəli olmasını təmin etmək.

- o Təcrübə və intuisiya ilə balanslaşdırılmış şəkildə sübutlara əsaslanan qərarlar vermək və hərəkətə keçmək.

- **Münasibətlərin idarə edilməsi**

Davamlı uğur üçün təşkilat təchizatçılar kimi maraqlı tərəflərlə münasibətlərini idarə edir.

- **Əsaslandırma:** Maraqlı tərəflər təşkilatın fəaliyyətinə təsir göstərir. Təşkilat maraqlı tərəflərin onun performansına təsirini optimallaşdırmaq üçün onlarla münasibətləri idarə etdikdə davamlı uğurun əldə edilmə ehtimalı daha yüksək olur. Təchizatçı və tərəfdaş şəbəkələri ilə münasibətlərin idarə edilməsi xüsusi əhəmiyyət kəsb edir.

- **Əsas Faydalar:**

- o Hər bir maraqlı tərəflə bağlı imkanlara və məhdudiyyətlərə cavab verməklə təşkilatın və onun maraqlı tərəflərinin gücləndirilmiş fəaliyyəti

- o Maraqlı tərəflər arasında məqsəd və dəyərlərin ümumi anlayışı

- o Resursları və səriştələri bölüşməklə və keyfiyyətlə bağlı riskləri idarə etməklə maraqlı tərəflər üçün dəyər yaratmaq imkanının artması

- o Mal və xidmətlərin sabit axınını təmin edən yaxşı idarə olunan təchizat zənciri

- **Atıla biləcək addımlar:**

- o Müvafiq maraqlı tərəfləri (məsələn, təchizatçılar, tərəfdaşlar, müştərilər, investorlar, işçilər və bütövlükdə cəmiyyət) və onların təşkilatla münasibətlərini müəyyən etmək.

- o İdarə edilməsi lazım olan maraqlı tərəf münasibətlərini müəyyən etmək və prioritetləşdirmək.

- o Qısamüddətli qazancları uzunmüddətli mülahizələrlə balanslaşdıran əlaqələr qurmaq.

- o Məlumatı, təcrübəni və resursları müvafiq maraqlı tərəflərlə birləşdirmək və bölüşmək.

- o Təkmilləşdirmə təşəbbüslərini inkişaf etdirmək üçün performansı ölçmək və maraqlı tərəflərə performansla dair geri bildirim təmin etmək.

- o Təchizatçılar, tərəfdaşlar və digər maraqlı tərəflərlə birgə inkişaf və təkmilləşdirmə fəaliyyətləri qurmaq.

- o Təchizatçılar və tərəfdaşlar tərəfindən həyata keçirilən təkmilləşdirmələri və nailiyyətləri təşviq etmək və tanımaq.

- **TƏTBİQ**

İdarəetmə, maliyyə, məlumatların toplanması, proqram xidmətləri. ISO 9000 təşkilatın ümumi keyfiyyəti idarəetmə proseslərinin tam hərtərəfli nəzərdən keçirilməsini təmin etmək üçün nəzərdə tutulmuşdur. ISO 9000 agentlik daxilində tam tətbiq oluna bilər. Yeddi prinsipin göstərdiyi kimi, KİP-lərin qiymətləndirilməsi və həyata keçirilməsi bütün aspektlərə təsir göstərə bilər.

Peşə Reabilitasiyası (PR) ISO 9000 sertifikatı alan və ya istifadə edən PR agentliklərinin nümunələri tapılmadı. Geniş mənada yeddi prinsipin tətbiqi hərtərəfli keyfiyyəti idarəetmə sistemi yaratmaq istəyən hər hansı PR agentliyi üçün rəhbər rolunu oynayacaqdır. Əgər tam sertifikatlaşdırma arzuolunan və ya mümkün deyilsə, ISO 9000-dən Ümumi Keyfiyyət İdarəetməsi (Total Quality Management) kimi digər KİS ilə birlikdə istifadə edilə bilər.

Digər Təşkilatlar ISO 9000 İnsan Xidmətləri Təşkilatları və İctimai Xidmət və ya Müdafiə Nazirliyinin Satınalma İdarəsi, Baş Mühəsibat İdarəsi və Federal Binaların İdarəedilməsi kimi digər əlaqədar

təşkilatlar tərəfindən istifadə edilmişdir. Bu ictimai təşkilatların hər biri öz satınalma sistemlərini təkmilləşdirmək üçün ISO 9000-dən istifadə etmişdir.

TƏNQİDLƏR VƏ YA NARAHAHLIQLAR

ISO 9000 əksər PR agentlikləri üçün çox mürəkkəb bir sistem kimi görünə bilər. O, əsasən məlumat və sistem proseslərinə əsaslanan audite güvənir. İstənilən dərin qiymətləndirmə üçün agentliyin auditdə iştirak edəcək xüsusi heyəti olmalıdır. Bundan əlavə, bəzi agentliklər maliyyə, IT və Personal kimi birbaşa xidmət agentlikləri (DSA) daxilində inzibati vahidləri paylaşa bilər. DSA ISO 9000 tərəfindən tələb olunan prosedurların nəzərdən keçirilməsinə və ya dəyişdirilməsinə icazə verməyə bilər. Standartlar müəllif hüquqları ilə qorunduğundan, onlardan yalnız satın alan agentlik tərəfindən istifadə edilə bilər [16].

PR-DƏ İSTİFADƏSİ ÜÇÜN TÖVSIYƏ

ISO 9000-in Peşə Reabilitasiyasında (PR) məhdud tətbiqi var. ISO 9000-dən istifadə edən Federal təşkilatlara əsaslanaraq, PR agentliyi satınalma proseslərini təkmilləşdirmək üçün standartlardan istifadə edə bilər. ISO 9000 prinsipləri, xüsusən də digər keyfiyyəti idarəetmə prosesləri ilə birləşdirildikdə, agentlik əməliyyatlarını əhatə edən sahələrdə geniş təlimat kimi istifadə edilə bilər, lakin bu halda sertifikatlaşdırma o qədər də məqsəduyğun görünür.

SERTİFİKATLAŞDIRMA

ISO 9000 yuxarıda sadalanan prinsiplərdən istifadə edən standartlar toplusudur. Təşkilat hazırlıq prosesindən və ardınca auditdən sonra sertifikatlaşmağı seçə bilər. Sertifikat almaq üçün təşkilat sertifikatlı məsləhətçi(lər) ilə müqavilə bağlamalıdır. Sertifikatlı məsləhətçi yeddi prinsipdən kontur kimi istifadə edərək təşkilatın bütün aspektlərini dərinləndirir. Sertifikatlı məsləhətçidən istifadə etməklə hazırlıq mərhələsi baş verir (təxminən 4-6 ay), ardınca isə audit aparılır [8].

XƏRC

Sertifikatlaşdırmanın əsasən iki hissəsi var: hazırlıq mərhələsi və audit mərhələsi. Beynəlxalq təcrübəyə və global mənbələrə əsasən, ümumi sertifikatlaşdırma xərcləri kiçik müəssisələr üçün \$5,000-dan \$25,000-a qədər dəyişə bilər; konsalting xərcləri \$2,000-\$15,000, sertifikatlaşdırma orqanı audit haqqı isə \$5,000-\$10,000 arasında ola bilər [3], [4]. Lakin **Azərbaycan reallığında** və yerli bazarda bu rəqəmlər əhəmiyyətli dərəcədə fərqlənir. Yerli konsalting şirkətlərinin xidmətləri, eləcə də təşkilatın ölçüsü və proseslərin mürəkkəbliyindən asılı olaraq, ölkəmizdə bu proses adətən daha münasib büdcə ilə həyata keçirilir. Sertifikatlaşdırma üçün təlim və hazırlıq müddəti isə orta hesabla 4-5 ay çəkir.

AZƏRBAYCANDA ISO 9000 STANDARTININ TƏTBİQİ VƏ XÜSUSİYYƏTLƏRİ

Azərbaycanın global iqtisadiyyata integrasiyası və qeyri-neft sektorunun sürətli inkişafı fonunda beynəlxalq standartların mənimsənilməsi yerli müəssisələr üçün strateji əhəmiyyət daşıyır. Ölkəmiz post-sovet məkanı olaraq ənənəvi QOST (Dövlət Standartları) sistemindən müasir ISO standartlarına keçid mərhələsini uğurla icra etmişdir. Bu prosese birbaşa **Azərbaycan Standartlaşdırma İnstitutu (AZ-stand)** rəhbərlik edir və beynəlxalq standartları Azərbaycan Respublikasının milli standartları (məsələn, AZS ISO 9000) kimi qəbul edərək yerli bazara uyğunlaşdırır [10]. Eyni zamanda, bu sahəyə ümumi dövlət nəzarəti və keyfiyyət infrastrukturunun inkişafı **Iqtisadiyyat Nazirliyi yanında Antiinhisar və İstehlak Bazarına Nəzarət Dövlət Xidməti** tərəfindən tənzimlənir [11].

Yerli tətbiqdə əsas aparıcı qüvvələrdən biri sənaye və global tərəfdaşlıq tələbləridir. Xüsusilə **neft-qaz sektorunda (SOCAR və xarici şirkətlərlə işləyən podratçılar)** və Avropa bazarlarına çıxış hədəfləyən aqrar və qida sənayesi şirkətlərində ISO 9000 standartının tətbiqi rəqabət üstünlüyü olmaqdan çıxaraq məcburi və ilkin tələbə çevrilmişdir [12].

Eyni zamanda, bu standartların yerli tətbiqini stimullaşdırmaq məqsədilə dövlət səviyyəsində bir sıra mexanizmlər mövcuddur. Məsələn, **Azərbaycan Respublikasının Kiçik və Orta Biznesin İnkişafı Agentliyi (KOBİA)** yerli müəssisələrin rəqabət qabiliyyətini artırmaq məqsədilə onlara beynəlxalq standartların və sertifikatların, o cümlədən ISO sertifikatlarının alınması prosesində maliyyə dəstəyi (subsidiyalar) göstərir [9]. Bu yanaşma kiçik və orta ölçülü bizneslərin maliyyə yükünü yüngülləşdirərək beynəlxalq idarəetmə standartlarına keçidini xeyli sürətləndirir.

NƏTİCƏ

Yekun olaraq, ISO 9000 keyfiyyətin idarə edilməsi və müştəri məmnuniyyəti sahəsində mükəmməlliyə çatmağa çalışan təşkilatlar üçün yüksək səmərəli əsas çərçivə kimi xidmət edir. Müştəri yönümlülükdən tutmuş sübutlara əsaslanan qərarların qəbuluna qədər yeddi əsas prinsipinə riayət etməklə şirkətlər daxili proseslərini asanlaşdırır, davamlı inkişafı təşviq edə və maraqlı tərəflərlə daha güclü əlaqələr qura bilərlər. Rəsmi sertifikatlaşdırma prosesi vaxt, xüsusi heyət və maliyyə resursları baxımından əhəmiyyətli sərmayə tələb etsə də, uzunmüddətli faydalar böyükdür. Bu standartlara sadıq

qalmağa hazır olan təşkilatlar üçün nəticə etibarilə gücləndirilmiş əməliyyat səmərəliliyi, global bazarda rəqabət qabiliyyətinin artması və ardıcıl olaraq daha yüksək keyfiyyətli məhsul və xidmətlər əldə edilir.

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INVESTIGATION AND METROLOGICAL EVALUATION OF ACCURACY PARAMETERS OF MITUTOYO MEASURING INSTRUMENTS

Agayev Fakhraddin

Azerbaijan State Oil and Industry University,
Department of Instrument Engineering, Professor

Ahmadov Sahib

Azerbaijan State Oil and Industry University,
Department of Instrument Engineering, Master's Student.

Abstract

In modern industrial environments and advanced manufacturing processes, measurement accuracy plays a crucial role in determining product quality, operational reliability, and overall safety. Even minor deviations in measurement results can lead to significant errors in production, especially in fields such as mechanical engineering and precision manufacturing, where tolerances are extremely tight. For this reason, evaluating the metrological characteristics of measuring instruments is not only a technical necessity but also an essential step in quality assurance systems.

This study focuses on the investigation of accuracy indicators of a Mitutoyo measuring instrument and provides a comprehensive metrological evaluation based on statistical analysis. The research aims to assess the reliability and consistency of the device by examining its performance under controlled conditions. In order to achieve this, repeated measurements were carried out on the same object to minimize the influence of external variables and to better understand the instrument's behavior.

Based on the collected data, key statistical parameters such as the mean value, standard deviation, relative error, and repeatability were calculated. These indicators provide valuable insight into both systematic and random errors present in the measurement process. In addition, measurement uncertainty was determined in accordance with standard metrological practices, allowing for a more complete evaluation of the measurement results. The obtained values were then compared with the maximum permissible error specified by the manufacturer to verify compliance with technical requirements.

The results of the analysis demonstrate that the Mitutoyo measuring instrument delivers stable, consistent, and reliable measurements within the defined tolerance limits. This confirms that the device is suitable for use in high-precision applications, provided that it is properly calibrated and operated under appropriate environmental conditions.

Furthermore, the study highlights the importance of regular calibration procedures, controlled environmental factors such as temperature and humidity, and the application of statistical methods in ensuring the accuracy and reliability of measurement systems. The findings emphasize that measurement quality is not solely dependent on the instrument itself, but also on how effectively it is maintained and utilized.

In conclusion, the proposed methodology for evaluating measurement accuracy and metrological characteristics can be successfully applied not only to Mitutoyo devices but also to other precision measuring instruments. This approach can support engineers and specialists in improving measurement practices and maintaining high standards in industrial quality control.

Keywords: measurement accuracy, metrological evaluation, measurement uncertainty, statistical analysis, repeatability, calibration

Introduction

In modern industrial production and quality control systems, the accuracy of measurements plays a decisive role in ensuring product functionality, safety, and service life. Even the smallest dimensional deviations can significantly influence the performance and reliability of the final product. This is particularly critical in sectors such as mechanical engineering, aerospace industry, automotive manufacturing, and other high-precision mechanical systems, where strict tolerances must be maintained. For this reason, it is essential that measurement processes are based on scientific principles and that the metrological characteristics of the instruments used are carefully evaluated and verified.

Dimensional metrology is a field of science concerned with the determination, comparison, and verification of dimensions in accordance with established standards. In any measurement process, not only the nominal accuracy of the instrument but also various influencing factors—such as environmental conditions, operator influence, calibration status, and applied methodology—affect the final result.

Therefore, the reliability of measurement results cannot be assessed based on a single parameter; instead, it requires a comprehensive and systematic approach. The separation of measurement errors into systematic and random components, along with the identification and reduction of their sources, constitutes one of the main directions of modern metrological analysis.

Precision measuring instruments, including micrometers, vernier calipers, dial indicators, and coordinate measuring machines (CMMs), are widely used in industrial environments. The structural design, sensitivity, and measurement range of these instruments determine their fields of application and operational capabilities. In particular, modern digital measurement systems equipped with advanced encoder technologies contribute to improved measurement stability, higher resolution, and enhanced repeatability. At the same time, factors such as environmental protection of the devices and their calibration condition have a direct impact on the consistency and reliability of measurement results.

In the process of metrological evaluation, the estimation of measurement uncertainty is of particular importance. A measurement result should not be considered merely as a single numerical value, but rather as a parameter that lies within a defined range of possible values. This approach plays a key role in the development of quality assurance systems that comply with industrial standards. International standardization frameworks provide a unified methodological basis, ensuring that measurement results are comparable and acceptable at a global level.

In this context, the investigation of the accuracy indicators of Mitutoyo measuring instruments and their metrological evaluation is of both scientific and practical significance. The aim of this study is to determine the accuracy level of the instrument through statistical analysis of measurement results, to identify and assess potential sources of error, and to justify its suitability for industrial applications. Furthermore, the study seeks to contribute to the improvement of measurement practices by emphasizing the importance of systematic evaluation, proper calibration, and controlled measurement conditions in achieving reliable and high-quality results.

Concept of measurement and basic terminology

Measurement is one of the fundamental components of modern science and engineering, playing a decisive role in ensuring product quality, process control, and compliance with international standards. In both industrial and laboratory environments, accurate measurements are essential for making informed decisions, maintaining safety, and achieving desired functional performance. The measurement process enables the assignment of numerical values to physical quantities, facilitates comparison of results, and supports the analysis and optimization of systems.

In contemporary metrological practice, measurement is not limited to obtaining a numerical result; it also involves evaluating the reliability and uncertainty associated with that result. This broader perspective allows for a more comprehensive understanding of measurement quality and ensures that obtained data can be confidently used in both scientific and industrial applications.

Measurement error represents the deviation between the measured value and the true value and may arise from various sources. According to international metrological standards, measurement errors are generally classified into three main categories: systematic errors, random errors, and gross errors. Systematic errors are consistent and repeatable deviations caused by identifiable factors such as calibration inaccuracies, environmental influences, or inherent instrument imperfections. These errors can typically be minimized or eliminated through proper calibration and methodological corrections.

$$\Delta x = x_{\text{measured}} - x_{\text{true}} \quad (1)$$

Δx – measurement error

Random errors, on the other hand, originate from unpredictable variations in measurement conditions, limitations of the measuring instrument, or minor environmental fluctuations. Although they cannot be completely eliminated, their impact can be reduced by performing repeated measurements and applying statistical analysis.

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i \quad (2)$$

Gross errors are usually the result of human mistakes, incorrect use of instruments, or unexpected external disturbances. If not identified and corrected, they can lead to significant deviations and unreliable results.

The concept of accuracy encompasses both trueness and precision. Trueness refers to how close the measured value is to the true value, while precision describes the consistency of repeated measurements under the same conditions. A reliable measurement system should demonstrate both minimal

systematic deviation and high repeatability. Repeatability, in particular, reflects the ability of a measurement system to produce consistent results when measurements are repeated under identical conditions and is considered a key indicator of measurement reliability.

Calibration is the process of aligning measuring instruments with recognized standards. Through calibration, systematic deviations are identified and compensated for, thereby improving measurement accuracy and traceability. Regular calibration, combined with proper maintenance of instruments and adherence to standardized measurement procedures, ensures the long-term reliability and stability of measurement systems. Furthermore, calibration enables the estimation of measurement uncertainty, allowing results to be expressed with a defined level of confidence.

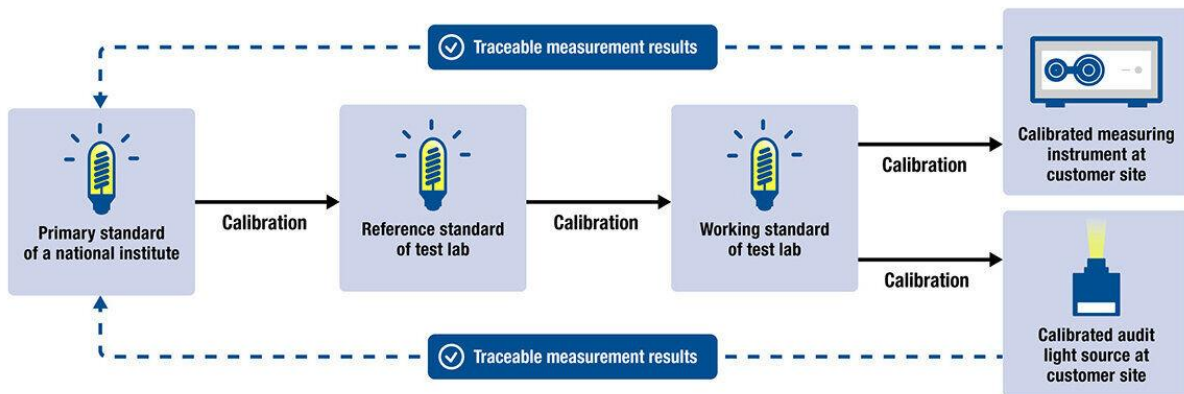


Figure 1. Calibration process of measuring instruments

The interrelationship between measurement errors, accuracy, repeatability, and calibration forms the foundation of modern metrology. A clear understanding of these concepts allows engineers and researchers to design and implement reliable measurement systems that comply with international standards. Systematic evaluation of error sources, application of repeatable measurement protocols, and the use of properly calibrated instruments significantly contribute to achieving high-quality measurement results.

In conclusion, modern measurement theory integrates both theoretical principles and practical approaches. It goes beyond simply assigning numerical values to quantities and emphasizes the importance of evaluating reliability, accuracy, and repeatability. Careful consideration of error types, instrument performance, repeatability, and calibration forms the basis of high-level measurement activities and ensures that results are meaningful from both scientific and practical perspectives.

Classification of measurement errors

Measurement errors represent the deviation of a measured value from the true value and may arise due to a variety of factors within the measurement process. In modern metrology, errors are typically classified into three main categories: systematic errors, random errors, and gross errors. This classification is essential for evaluating measurement quality, minimizing inaccuracies, and ensuring the reliability of results.

Systematic errors

Systematic errors are consistent and repeatable deviations that arise from identifiable causes. These errors may result from the design and condition of the instrument, calibration inaccuracies, environmental influences, or methodological mistakes made by the operator. They introduce a constant bias into measurement results, causing them to deviate from the true value in a predictable manner.

$$b = \bar{x} - x_{true} \quad (3)$$

The influence of systematic errors can be reduced or eliminated through proper calibration procedures and correction methods. For example, factors such as temperature variations, mechanical wear of instruments, or misalignment can lead to systematic deviations. However, once identified, these errors can be compensated for, thereby improving measurement accuracy. Without proper analysis and correction of systematic errors, measurement results cannot be considered reliable for scientific or industrial applications.

Random errors

Random errors are unpredictable variations that occur during the measurement process. They are typically caused by small fluctuations in measurement conditions, limitations in instrument sensitivity, or minor environmental changes. When repeated measurements are performed under the same conditions, random errors lead to variations in the obtained results.

Although random errors cannot be completely eliminated, their effect can be minimized by conducting multiple measurements and applying statistical methods such as averaging and variance analysis.

$$s^2 = \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2 \quad (4)$$

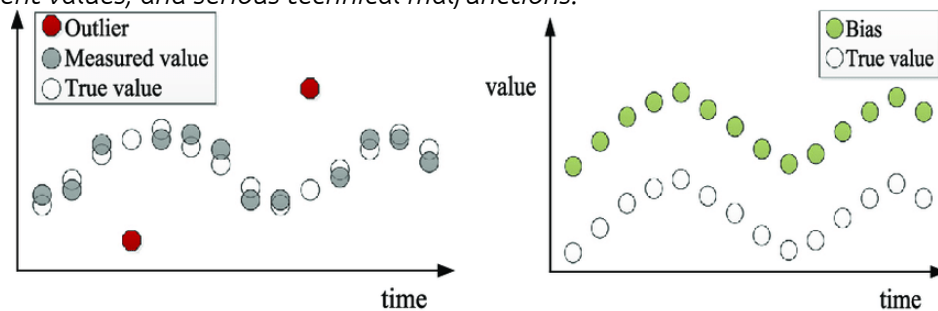
This formula displays the **sample variance**, typically denoted as s^2 , measures the **spread** or dispersion of a data set. It calculates the average squared distance of each data point from the mean. The use of (known as **Bessel's correction**) instead of n is used when calculating variance from a sample to provide an unbiased estimate of the population variance.

Random errors play a crucial role in determining the precision and repeatability of a measurement system. Understanding and quantifying these errors is essential for improving measurement reliability and ensuring consistent results.

Gross errors

Gross errors, also known as blunders, are significant deviations caused primarily by human mistakes, improper use of instruments, or unexpected external influences. Unlike systematic and random errors, gross errors result in large discrepancies and are usually considered outliers that should be excluded from analysis.

Examples of gross errors include incorrect positioning of the instrument, misreading or recording of measurement values, and serious technical malfunctions.



(c) measured data with drift

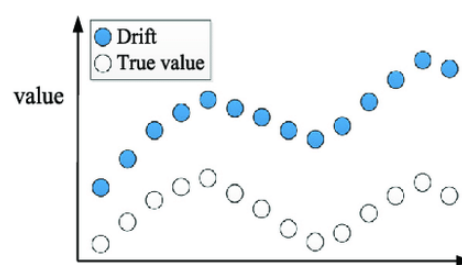


Figure 2. Measured data with different types of gross errors

Preventing such errors requires strict adherence to measurement procedures, proper training of personnel, regular calibration of instruments, and careful verification of results. Early detection and correction of gross errors are essential for maintaining the integrity and reliability of measurement data.

Metrological importance of error classification

The proper classification of measurement errors is fundamental to improving the quality of the measurement process and ensuring compliance with international standards. By understanding the characteristics and sources of systematic, random, and gross errors, appropriate corrective and preventive measures can be applied.

In modern measurement systems, error classification serves not only as a theoretical framework but also as a practical tool for refining measurement procedures, enhancing calibration practices, and improving statistical data processing. It enables engineers and researchers to identify weaknesses in measurement systems and implement targeted improvements.

Thus, categorizing errors and understanding their nature plays a vital role in evaluating measurement quality and ensuring the reliability of results. Systematic investigation of error sources, combined with calibration and repeated measurement techniques, allows for the achievement of high-accuracy results and provides a reliable data foundation for both scientific research and industrial applications.

General characteristics of Mitutoyo measuring instruments

Mitutoyo Corporation, established in Japan in 1963, has grown into one of the global leaders in the field of precision measuring instruments and metrological solutions. Over the decades, the company has built a strong reputation for producing high-quality and highly reliable measurement equipment that meets the demanding requirements of modern industry. Its product range includes high-precision measuring tools such as coordinate measuring machines (CMMs), micrometers, vernier calipers, and dial indicators, all of which are widely used across various sectors, including automotive, aerospace, medical manufacturing, and industrial laboratories.

In addition to manufacturing physical measuring instruments, Mitutoyo provides advanced digital measurement systems, specialized software, and integrated metrology solutions that facilitate data acquisition, process control, and result analysis. These digital solutions allow users not only to perform measurements but also to efficiently manage, store, and interpret measurement data. Furthermore, the company supports its products with comprehensive technical documentation, calibration guidelines, and user training materials, ensuring that measurement processes are carried out correctly and in accordance with international standards. This integrated approach significantly contributes to maintaining measurement quality and traceability.

The product portfolio of Mitutoyo is extensive and designed to meet a wide range of technical requirements. Instruments are characterized by parameters such as measurement range, resolution, and maximum permissible error, which determine their suitability for specific applications. Vernier calipers, for example, are among the most commonly used measuring tools due to their versatility in performing internal, external, and depth measurements.

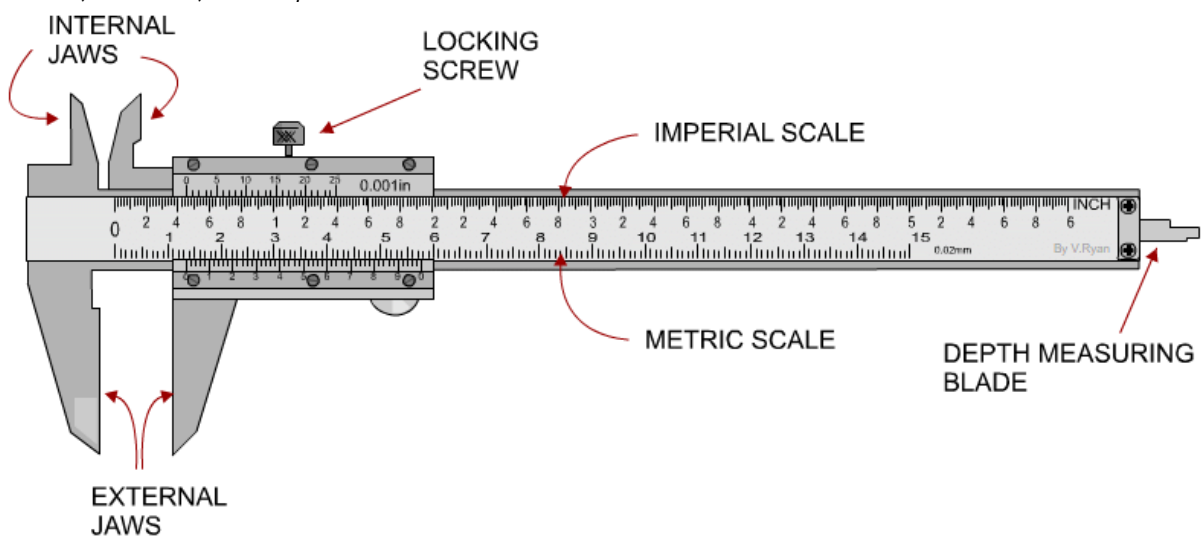


Figure 4. Structure of Vernier Calipers

Mitutoyo calipers are available in digital, dial, and vernier types, offering different levels of precision depending on the application. Digital calipers, in particular, provide readings with micrometer-level resolution, making them suitable for measuring small and complex components with high accuracy. Proper calibration and correct handling of calipers play a crucial role in minimizing systematic errors and improving measurement reliability.

Micrometers are specifically designed for measuring very small dimensions and fine components with a high degree of accuracy. Mitutoyo micrometers are often equipped with digital displays and advanced mechanical designs that enhance repeatability and measurement consistency. These instruments are widely used in both laboratory and industrial environments where precise dimensional control is required. They are available in various measurement ranges, allowing users to select the appropriate tool for specific measurement tasks. The robust construction and fine adjustment mechanisms of micrometers contribute to their ability to deliver highly reliable results even under demanding conditions.

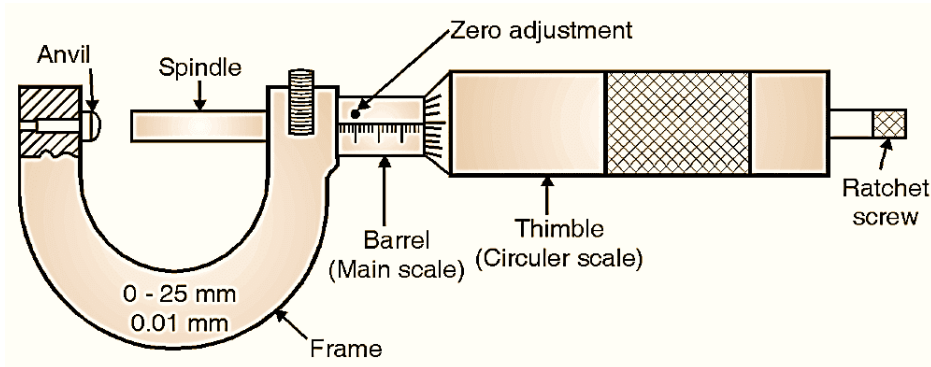


Figure 5. Structure of micrometer

Dial indicators are used to detect small displacements and surface deviations. Mitutoyo indicators are available in both mechanical and digital formats and are known for their precision and ease of use.

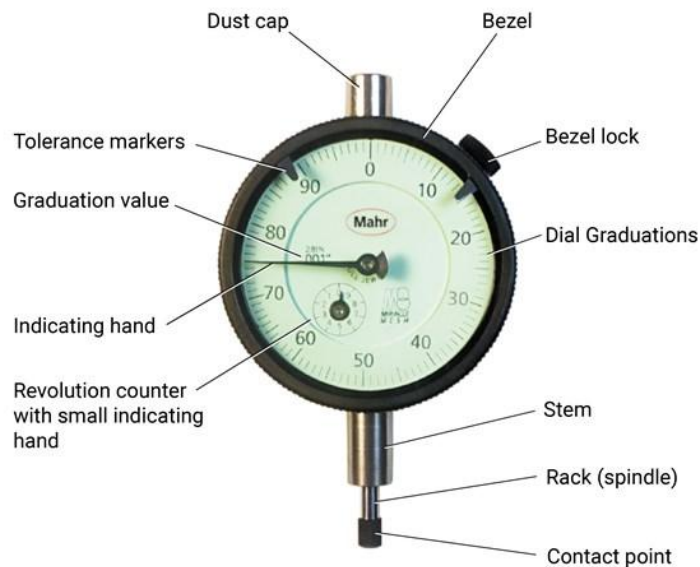


Figure 6. Parts of dial indicators

These instruments are essential for evaluating surface quality, alignment, and geometric accuracy of components. Their ability to provide consistent and repeatable readings makes them indispensable in quality control processes, particularly in machining and assembly operations.

Coordinate measuring machines (CMMs) represent one of the most advanced categories of measuring systems offered by Mitutoyo. These high-technology systems are designed for three-dimensional measurement and analysis of complex geometries.

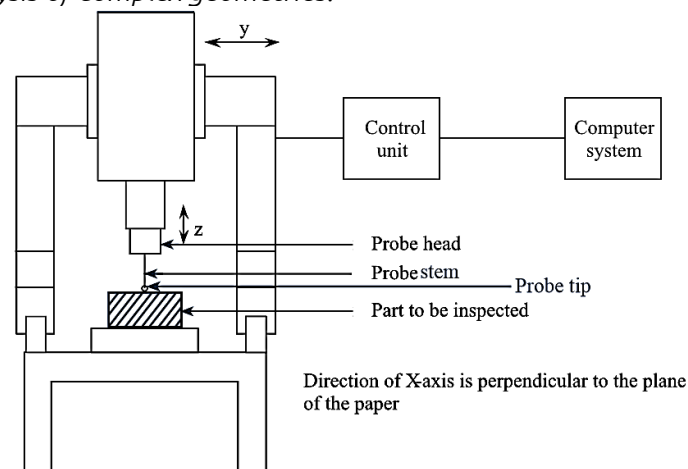


Figure 7. Working principle of Coordinate Measuring Machine (CMM)

Mitutoyo CMMs can be integrated with CAD software, enabling automated measurement routines and highly accurate inspection processes. They are available in different accuracy classes, including

standard, high-precision, and ultra-high-precision systems, depending on the application requirements. CMMs are widely used in both industrial production and laboratory environments for part verification, quality control, and optimization of manufacturing processes.

The technical characteristics of Mitutoyo instruments determine their effectiveness in various measurement tasks. The measurement range defines the minimum and maximum dimensions that can be measured, while the resolution indicates the smallest detectable increment. Instruments such as micrometers and calipers can achieve micrometer-level sensitivity, whereas CMMs are capable of performing precise measurements over much larger, even meter-scale, dimensions in three-dimensional space. Another important parameter is the maximum permissible error, which defines the acceptable limit of deviation in measurement results and ensures compliance with international standards.

Moreover, modern Mitutoyo instruments often incorporate advanced features such as data output interfaces, wireless communication capabilities, and integration with quality management systems. These features enhance productivity, reduce human error, and enable real-time monitoring of measurement processes. As a result, measurement operations become more efficient, consistent, and aligned with Industry 4.0 requirements.

In conclusion, Mitutoyo measuring instruments offer a combination of high accuracy, reliability, and versatility for both industrial and laboratory applications. Their advanced design, technological innovation, and compatibility with modern measurement systems contribute to maintaining metrological standards and improving overall measurement quality. Beyond simply providing measurement results, Mitutoyo products support repeatability, calibration, and compliance with international standards, making them essential tools in contemporary scientific research and industrial production environments.

Conclusion

Within the scope of the conducted research, the accuracy characteristics of the Mitutoyo measuring instrument were analyzed using both experimental procedures and statistical methods. During the experiment, multiple measurements were performed under identical and controlled conditions in order to minimize external influences and ensure consistency of results. The obtained data were then processed statistically to evaluate the stability and reliability of the measurement process.

The results of the calculations demonstrated that the mean value of the measurements was very close to the nominal (reference) value, while the standard deviation remained at a relatively low level. This indicates that the instrument exhibits a high degree of repeatability and that the measurement process is stable and consistent. In addition, the calculated relative error values were found to be within the permissible metrological limits, confirming that the device is suitable for industrial applications where precision is required.

The evaluation of measurement uncertainty showed that the main contributing factors include the human factor, environmental measurement conditions, and the sensitivity limits of the instrument. However, these influences were found to be minimal and did not significantly affect the overall measurement results. The application of repeated measurements and statistical analysis helped to reduce the impact of random variations and improve the reliability of the final outcomes.

Based on the overall analysis, it can be concluded that the investigated Mitutoyo measuring instrument demonstrates high accuracy, stability, and reliability. Its performance meets the requirements of precision measurement tasks and confirms its suitability for use in industrial quality control and production environments.

The application of such high-precision instruments in manufacturing and inspection processes plays an important role in reducing measurement errors, improving product quality, and ensuring compliance with international standards. Furthermore, the use of statistically supported metrological evaluation methods enhances confidence in measurement results and contributes to more effective decision-making in engineering practice.

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THE IMPACT OF QUALITY CONTROL AND STANDARDIZATION ON LABORATORY RESULTS IN HEMATOLOGY ANALYZERS

Valili Aziz

Azerbaijan State University of Oil and Industry,
Instrumentation engineering department, master

Xidirov Akif

Azerbaijan State University of Oil and Industry, Instrumentation engineering department, candidate of
Physical and Mathematical Sciences, docent
20 Azadlig Ave., AZ1010 Baku, Azerbaijan

Abstract

Hematology analyzers are essential diagnostic devices used in clinical laboratories for the automated analysis of blood samples. These systems measure parameters such as red blood cells (RBC), white blood cells (WBC), hemoglobin (HGB), and platelets (PLT) with high precision. The reliability of obtained results directly depends on proper calibration, technical maintenance, and quality control procedures.

The aim of this study is to analyze the role of quality control and standardization in hematology analyzers and to determine how technical errors influence laboratory results. Based on experimental observations, improper calibration, equipment malfunction, and inadequate quality control can lead to deviations in analytical results and affect clinical decisions.

Keywords: Hematology analyzer, RBC/PLT electrode, WBC/HGB chamber, flow cell calibration, quality control, Diff, laboratory diagnostics, standardization

Introduction

In modern healthcare systems, laboratory diagnostics plays a crucial role in the early detection of diseases, accurate diagnosis, and the selection of effective treatment strategies. Since a significant portion of clinical decisions is based on laboratory test results, the accuracy and reliability of these results are among the key factors determining the quality of medical services. In this context, the technical level of analytical instruments used in laboratories, their proper operation, and the implementation of quality control mechanisms are of paramount importance.

Hematology analyzers are considered one of the most essential instruments in modern laboratory diagnostics. These devices provide automated, rapid, and highly accurate analysis of blood components, including red blood cells (RBC), white blood cells (WBC), platelets (PLT), and other hematological parameters. Compared to traditional manual methods, hematology analyzers significantly reduce human-related errors while increasing laboratory efficiency and productivity.

Modern hematology analyzers are capable not only of counting blood cells but also of determining their size, morphology, and certain functional characteristics. In particular, advanced systems such as 5-diff analyzers perform differential leukocyte analysis, providing detailed information about the immune system status. These capabilities make hematology analyzers indispensable in the diagnosis of anemia, infections, inflammatory processes, hematological disorders, and other clinical conditions.

Despite their advanced technological capabilities, the accuracy of results produced by hematology analyzers depends on several technical and methodological factors. These include proper calibration of the device, quality and storage conditions of reagents, stability of optical and electrical measurement systems, and the effectiveness of quality control procedures applied in the laboratory. Even minor deviations in any of these parameters can lead to significant errors in analytical results.

Significance

The performance of hematology analyzers is highly dependent on the integrity and functional stability of their internal components, including the flow cell, impedance electrodes (RBC/PLT), WBC chamber, and HGB measurement chamber. These components play a fundamental role in ensuring accurate blood cell counting, hemoglobin quantification, and differential leukocyte analysis. Any deterioration, contamination, or mechanical failure in these parts can significantly compromise analytical accuracy and lead to clinically misleading results.

One of the most critical components is the flow cell, which ensures the controlled passage of blood cells through optical or impedance detection zones. Even minor contamination such as protein deposits, fibrin buildup, or micro-scratches on the flow cell surface can distort laser scattering signals. This may result in incorrect leukocyte differentiation, abnormal scattergram patterns, and misclassification of

immature or abnormal cells. Therefore, maintaining a clean and structurally intact flow cell is essential for reliable WBC differential analysis.

The RBC/PLT impedance electrodes are equally important, as they are responsible for detecting electrical pulses generated by individual cells passing through an aperture. Over time, electrode oxidation, corrosion, or poor electrical contact can alter signal amplitude and baseline stability. This leads to errors in red blood cell and platelet counts, as well as secondary deviations in derived parameters such as MCV, MCH, and MCHC. In some cases, platelet clumping artifacts or falsely elevated RBC counts may occur, directly affecting clinical interpretation.

The WBC chamber plays a key role in ensuring proper dilution, lysis, and uniform distribution of leukocytes prior to measurement. Any residual contamination, reagent crystallization, or volume inconsistency within the chamber can disrupt the lysis process and lead to inaccurate white blood cell counts. This may result in either falsely decreased or increased WBC values, potentially masking conditions such as leukopenia, infection, or hematologic malignancies.

Similarly, the HGB measurement chamber is critical for photometric analysis based on light absorption principles. Contamination of optical windows, degradation of light sources, or improper reagent reactions (e.g., Drabkin's reaction inefficiency) can cause systematic errors in hemoglobin measurement. These errors directly affect hematocrit calculations and overall anemia evaluation, making accurate HGB chamber maintenance essential for patient diagnosis.

Research Objective

The main objective of this study is to investigate the role of quality control and standardization in hematology analyzers and to evaluate how technical, mechanical, and analytical errors influence the accuracy and reliability of laboratory results.

In particular, this research aims to: analyze the working principles of key hematology analyzer modules such as the flow cell, PLT/RBC impedance electrode system, and WBC/HGB measurement chambers; determine the impact of calibration errors on analytical accuracy and result stability; evaluate the influence of reagent quality, maintenance procedures, and system stability on CBC and differential blood count results. Identify the most common sources of technical errors in hematology analyzers, including fluidic system failures, optical disturbances, and electrical instability assess the effectiveness of internal quality control (IQC) and external quality control (EQC) systems in minimizing analytical deviations; propose practical approaches for improving standardization, reducing measurement uncertainty, and enhancing diagnostic reliability in clinical laboratory practice.

Furthermore, the study focuses on demonstrating, through practical and technical analysis, how even minor deviations in analyzer components can lead to significant diagnostic errors, potentially affecting clinical decision-making and patient safety.

1. Hematology Analyzers: Principles and Clinical Importance

Hematology analyzers are highly sophisticated automated diagnostic systems that play a central role in modern clinical laboratory medicine. These instruments are designed to perform rapid, high-throughput, and precise analysis of blood samples, providing critical parameters such as red blood cell (RBC) count, white blood cell (WBC) count, platelet (PLT) count, hemoglobin (HGB), hematocrit (HCT), and red cell indices (MCV, MCH, MCHC).

The working principles of hematology analyzers are based on a combination of physical and biochemical detection methods:

- **Electrical impedance (Coulter principle):** Used primarily for RBC and PLT counting, where cells passing through an aperture generate electrical pulses proportional to their volume.
- **Optical light scattering and flow cytometry:** Used for WBC differentiation, enabling classification of leukocyte subpopulations based on size and internal complexity.
- **Photometric analysis:** Used for hemoglobin measurement through absorbance of specific wavelengths.

These analytical processes rely on precise coordination between internal subsystems, including fluidics, electronics, optics, and software algorithms. Any deviation in these systems can significantly affect analytical outcomes.



Figure 1. Hematology analyzer Yumizen H550 in Laboratory.

One of the most critical yet often underestimated factors influencing analyzer performance is the condition of internal spare parts such as the flow cell, WBC/HGB chambers, and impedance electrodes. These components are directly involved in sample processing and signal generation.

Such deterioration introduces both systematic errors (bias) and random errors (precision loss). Therefore, continuous monitoring, preventive maintenance, and timely replacement of these components are essential to maintain analytical reliability and compliance with laboratory quality standards.

2. RBC / PLT Electrodes: Function and Analytical Role.

RBC and platelet (PLT) electrodes are fundamental components of hematology analyzers that operate based on the electrical impedance principle, also known as the Coulter principle. In this system, blood cells suspended in an electrolyte solution pass through a small aperture between two electrodes. Each cell displaces a specific volume of electrolyte, generating a measurable electrical pulse. The magnitude of this pulse is directly proportional to the volume of the cell, allowing accurate determination of both red blood cells and platelets.

The electrodes play a critical role in maintaining a stable electrical field across the aperture. This stability ensures that each cell generates a consistent and distinguishable signal. Under ideal conditions, the analyzer can accurately differentiate between RBC and PLT populations based on pulse amplitude distribution. However, the performance of this system is highly dependent on the physical and chemical condition of the electrodes and the aperture zone.

Over time, electrodes are exposed to continuous electrical activity and biological material, leading to gradual degradation. One of the most common issues is oxidation of the electrode surface, which reduces conductivity and weakens the electrical signal. This results in lower pulse amplitude and unstable baseline readings. As a consequence, the analyzer may incorrectly interpret cell sizes, leading to inaccurate RBC and PLT counts.

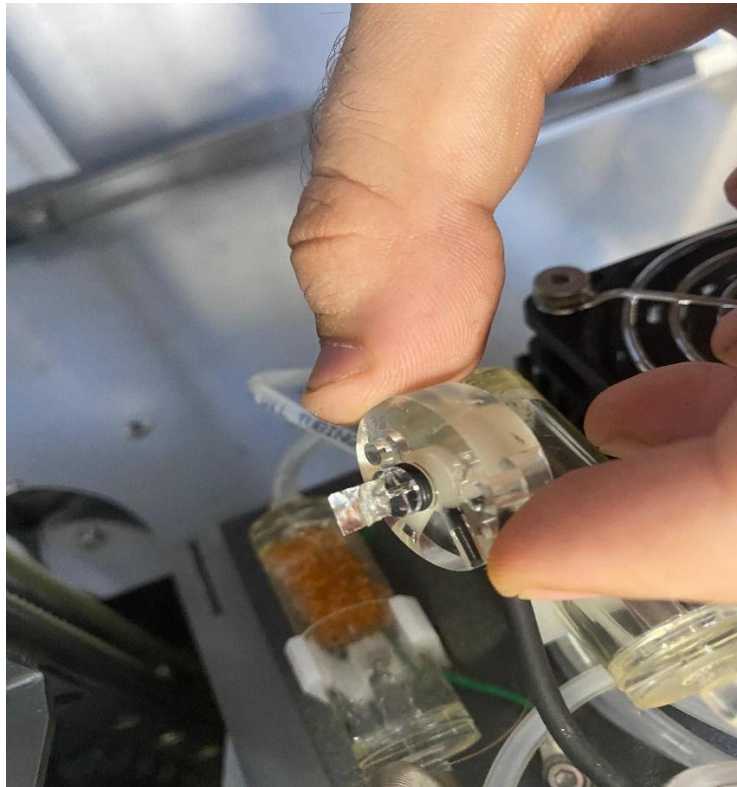


Figure 2. Replacement PLT/RBC electrode in Hematology analyzer.

RBC and PLT electrodes are essential for maintaining the electrical accuracy of hematology analyzers. Their condition directly influences impedance signal quality, cell discrimination, and overall analytical reliability. Regular maintenance, cleaning, and timely replacement are necessary to prevent analytical errors and ensure high-quality laboratory results that support accurate clinical decision-making.

RBC Calculation

Reference Value: $RBC = 4.8 \times 10^{12}/L$

Before Electrode Replacement:

5.5, 5.6, 5.7, 5.6, 5.5, 5.7, 5.6, 5.5, 5.6, 5.7

$$\text{Mean} = \frac{56.0}{10} = 5.6$$

$$\text{Bias} = \frac{5.6 - 4.8}{4.8} \times 100 = 16.7\%$$

After Electrode Replacement:

4.8, 4.9, 4.7, 4.8, 4.9, 4.8, 4.8, 4.9, 4.7, 4.8

$$\text{Mean} = 4.81$$

$$\text{Bias} = \frac{4.81 - 4.8}{4.8} \times 100 = 0.2\%$$

3. WBC and HGB Chambers: Structure, Function, and Analytical Impact.

The WBC and HGB chambers are fundamental components of hematology analyzers, playing a critical role in the preparation and measurement of blood samples. These chambers are integrated within the fluidic system of the analyzer and are responsible for ensuring that the sample undergoes precise dilution, chemical treatment, and measurement under controlled conditions. Their proper functioning is essential for achieving accurate and reproducible results, particularly for white blood cell counting and hemoglobin determination. WBC chamber is primarily designed to facilitate the selective lysis of red blood cells while preserving white blood cells for accurate counting and differentiation. This process relies on the use of specialized reagents that break down erythrocyte membranes without significantly altering leukocyte structure. The chamber ensures that the sample is diluted to an optimal concentration and that cells are uniformly distributed before entering the detection system. Any deviation in this process, even at a microfluidic level, can lead to significant analytical errors.



Figure 3. Replacement WBC/HGB chamber in Hematology analyzer.

Over time, the WBC chamber is exposed to repeated cycles of biological samples and chemical reagents, which can result in contamination, residue accumulation, and mechanical degradation. One of the most common issues is incomplete red blood cell lysis, which occurs when the reagent reaction is insufficient or when residues interfere with chemical activity. In such cases, remaining erythrocytes may be mistakenly counted as leukocytes, leading to falsely elevated WBC values. Conversely, if leukocytes adhere to the chamber walls due to surface contamination or protein buildup, the measured WBC count may be falsely decreased.

HGB Calculation

Reference Value:

HGB = 14.0 g/dL

Before Chamber Replacement:

12.8, 13.0, 12.9, 13.1, 12.7, 12.8, 13.0, 12.9, 12.8, 13.0

Mean = 12.9

SD \approx 0.12

CV = 0.93%

$$\text{Bias} = \frac{12.9 - 14.0}{14.0} \times 100 = -7.8\%$$

After Replacement:

13.9, 14.0, 14.1, 14.0, 13.9, 14.1, 14.0, 14.0, 13.9, 14.0

Mean = 14.0

SD \approx 0.07

CV = 0.5%

$$\text{Bias} = \frac{14.0 - 14.0}{14.0} \times 100 = 0\%$$

4. Flow Cell: Structure, Function, and Impact on Leukocyte Differential

The flow cell is a central component of hematology analyzers, particularly in systems that utilize optical or laser-based detection methods for leukocyte analysis. Its primary function is to ensure the controlled and uniform passage of cells through the detection zone, where optical signals such as forward scatter and side scatter are measured. This process enables the classification of leukocytes into distinct subpopulations, commonly referred to as the 5-differential (5-DIFF), which includes neutrophils, lymphocytes, monocytes, eosinophils, and basophils.

5-DIFF Parameters:

- NEUT (Neutrophils)
- LYMPH (Lymphocytes)
- MONO (Monocytes)
- EOS (Eosinophils)
- BASO (Basophils)

The operation of the flow cell is based on hydrodynamic focusing, a principle in which the sample stream is surrounded by a sheath fluid that narrows and aligns the cells into a single-file stream. This alignment is crucial for ensuring that each cell passes individually through the laser beam, allowing accurate measurement of its physical and structural properties. The flow cell contains microfluidic channels, optical windows, and detection interfaces, all of which must remain clean and precisely aligned to maintain optimal performance.

Despite its precision design, the flow cell is highly susceptible to contamination and mechanical degradation. Continuous exposure to blood samples and reagents leads to the gradual accumulation of protein deposits, fibrin, and other biological materials on the internal surfaces. These deposits disrupt the laminar flow of cells, causing irregular trajectories and inconsistent signal detection. As a result, the scatter patterns generated by the analyzer become distorted, making it difficult to accurately distinguish between different leukocyte populations.



Figure 4. Flow cell in Hematology analyzer.

Another common issue is the formation of microbubbles within the flow cell. Air bubbles can interfere with the optical path by blocking or scattering the laser beam, leading to signal loss or noise. This results in incomplete or inaccurate detection of cells, further compromising the reliability of the analysis. Additionally, physical damage such as micro-scratches on the optical surfaces can alter the direction and intensity of light, affecting both forward and side scatter measurements.

Partial clogging of the flow cell channels is also a significant concern. Even minor obstructions can disrupt the uniform flow of cells, causing fluctuations in signal intensity and increasing measurement variability. In severe cases, clogging may prevent cells from reaching the detection zone altogether, resulting in falsely low counts or abnormal distribution patterns. From an analytical perspective, flow cell degradation introduces both systematic and random errors. Systematic errors are reflected as consistent bias in leukocyte differential counts, while random errors are observed as increased variability and poor reproducibility. For example, under normal conditions, neutrophils may account for approximately 60% of total leukocytes, while lymphocytes represent around 30%. When the flow cell is compromised, neutrophils may falsely increase to 68%, while lymphocytes decrease to 22%, indicating a significant analytical shift. This corresponds to a bias exceeding 10–25%, depending on the severity of contamination.

After proper maintenance or replacement of the flow cell, the system typically returns to its reference performance, with clear scattergram separation and accurate leukocyte classification. Bias values reduce significantly, often to below 2%, and the coefficient of variation also stabilizes, confirming improved precision and reliability. Therefore, the integrity of the flow cell is essential not only for optical accuracy but also for clinical reliability, as incorrect leukocyte differentiation may directly affect diagnostic decisions related to infections, inflammatory conditions, and hematologic disorders.

5. Problems and Solutions.

The performance of hematology analyzers is strongly influenced by the condition of their internal mechanical, optical, and electrical components. Although modern analyzers are highly automated and precise, they remain sensitive to wear, contamination, and degradation of critical spare parts such as the flow cell, WBC/HGB chambers, and RBC/PLT electrodes. Over time, these issues introduce both systematic and random analytical errors, which can significantly affect diagnostic accuracy. Therefore, understanding the main problems associated with these components and implementing appropriate solutions is essential for maintaining reliable laboratory performance.

One of the most frequent problems observed in hematology analyzers is contamination of internal pathways. In the flow cell and chamber systems, repeated exposure to biological samples leads to the accumulation of proteins, fibrin, cellular debris, and reagent residues. This contamination gradually alters fluid dynamics and optical or electrical signal transmission. As a result, cells may not flow in a uniform manner, and detection signals become distorted. In optical systems, this leads to blurred or overlapping scattergrams, while in impedance systems it results in unstable pulse formation. The analytical consequence of this problem is an increase in measurement bias and reduced precision, particularly in leukocyte differentiation and platelet counting. Another significant issue is mechanical wear and structural degradation of components. Flow cells may develop micro-scratches on optical surfaces, while chamber walls may lose their hydrophobic properties due to prolonged chemical exposure. These physical changes disrupt the controlled environment required for accurate measurement. Even minor structural damage can lead to changes in signal intensity or flow resistance, which directly impacts analytical reproducibility. In severe cases, partial obstruction or microchannel narrowing may occur, leading to intermittent measurement errors or complete system blockage.

Electrical instability is a major problem in RBC and PLT electrode systems. Electrodes are continuously exposed to electrical currents and electrolyte solutions, which over time can lead to oxidation, corrosion, and surface degradation. This reduces conductivity and causes fluctuations in baseline signal levels. As a result, the analyzer may misinterpret pulse amplitudes, leading to incorrect cell size classification. This problem is particularly critical for platelet analysis, where small changes in signal intensity can significantly alter results due to the small size of platelets.

Conclusion

This study highlights the critical importance of internal spare parts in determining the analytical performance, accuracy, and reliability of hematology analyzers. The evaluation of key components such as the flow cell, WBC/HGB chambers, and RBC/PLT electrodes demonstrates that even minor mechanical, optical, or electrical degradation can significantly affect laboratory results and lead to clinically relevant errors.

The obtained results clearly show that deterioration of these components introduces both systematic and random errors. Before replacement, significant analytical bias was observed across all major hematological parameters. For instance, RBC measurements exhibited deviations of approximately 15–17%, platelet counts showed errors reaching nearly 30%, WBC results demonstrated bias exceeding 20%, and hemoglobin values were underestimated by around 7–8%. In addition, leukocyte differential analysis (5-DIFF) was severely affected due to flow cell dysfunction, resulting in incorrect separation of cell populations and distorted scattergram patterns.

These analytical deviations are not only statistically significant but also clinically critical. Misinterpretation of hematological parameters may lead to incorrect diagnosis of conditions such as anemia, thrombocytopenia, infections, or hematological malignancies. Therefore, the reliability of hematology analyzers is directly dependent on the integrity of their internal components.

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INFLUENCE OF ANTISTATIC TREATMENT ON PHYSICAL AND MECHANICAL PROPERTIES OF BLENDED FABRIC

Yerikzhan Akhmetov

Master's student

ORCID: 0009-0007-5059-9903

Indira Jurinskaya

PhD, Associate Professor

ORCID: 0000-0002-3607-2001

Balaussa Berdibek

Bachelor student

Assemgul Burkitbay

Ph.D., Acting Associate Professor

ORCID: 0000-0002-1467-5354

Almaty Technological University, Almaty, Kazakhstan

Abstract

The accumulation of static electricity in synthetic and blended textile materials remains a persistent challenge in the textile industry, adversely affecting the hygienic properties, consumer comfort, and operational safety of garments, particularly in environments with low humidity or where workers are exposed to sensitive electronic equipment. Polyester/cotton blended fabrics, owing to their widespread use in workwear and functional apparel, are particularly susceptible to electrostatic charge buildup, as the polyester component is inherently hydrophobic and exhibits poor charge dissipation. This study presents an investigation into the antistatic finishing of a polyester/cotton blended fabric (article TC-1032, 65/35 wt.%) using a three-component aqueous finishing composition comprising polyethylene glycol-400 (PEG), cetrimonium chloride (CC), and polyvinyl alcohol (PVA). Three concentration levels were examined: Concentration I (PEG 2.5 wt.%, CC 2.5 wt.%, PVA 0.8 wt.%), Concentration II (PEG 5.0 wt.%, CC 5.0 wt.%, PVA 1.6 wt.%), and Concentration III (PEG 10.0 wt.%, CC 10.0 wt.%, PVA 3.2 wt.%). The fabric was treated by the pad-dry-cure method: impregnation by immersion, padding to a wet pick-up of 80–90%, drying at 70°C for 15 minutes, and thermal fixation at 180°C for 1–2 minutes. The electrostatic charge was measured using an MT-403 electrometer in accordance with SanPiN 2.4.7/1.1.1286, calculated as the difference between the potential at rest and the potential after roller friction. Tensile strength was evaluated according to GOST 3813, and pilling resistance was assessed by the Martindale method (ISO 12945-2) after 2000 abrasion cycles using a five-point scale. Wash durability of the antistatic effect was evaluated after five standard laundering cycles. The results demonstrated that all three concentration levels produced a measurable reduction in electrostatic charge. The most pronounced effect was achieved at Concentration III, where the electrostatic potential decreased from 3.76 kV/m to 1.36 kV/m, representing a reduction factor of 2.8. This improvement is attributed to the formation of a dense hydrophilic coating on the fibre surface through the combined action of PEG (hygroscopic agent), CC (cationic surfactant), and PVA (film-forming binder). Wash durability testing confirmed that the antistatic effect is largely retained after five laundering cycles, with the charge increasing by only 0.01 kV/m at the lowest concentration. Assessment of mechanical properties revealed that tensile strength decreased by 6 to 13% depending on concentration, with all values remaining within the acceptable range for apparel applications. Pilling resistance improved significantly from an initial grade of 3 to grades 4–5, attributed to the protective film deposited by PVA on the fibre surface, which inhibits the formation of pills during wear and laundering. The proposed finishing technology is straightforward to implement, requires commercially available components, and produces durable antistatic and improved mechanical properties, making it well-suited for industrial application in the production of workwear, medical textiles, and functional apparel where both electrostatic safety and mechanical durability are critical requirements.

Keywords: antistatic treatment, blended fabric, polyethylene glycol, cetrimonium chloride, pilling resistance, electrostatic properties.

Introduction

Synthetic and blended fabrics are widely used in garment production due to their high performance characteristics. However, their tendency to accumulate static electricity is a significant drawback that deteriorates the hygienic properties and consumer qualities of textile products [1, 2]. One promising

solution is antistatic finishing using compositions based on polyethylene glycol (PEG) and cationic surfactants [3].

Beyond confirming the reduction of electrostatic charge, it is equally important to assess how such treatment affects the physical and mechanical properties of the fabric — specifically tensile strength and pilling resistance. A comprehensive evaluation of these properties is the objective of this work.

Materials and Methods

Test material: blended fabric, article TC-1032 (65 wt.% polyester / 35 wt.% cotton), plain weave. The finishing composition (wt.%) is shown in Table 1.

Table 1 — Finishing composition

Component	Concentration I, wt.%	Concentration II, wt.%	Concentration III, wt.%
Polyethylene glycol-400 (PEG)	2.5	5.0	10.0
Cetrimonium chloride (CC)	2.5	5.0	10.0
Polyvinyl alcohol (PVA)	0.8	1.6	3.2

Treatment procedure: all components were dissolved in demineralised water at 40–50 °C (PEG and PVA first, then CC added under stirring). The fabric was impregnated by immersion, padded to a wet pick-up of 80–90 %, dried at 70 °C for 15 min, and thermally fixed at 180 °C for 1–2 min.

Electrostatic charge was measured using the MT-403 device (per SanPiN 2.4.7/1.1.1286) as: $E = E_r - E_v$, where E_r is the potential at rest and E_v is the potential after roller friction.

Tensile strength was measured per GOST 3813; pilling resistance per ISO 12945-2 (2000 cycles).

Results and Discussion

Electrostatic charge measurements are presented in Table 2.

Table 2 — Electrostatic charge of the fabric

PEG / CC / PVA, wt.%	Untreated fabric E , kV/m	Treated fabric E , kV/m	Reduction, kV/m
2.5 / 2.5 / 0.8	0.45	0.29	0.16
5.0 / 5.0 / 1.6	1.30	0.14	1.16
10.0 / 10.0 / 3.2	3.76	1.36	2.40

Antistatic finishing reduced electrostatic charge across all concentration levels. The greatest effect was achieved at PEG — 10.0 wt.%, CC — 10.0 wt.%, PVA — 3.2 wt.%, due to the formation of a denser hydrophilic layer on the fibre surface that promotes charge dissipation.

Wash durability results are shown in Table 3. Tensile strength and pilling results are shown in Tables 4 and 5.

Table 3 — Wash durability of the antistatic effect (PEG — 2.5 wt.%, CC — 2.5 wt.%, PVA — 0.8 wt.%)

Condition	E_r , kV/m	E_v , kV/m	E , kV/m
Untreated fabric	2.58	3.03	0.45
After treatment	1.61	1.90	0.29
After 5 washes	1.41	1.71	0.30

The negligible change in electrostatic charge (from 0.29 to 0.30 kV/m) after five washing cycles confirms the high durability of the finishing under repeated laundering conditions.

Table 4 — Tensile strength of the fabric

PEG / CC / PVA, wt.%	Tensile strength, N
Untreated sample	815
2.5 / 2.5 / 0.8	760
5.0 / 5.0 / 1.6	720
10.0 / 10.0 / 3.2	710

The reduction in tensile strength ranges from 6 to 13 % relative to the untreated sample. These values remain within acceptable limits and do not compromise the mechanical integrity required for garment applications.

Table 5 — Pilling resistance (2000 cycles, grade on 1–5 scale)

PEG / CC / PVA, wt.%	Pilling resistance, grade
Untreated sample	3
2.5 / 2.5 / 0.8	4
5.0 / 5.0 / 1.6	5
10.0 / 10.0 / 3.2	5

Antistatic treatment improved pilling resistance from grade 3 (moderate pilling) to grade 4–5 (slight to no pilling). This improvement is attributed to the protective film formed by PVA on the fibre surface, which reduces the tendency of fibres to tangle and form pills.

Conclusions

The study demonstrated that finishing a polyester/cotton blended fabric (65/35 wt.%) with a composition of polyethylene glycol-400, cetrimonium chloride, and polyvinyl alcohol achieves the following:

1. Electrostatic charge reduced by a factor of 1.1–2.8 depending on concentration, with the effect retained after 5 washing cycles.

2. Pilling resistance improved from grade 3 to grade 4–5.

3. Tensile strength decreased by no more than 13 %, remaining within acceptable limits for apparel use.

The simplicity of the process and the availability of the components make this method a promising candidate for industrial application, particularly in the production of workwear and functional textiles.

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