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DIRECTIONS FOR IMPROVING BUDGETARY AND TAX POLICY IN ENSURING FINANCIAL SECURITY

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Abstract

A financial and economic security system is one of the most important conditions for the effective functioning and development of both business and government activity in the country. The financial and economic security of economic entities and the state is a complex system, encompassing a set of internal and external indicators aimed at the efficient use of resources. Currently, the management of financial resources and the optimization of their use, as well as the use of financial instruments aimed at ensuring stable and efficient financial and economic processes, are becoming increasingly important. This article examines financial security at the micro and macro levels. It identifies factors influencing financial security that must be considered in the financial and economic activities of economic entities and the implementation of state financial policy.

Keywords: *financial security, budget-tax system, financial policy, globalization process, financial markets, state budget, budget funds, budget policy, inflation.*

Introduction

The integration of the Azerbaijani economy into the world economy, the change in the balance of power in the world, and the increase in competition in the global market make the problems of ensuring economic security even more urgent. One of the most important components of the country's economic security is financial security. Without the stable functioning of the country's financial system and financial market, it is impossible to expand the economic and scientific potential necessary to ensure Azerbaijan's worthy place in the world economy.

In recent years, the globalization process in the world has begun to have an increasingly strong impact on the stability of the national financial system and financial market in many countries, including Azerbaijan. As a result of the globalization process, the world financial market has grown progressively and the mobility of production factors has increased significantly. As a result, the financial sector is beginning to play a more important role in economic development than before, which poses a potential threat to macroeconomic stability and the stability of national financial systems.

The increasing interconnection and interdependence of national financial markets and the emergence of new financial instruments have led to an increase in the speed of financial flows between countries. As a result of the activities of transnational financial institutions, which are beyond the control of national governments, the volume of financial resources moving has begun to increase significantly. Opportunities for speculative operations unrelated to real production are increasing. Economic operations are increasingly becoming global in nature, which expands the possibilities for tax evasion and money laundering.

With the increasing integration of Azerbaijan into the world economy, the threats to the sustainable functioning of the national financial system created by globalization are increasing due to the weakness of the national banking system, significant imbalances in the development of individual sectors of the stock market, insufficient development of financial infrastructure, insufficient level of economic and financial legislation, and the increase in the "intellectualization" of financial crimes. The Azerbaijani economy, which has not yet completed its modernization with its increased openness to the world market, is becoming more vulnerable to various types of financial threats, and their identification, prediction, prevention and neutralization are becoming an important state task. Without addressing

these threats, it is impossible to ensure the sustainable development of the country and strengthen its economic security.

Thus, ensuring financial security is of critical importance for the economic and social development of every country, which aims to protect the health of financial systems, ensure economic stability, and increase the overall well-being of the country.

Discussion

One of the most important components of ensuring the economic security of the state is the formation of financial security, which determines not only the current well-being of the state, but also its long-term development prospects.

Financial security contributes to the preservation and stabilization of statehood as a whole, the determination of priority directions of state policy and sovereignty.

Today, we are witnessing fundamental changes both in the Azerbaijani economy and in the global financial and economic system as a whole. Large-scale changes are taking place in the direction of trade flows, global financial and payment systems are taking on a new shape under the influence of new digital technologies, and transformations in energy, transport, as well as many other economic sectors are becoming inevitable. At the same time, after a period of rapid globalization, regionalization and localization have intensified, especially in the areas of important goods and technologies, food and energy. In general, governments have become increasingly aware of the importance of their independence and non-dependence in making economic decisions.

The changes taking place in the world economy also affect the Azerbaijani economy, and this prompts us to carefully analyze the emerging difficulties and opportunities, to find adequate responses to current challenges. Numerous negative social, political and economic events require states to have an effective financial strategy and ensure financial security. Fiscal and financial policy plays a key role in this area by creating the necessary conditions and incentives for sustainable socio-economic development in the changes taking place.

One of the priority tasks of the state's economic development is to ensure financial stability, prosperity of the population and a high standard of living. It is through the use of budget regulation mechanisms, investments and other extra-budgetary sources that the state can regulate the activities of economic entities, ensure the solution of socio-political problems and support the well-being of citizens.

On the one hand, the state budget is an instrument for implementing state policy in the field of financial security, and on the other hand, it reflects the main directions of the state's financial and economic development. By planning and allocating the main resources, the state determines the directions of spending funds, the characteristics of the implementation of monetary funds in the process of determining priorities, and creates the necessary conditions for sustainable economic development.

Proper allocation and use of budget funds allows the state to ensure the stability of the economy, social protection, infrastructure development, scientific and technical progress and other areas of development.

The state budget of each country plays an important role in supporting the country's economic growth and financial security, since it is through the budget that the state invests in various sectors of the economy, infrastructure, scientific and research work and other priority areas. The state budget helps to maintain economic stability, create conditions for growth and innovation, and at the same time, the state apparatus and local self-government bodies, exercising their powers to form centralized funds (budget funds) of public legal entities, distribute and use resources, and act as the main subject of ensuring financial security.

In our opinion, the functions of the state budget are reflected in the following aspects:

- the ability to plan and regulate income and expenses by specifying and redistributing the sources of budget revenues for various budget items and areas of activity of the state. In this context, it becomes possible to efficiently distribute and receive state budget funds, study budget funds and areas of their allocation;

- the state budget is a financial control mechanism and a mechanism for ensuring transparency in the distribution of funds between regions, expenditure items, and economic entities. The process of controlling the implementation of the budget is necessary to prevent financial violations, including corruption, as well as to ensure the responsible use of state funds.

- the maximum importance of the size of the budget is in the areas of social protection, culture, education and healthcare. It is through the state budget that the distribution of state revenues is carried out for the implementation of social projects and programs, social and pension provision, culture, sports, education and youth policy. The state budget funds are directed to financing the provision of basic areas

of life in order to assist and support low-income and needy segments of the population.

The size and adequacy of the state budget help determine the level of welfare of the budgetary sphere and the prospects for economic development. The same The current situation, globalization and various negative socio-economic and political events significantly affect the formation of the state budget, as well as ensuring the financial security of the state. This necessitates the development of mechanisms that ensure the financial security of the state and budget distribution tools.

One of the most important directions of state policy in ensuring the financial security and stability of the state, in addition to budget financing, is the development and implementation of investment projects and programs aimed at supporting various areas of industry, production, science. This creates maximum opportunities for low-income economic entities and non-profit organizations to operate stably, to assist their development and provide high-quality services and to sell essential goods. This, in turn, makes these products as accessible as possible to low-income and needy groups of the population, and at the same time creates conditions for the functioning of important social institutions such as the family, educational institutions, and healthcare institutions. All this is an integral part of ensuring the national security of the state and a decent standard of living for the population.

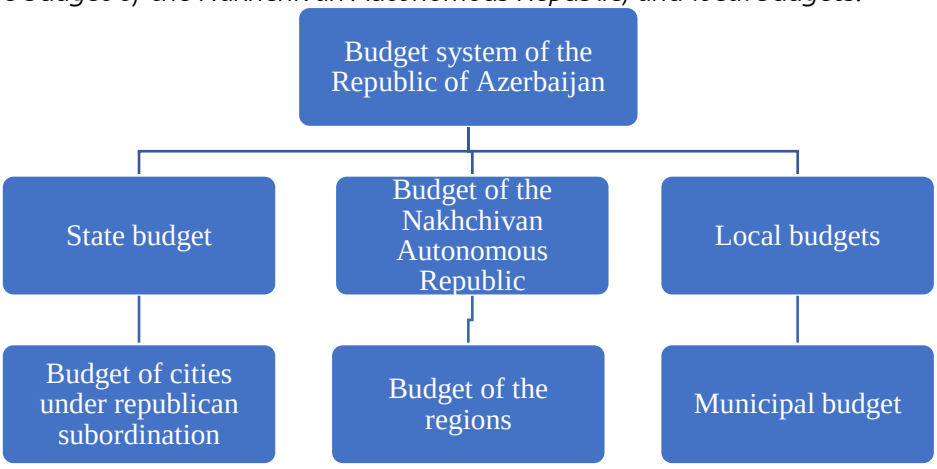
One of the important issues at the present time is to determine the role of the budget policy of Azerbaijan in ensuring the financial and technological sovereignty of the country within the framework of the modern economic model.

The budget policy of Azerbaijan is determined by the Constitution of the Republic of Azerbaijan and the Budget Code of the Republic of Azerbaijan (a set of laws defining the functions and legislative acts of individual bodies in the budget process).

Budget policy should solve the following tasks:

- determining the sources of income of the state budget;
- ensuring the conditions for the formation of all possible financial sources;
- determining the appropriate distribution and use of financial resources;
- determining the structure of the consumption part of the budget;
- determining the amount of expenses that are allocated between budgets of different levels;
- forming, regulating and stimulating economic and social processes through financial methods;
- determining the specific weight of the state budget in the general consolidated budget;
- determining the goals of public debt management;
- determining the budget deficit or surplus;
- establishing a financial mechanism and developing it in accordance with changing goals and objectives.

The budget system in the Republic of Azerbaijan consists of the state budget of the Republic of Azerbaijan, the budget of the Nakhchivan Autonomous Republic, and local budgets.



Scheme 1. State budget system of the Republic of Azerbaijan
Source: compiled by the author.

The purpose of the state budget system of the Republic of Azerbaijan is to solve economic, social and other strategic goals and problems in accordance with the procedure established by law and to ensure the accumulation and use of financial resources for the implementation of state functions.

The state budget system of the Republic of Azerbaijan consists of centralized revenues and expenditures, local revenues and expenditures

The budget system of the Nakhchivan Autonomous Republic is determined by the Constitutions of

the Republic of Azerbaijan and the Nakhchivan Autonomous Republic, as well as legislative acts. The budget of the Nakhchivan Autonomous Republic is formed at the expense of state taxes, other payments, interest and penalties calculated on these taxes and payments, as well as other income established by the Tax Code of the Republic of Azerbaijan. The funds of the budget of the Nakhchivan Autonomous Republic are directed to financing measures related to the socio-economic development of the Autonomous Republic and improving the well-being of the population.

The local budget is a financial resource formed and used in accordance with the status of a local self-government body to implement the principles of self-government and exercise the powers established by the Constitution and laws of the Republic of Azerbaijan. The preparation and execution of the local budget is carried out in accordance with the general principles of the budget system and the budget classification applied in the Republic of Azerbaijan.

The budget system of the Republic of Azerbaijan has recently undergone a serious stress test in connection with the coronavirus pandemic, which required significant efforts to strengthen the healthcare system and support the economy. During this period, the stability of state finances was maintained, and the growth of state debt was very low compared to other major economies. In the last two years, the importance of the budget has increased in ensuring the defense of the state, along with maintaining macroeconomic stability and creating favorable conditions for economic and social development.

Throughout the modern history of Azerbaijan, the country's economy has regularly developed in conditions of fluctuations in world markets, which required adequate responses from the country's budget system. Back in 2004, budget rules regulating the use of oil and gas revenues were introduced and the State Oil Fund was established. This structure was intended to accumulate budget reserves for use in unfavorable economic conditions during periods of high energy prices. Thus, in general, this mechanism, established twenty years ago, remains the cornerstone of Azerbaijan's budget policy. Just a few years after its creation, during the global financial crisis of 2008-2009, it convincingly demonstrated its effectiveness.

After the fluctuations in the world economy associated with the financial crisis of 2008, global structural changes began to occur. Thus, in 2014, the Azerbaijani economy faced several external shocks. Against the background of the "Shale Revolution" in the United States, the rapid increase in global oil supply on the world energy market led to a rapid decline in oil prices, which created major risks for Azerbaijan's budget revenues.

In response to these challenges, a number of fiscal and tax reforms were implemented in a short period of time. These reforms, in addition to overcoming the difficulties of the period, also supported structural changes in the economy and laid the foundation for the efficient and stress-resistant budget system that exists today.

The first stage of these reforms began in the five-year period from 2014 to 2019, during which the country implemented a package of anti-crisis measures, consolidated the budget system, and ensured the financing of strategically important national development goals, fully adapted to the changed conditions. It should be noted that in 2014, the price of "Brand" crude oil, which balanced the state budget, was slightly below $ 100 per barrel. This meant that the volume of obligations assumed in the favorable commodity market conditions observed in the previous period would continue. However, the situation turned out to be completely different. During this period, the price of a barrel of branded crude oil in the global energy market almost halved, from $ 105 in January 2014 to $ 42 in January 2015, and as a result, our country's budget revenues decreased sharply. There were significant decreases in the volume of foreign currency from energy exports, which led to a sharp depreciation of the manat. Thus, as a result of the decline in oil prices on the world market in 2014, as mentioned above, the decrease in oil revenues sharply reduced the inflow of foreign currency into our country, and the manat exchange rate depreciated due to the demand for dollars exceeding the supply in the country's economy. The pressure on the country's currency has increased significantly. As a result, in 2015, in order to regulate the situation in the domestic currency market, the stability of the country's balance of payments and international solvency, the manat was devalued twice. After these developments in the financial sector, a decrease in activity began to be observed in the country's banking sector.

2015-2016 was a period of active adaptation to new budget conditions, primarily to hydrocarbon prices. The fiscal policy implemented to support economic activity was of a stimulating nature (in 2015 and 2018, the consolidated budget deficit was 7.9% and 2.6% of GDP, respectively, compared to 1.1% of GDP in 2014). The funds accumulated in the Oil Fund made it possible to maintain a soft fiscal policy in a period of declining budget revenues. At the same time, efforts were made to recapitalize the banking

system using credit bonds in order to maintain financial stability.

In response to these challenges, a number of fiscal reforms were implemented in a short period of time, and in 2016, the main Strategic Roadmap for the National Economy of the Republic of Azerbaijan was adopted. As a result of the reforms, the main goal of the state was to reduce allocations from the State Oil Fund during the formation of the state budget and create mechanisms for the effective use of budget expenditures. These reforms not only helped to overcome the difficulties of that time, but also supported structural changes in the economy and laid the foundation for the efficient and crisis-resistant budget system that exists today.

The next important step was the implementation of the budget consolidation program, which began in 2017 and whose structure was to ensure the long-term sustainability of economic growth. In the course of the budget consolidation program, measures to increase the efficiency of expenditures, which is the main factor in reducing the non-oil and gas budget deficit, were given an important role. In addition, improved tax administration allowed for an increase in budget revenues without revising the base taxes.

During this period, the government implemented a number of measures related to both the management of budget revenues and increasing the efficiency of budget expenditures.

It is important to analyze the steps taken in recent years to improve the budget policy of Azerbaijan and identify the main results achieved. To achieve these goals, the following tasks should be solved in the budget system:

- achieving sustainability and balance in the state budget system;

- increasing the efficiency of budget expenditures;

- combating abuse and embezzlement of state funds, corruption, the shadow and criminal economy, and improving financial discipline.

In terms of ensuring financial security, such features of the budget system as sustainability, balance and efficient use of budget funds are of great importance. Let us pay attention to the characteristics of the Budget system formed under the influence of external factors (Table 1).

Table 1. Characteristics of the budget system

Budget system sustainability	*The ability to take into account the changing conditions of objective reality and respond to changes in the environment without changing the basic characteristics and parameters through mechanisms for redistributing financial resources.*
Balancing the volume of revenues and expenditures of the budget system	*Taking into account all necessary conditions and objective needs while maintaining the principles of priority. Balancing income and expenditure volumes ensures the solvency of state institutions.*
Budget system effectiveness	*Achieving target indicators based on the country's socio-economic priorities*

Source: compiled by the author.

The budget system plays a decisive role in ensuring economic security. Therefore, a sufficiently efficient system for the distribution of state budget funds should be developed. In our research, the importance of the budget system in ensuring financial security is analyzed, the economic security goals solved within the budget system are determined, the levels of the budget system are determined, and priority financing directions are determined in accordance with the national interests of Azerbaijan. The objectives of the research are to determine the importance of the budget system in ensuring financial security.

The budget system performs important functions such as economic, legal, socio-political, social categories, and ensures stability in the implementation of economic and social programs. The main functions of the state budget system are as follows:

- financing social and economic programs;

- ensuring the independence of financial and economic activities;

- strategic planning of socio-economic development;

- supporting the stable development of priority sectors of the economy.

The main mechanism for ensuring economic security is economic growth, and the budget system plays a leading role in creating conditions for this. The state budget system provides financial resources for the development of priority economic sectors and support for economic growth based on the determination of national priorities. The principle of targeted financing of the budget system operates in the field of ensuring economic security through national projects. At the same time, systematic projects are being implemented in the country to support the economy and stimulate economic growth: small and medium-sized businesses, support for individual entrepreneurial initiatives, digital economy, support for labor productivity and employment, international cooperation and export.

The state of the financial system is an important component of economic security and is able to provide the economic system with the necessary resources for economic growth. The budget system, as the primary form of regulation of state budget relations, forms socio-economic relations and performs important regulatory functions of the state's domestic policy, regulates the financial activities of budget institutions, banking institutions, controls the payment of benefits and wages, financial discipline and the implementation of targeted financing.

The adopted new budget rule has had a significant impact on strengthening macroeconomic stability through several channels. First of all, it improved the countercyclical properties of the budget policy, so that despite fluctuations in oil prices, the level of budget expenditures should remain stable and predictable. In addition, the impact of the oil price on the manat exchange rate was significantly reduced through the mechanism of buying and selling foreign exchange assets during deviations between the actual price and the base price. Finally, by choosing a conservative cut-off for the base price of oil, the dependence of the budget system on oil and gas revenues was reduced.

The second important goal of budget consolidation was to increase non-oil and gas budget revenues without increasing the tax burden on taxpayers. To achieve this, it was necessary to improve the quality of tax administration and remove potential taxpayers from the shadows, as a result of which the collection of value-added tax significantly increased.

Thus, on the one hand, the convenience and quality of tax services increased, and on the other hand, control over taxpayers was strengthened through the use of information technologies. The main goal of the reforms was to ensure a fair distribution of the tax burden among economic participants.

In addition to the reforms discussed above, work has been carried out in many other areas of budget and tax policy. As a result of the reforms implemented, a consolidated budget surplus was created in 2022, which amounted to 3.0% of GDP. The non-oil and gas budget deficit increased from a specific weight of 16% of GDP in 2010 to 29%. During this period, public debt increased from 12% in 2010 to 20% of GDP in 2024 (table 2).

Table 2. Parameters of the economy and budget in 2010-2024

Indicators	2010	2015	2020	2022	2024
Brand crude oil price (USD/barrel)	80	50	42	90	78
Consolidated budget: deficit (-) / surplus (+) (percentage of GDP)	-1.5	-7.9	-9.8	+3	+3.2
Non-oil and gas balance (% of GDP)	16	20	25	28	29
Public debt (percentage of GDP)	12	22	24	22	20

Source: State Statistical Committee of the Republic of Azerbaijan, 2024. - http://stat.gov.az/

Thus, not only were the difficulties associated with structural transformation overcome and effective budget consolidation achieved, but also the fiscal space was significantly expanded and financing mechanisms for strategically important development goals were modernized.

The crisis that arose during the COVID-19 pandemic differed from previous ones in the nature of the shocks it caused. We can cite as examples the forced restrictions on the activities of enterprises in most sectors of the industry, the decline in aggregate external and domestic demand, the need for a sharp increase in healthcare spending, and the fall in oil prices (in March-April 2020, the price of oil fell to $ 15 per barrel). In such conditions, most countries allocated record budget funds to combat the crisis, which significantly exceeded the volume of anti-crisis packages during the international financial crisis of 2008-2009.

Countries that adopted large-scale anti-crisis programs, of course, paid for it with a sharp increase in public debt. For example, in the United States, public debt increased by about 18 percentage points of GDP in 2020-2021, exceeding 126% of GDP. In developed countries as a whole, the level of public debt increased by about the same percentage point of GDP. In Azerbaijan, the increase in this indicator increased by 4 percentage points from 20% of GDP in 2018 to 24% of GDP. An unexpected result that can be obtained by comparing the scale of budget support with GDP losses is that in a number of countries, government efforts do not always yield noticeable results. The right column of Table 3 shows the deviation of actual GDP in 2020-2021 from the level expected before the start of the pandemic. The presented calculations show that, for example, in the UK and Italy, despite the exceptionally large-scale budget injections into the economy, GDP losses significantly exceeded the average for comparable countries. The same applies to India.

The reason for this situation seems to be that the specific nature of the shocks during the pandemic makes it difficult to use standard anti-crisis policy approaches. As a result, the simple logic of "the more support the economy receives, the better" did not apply in this case, and the effectiveness of anti-crisis policy was determined not by the volume of budget support, but by the correct choice of its form and direction.

Table 3. Volume of budget support and economic consequences of shocks in 2020-2021

Indicators	The volume of anti-crisis support during the pandemic		Total debt of governments at all levels		In production volumes in 2020–2021 itkilər
	directly	indirectly	By the end of 2021	Changes in 2020-2021	
	GDP-2020 in %		GDP in %	GDP	%
Developed countries that are members of the G20					
England	19.3	16.7	105.2	20.7	-10.2
Italy	10.9	35.3	149.9	15.7	-6.5
USA	25.5	2.4	126.4	17.7	-2.7
Average for a group of countries	15.3	15.7	118.4	14.8	-4.3
Emerging markets in the G20					
Brazil	9.2	6.2	90.1	3.0	-4.1
India	4.1	6.2	90.1	3.0	-4.1
Saudi Arabia	2.6	1.0	28.8	7.3	-5.3
Average for a group of countries	5.0	3.7	16.5	2.7	-2.8
Azerbaijan					

Source: Compiled by the author based on World Bank data.

Despite the relatively modest scale of the anti-crisis package in Azerbaijan, GDP losses were among the smallest among developing countries.

When assessing the implementation of budgetary policy in the context of successive shocks, we can point to the approaches that played an important role in managing this extremely turbulent period.

Along with additional anti-crisis measures, budgetary policy in Azerbaijan is aimed at financing medium-term priorities aimed at achieving national development goals that contribute to increasing economic potential and the quality of life of citizens.

Inflation remains one of the most pressing problems of the modern global economy. Inflation should be understood as a long-term and sustained trend towards an increase in the average price level and a corresponding depreciation of money. When prices rise significantly and persistently, inflation is most likely caused by high growth rates of the money supply. As Milton Friedman wrote, "Inflation is always and everywhere a monetary phenomenon"[39, p. 129]. The level of inflation acts as an indicator of the stability and balance of the country's economy and its money supply.

The most important element of state regulation is anti-inflationary policy, in which the tax-budget component plays a special role.

In the modern world, the trend typical for most countries is a continuous increase in prices. Regardless of the phases of the economic cycle, prices rarely fall, and inflation is observed even during recessions. Various factors can cause price increases, but not every price increase is inflation. Inflation can be defined as an imbalance between aggregate demand and aggregate supply.

As inflation deepens, it seriously intensifies economic and social tensions in society, becoming an obstacle to reproduction [40, p. 325]. Therefore, the goal of government regulation policy is to achieve disinflation (a decrease in the rate of price growth), gradually turning into deflation (a steady downward trend in average prices). Unlike inflation, which occurs as a result of an increase in the amount of money relative to the mass of goods and services, deflation begins when the demand for money lags behind the actual supply.

When choosing a specific anti-inflation policy model, the government should take into account the entire spectrum of specific circumstances characteristic of a particular country. This fact leads to the widespread use of two approaches to solving this problem in international practice:

- a tough fight against inflation at the state level.

Inflation processes, including in the Azerbaijani economy, depend on the characteristics of fiscal policy. Studies by local analysts show that inflation in Azerbaijan is associated with certain parameters of the budget system (Table 4). Inflation, in turn, affects the fiscal balance.Thus, inflation and fiscal imbalance are mutually reinforcing phenomena.

At the same time, both the imbalance of the state budget and high inflation necessitate changes in the state's fiscal policy.

Table 4. Characteristics of the interaction between inflation and the state's fiscal system

Implementation of a number of adjustment measures. The impact of state budget system parameters on inflation		*The impact of inflation on the fiscal balance*	
Budget system parameters	*Mechanism of action*	*Impact effect*	*Mechanism of action*
Structure of state budget revenues and expenditures	*The excess of budget system expenditures over revenues leads to budget deficits and inflation. However, increased government spending is appropriate only when its effectiveness exceeds private spending (which is usually observed in the long run). In conditions of economic growth, a faster increase in budget revenues can be viewed as an automatic stabilizer ("tax brake").*	*Amortization of tax revenues is the time lag between the calculation of taxes, budget revenues, and government expenditures (Oliver-Tanzi effect)*	*High inflation reduces the real value of tax revenues to the state budget, which negatively affects the state's fiscal balance. At the same time, high inflation encourages taxpayers to delay tax payments.* *The Oliver-Tanzi effect is strengthened when government spending is dominated by actual purchases of goods and services at market prices.*
Büdcə kəsirinin həcmi və onun maliyyələşdirilməsi üsulları	*Büdcə kəsirini daxili və xarici bazarlardan borc almaqla, yığılmış ehtiyatlardan istifadə etməklə və ya vergiləri artırmaqla maliyyələşdirmək olar. Həddindən artıq hallarda, pul emissiyası ilə maliyyələşdirilə bilər.* *İstənilən maliyyələşdirmə üsulu ilə büdcə kəsiri inflyasiyanın artmasına gətirib çıxarır (tələb inflyasiyasını tetikler).*	*İqtisadiyyatda nominal gəlirin artması və buna uyğun olaraq büdcəyə nominal vergi daxilolmalarının artması (D. Patinkin effekti)*	*Sabit nominal büdcə ödənişləri ilə fiskal balansın təkmilləşdirilməsi. D. Patinkin effekti o halda artır ki, dövlət xərclərində dövlət sektorunda çalışan işçilərin əmək haqqı ödənişləri və indeksasiyası tam olmayan digər oxşar ödənişlər üstünlük təşkil edir, inflyasiyadan geri qalır və ya yerinə yetirilmir.*
Dynamics of the share of the public sector in the economy	*Investing state budget funds only in the development of public sector enterprises in the long term has a positive impact on the state budget balance and the growth rate of inflation, respectively.*	*The impact of disproportionate taxation arising from a progressive tax system*	*Inflation is accompanied by an increase in taxpayers' incomes and their transfer to groups with higher tax rates, which leads to an increase in nominal budget revenues and reduces fiscal imbalances..*
The existence and effectiveness of stabilizing institutions that allow for the implementation of countercyclical fiscal policy	*For example, price collusion plays a significant role in the pricing process, necessitating the activation of antitrust authorities. In the absence of adequate government measures, institutional factors act as a permanent and significant source of structural distortions and inflation.*	*The impact of curbing economic growth*	*Significant and poorly predictable changes in the price structure create uncertainty, impair balancing and planning capabilities, and reduce investment activity. High inflation leads to economic recession and negatively affects the fiscal balance of the budget.*
		Reduction in public debt servicing costs as a result of lower real interest rates	*positive impact on the fiscal balance (in conditions of high inflation, the debt is devalued, which leads to a decrease in real costs of debt service with a fixed nominal interest rate)*
		Inefficiency of budget lending	*Increases fiscal imbalance (real interest rates fall, making any lending inefficient)*

Source: compiled by the author.

Along with the development in the global economy after the pandemic, the excess of demand over supply in the world market and the shortages in the supply process have led to increased inflationary pressures on the economy. The war that began between Ukraine and Russia in 2022 has had a serious impact on the international economic and political situation and has further increased inflationary trends worldwide.

It should be noted that. despite the increase in global inflation levels worldwide, a decrease in inflation levels has been observed in our country as a result of the influence of external and internal factors.

Financial security is one of the important conditions for the country's macroeconomic stability and economic development. This security is mainly ensured by maintaining price stability and keeping inflation under control. Budgetary policy and budget strategies are the main tools in shaping the

country's economic and financial security and play an important role, in particular, in the fight against inflation.

The components and principles of the budget strategy and anti-inflation policy implemented in our country are as follows:

- Budget strategy: A set of basic plans and measures designed to manage financial resources in accordance with the macroeconomic security and development goals of the state.

- Anti-inflation policy: A system of monetary, fiscal and structural measures and tools that ensure price stability and low inflation.

- Basic principles: Aligning the budget with economic structure and demand, limiting the deficit, supporting monetary policy and maintaining macroeconomic stability.

- Anti-inflation measures taken as a result of the budget policy implemented in our country in recent times have had a positive impact on the country's economic and financial security. As a result of the anti-inflation measures taken, inflation has been brought under control (Table 5).

***Table 5.** Anti-inflation and budget measures implemented to ensure financial security between 2010 and 2024*

Years	Event and mechanism	Note and explanation	Impact on results and points
2010-2014	Structural budget and economic policy	Optimization of spending on energy and infrastructure projects.	Price and inflation levels are low and stable, the market is protected.
2015-2018	Measures in currency and monetary policy	Management of foreign exchange reserves, maintaining a stable exchange rate of the manat.	Price increases and inflation are limited, and the risk level is low.
2020-2024	Risk prediction and transparency	Stress tests, risk modeling and analytics tools.	Protection against global and regional risks and economic security.
2021-2024	Structural and diversification measures	Expansion and diversification of the energy and non-oil sectors.	Strengthening foreign exchange reserves and macroeconomic security.

Source: compiled by the author.

As can be seen from the data in Table 5, the measures taken during 2010-2024 have shown their effectiveness. Economic security and price stability in Azerbaijan are the main priorities for long-term macroeconomic security and macroeconomic risk management. Anti-inflationary measures implemented in budget strategies and budget policy are the main mechanisms of protection against energy price volatility, external and internal economic risks and have been constantly strengthened through structural changes and process reforms during 2010-2024.

2010–2014 was the first stage of stability and structural changes, and extensive measures were implemented to structure and optimize expenditures aimed at energy and infrastructure projects, manage external and internal risks with minimal risk, balance budget revenues and expenditures, pay special attention to non-oil and social expenditures, and manage currency and inflation risks. As a result of the measures taken during this period, prices and inflation levels were low and stable, foreign exchange reserves were high and at a safe level, and economic security was ensured as risks were managed normally and sustainably.

2015–2018: Measures taken to address the sharp decline in energy prices and strengthen protection mechanisms include a reduction in the budget deficit and foreign exchange reserves due to the decline in energy prices, fiscal and monetary measures, including the optimization of the structure of expenditures and revenues, strict management of savings and budget deficits, and strengthening of foreign exchange policy and external risk management mechanisms in order to reduce price increases and inflation. As a result of the measures taken, economic and financial security was further strengthened by maintaining low prices and inflation, and the budget and macroeconomic balance was preserved despite the decline in energy markets and energy revenues.

In 2018–2020, measures were taken to strengthen security through structural and policy reform, such as diversifying the budget structure, developing and diversifying the non-oil sector, protecting foreign exchange reserves and optimizing the structure of external debt, analyzing and shaping macroeconomic policy and budget measures to better manage prices and inflation, and as a result of these measures, the structure of foreign exchange reserves and the budget was optimized, and security mechanisms were strengthened.

After 2020: further optimization of the structure of budget expenditures related to protecting financial security in the context of the pandemic and energy market uncertainty and protection against uncertain risks of energy markets, strengthening the structure of foreign exchange reserves and external debt, and prevention of external and internal risks were implemented.

Table 6. Annual percentage change in economic and social indicators of the Republic of Azerbaijan in 2010–2024 (compared to the previous year)

Indicators	2010	2015	2018	2020	2022	2024
GDP (billion manat)	42.5	54.4	80.1	72.6	134.0	126.3
GDP growth rate (%)	2.2	-1.0	3.5	-4.9	4.2	5.5
Fixed capital investment (%)	8.5	6.0	7.2	4.0	9.0	11.0
Real income of the population (%)	3.5	1.0	2.2	-0.5	3.0	4.2
Inflation (%)	8.5	12.3	2.9	12.5	3.4	3.8
State budget revenues (billion manat)	11.4	17.5	24.4	24.7	30.7	37.2
State budget expenditures (billion manat)	11.8	17.8	22.7	26.4	32.1	37.7
General budget deficit or surplus (as a percentage of GDP)	+1.2	-3.5	+0.4	-3.0	+0.8	+1.2

Source: State Statistical Committee of the Republic of Azerbaijan, 2024. - http://stat.gov.az/

Table 6 shows the dynamics of economic and social indicators of the Republic of Azerbaijan in 2010-2024. As can be seen from the data in the table, as a result of the measures taken between 2010-2024, GDP increased from 42.5 billion manat to 126.3 billion manat. During this period, state budget revenues increased by 11.8 billion manat to 37.2 billion manat. During 2010-2024, state budget expenditures increased from 11.8 billion manat to 37.7 billion manat. Despite the increase in inflationary pressures in the world economy during this period, the inflation rate in our country decreased from 8.5% to 3.8%. The decrease in the inflation rate was influenced by a well-implemented budget strategy. Thus, during this period, the budget revenues and expenditures were adjusted to structural and interest indicators, the structures of the energy and non-oil sectors were optimized, and long-term and sustainable regulation of civil service and social expenditures was carried out, which formed a sustainable budget balance and reduced the deficit. During this period, the structure of currency and foreign exchange reserves was strengthened, the ratio of foreign exchange reserves to GDP was maintained within the norm, risks were reduced through restructuring and structural changes of external debts, the Central Bank adjusted interest rates and monetary policy in line with inflation, and price stability was ensured through currency and macroeconomic structural adjustments. The process of forecasting inflation and managing inflation expectations was implemented within the budget strategy (Table 7).

Table 7. Economic indicators of the Republic of Azerbaijan in 2010–2024

Indicators	2010	2015	2018	2020	2022	2024
Brand oil price (USD/barrel)	80	50	70	42	90	78
GDP (billion manat)	42.5	54.4	80.1	72.6	134.0	126.3
State budget revenues (billion manat)	11.4	17.5	24.4	24.7	30.7	37.2
GDP %	20	22	20	19	22	23.5
State budget expenditures (billion manat)	11.8	17.8	22.7	26.4	32.1	37.7
GDP %	19	25	22	24	20	
Inflation %	8.5	12.3	2.9	12.5	3.4	3.8
External debt (USD billions)	2.4	3.8	4.7	4.7	5.0	5.4
Including: % of GDP	4.4	7.5	9.7	9.8	8.6	8.0
Foreign exchange reserves (billion USD)	5.8	9.5	14.2	14.8	16.5	18.0
Including: % of GDP	10.5	18.7	29.1	30.7	28.2	27.7

Source: State Statistical Committee of the Republic of Azerbaijan, 2024. - http://stat.gov.az/

In response to the challenges of 2014-2015, successive budget reforms, intensified and aimed at eliminating external constraints and dependence on global hydrocarbon markets, have, in our opinion, strengthened the stabilizing features of macroeconomic policy, which are the basis of the country's financial sovereignty. Positive structural changes in budget revenues, compliance with fiscal rules, flexibility and efficiency of budget decisions have allowed us to maintain the sustainability of public finances in crisis situations, including during the pandemic and the radical transformation of recent years, to implement large-scale economic and social support programs.

Conclusion

As a result of our research, we can say that the State budget system is an important component and basis of national economic security. The budget system ensures the activities of administrative-territorial units and the fulfillment of obligations of public law entities. The mechanisms of the budget system are aimed at developing the necessary tools to strengthen control over the targeted use of budget funds. The mechanisms of the budget system create conditions for economic growth, improving the living standards of citizens, import substitution, increasing labor productivity, implementing investment projects, achieving independence of energy infrastructure (energy security), increasing the competitiveness of local producers, creating reserve potential and necessary resource reserves.

In the context of our research, we determined that the volume and distribution of financing from the budget are closely related to the well-being of the population and the activities of state sector

enterprises, which directly affects the national security of the country.

As a result of the research, we determined that the role of the state budget in ensuring the financial security of the Azerbaijani state consists in forming the basis for the activities of strategically important areas of the state and civil society.

We have implemented the following research questions:

- We have identified the content and features of the formation of the state budget of the Republic of Azerbaijan, including the insufficient amount and diversity of budget funds. This is due to changes in the profitability of international enterprises and companies due to restrictions and sanctions;

- We have defined the concept of state financial security in the context of its uncertainty and multifacetedness. We have determined that it includes both ensuring stable conditions for the development of the Azerbaijani economy and the absence of external threats to the stability of the state's activities;

- The role of the budget in ensuring financial security, which reflects the importance of attracting the maximum number of sources and equal, rational distribution of budget funds, is determined.

The main conclusion is the confirmation of the importance of the state budget in ensuring national security, especially financial security, and the need to develop strategies for the efficient use of financial resources.

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GEORGIAN AGRICULTURAL INSURANCE STATE PROGRAM AND ITS DEVELOPMENT PROSPECTS

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Abstract

In Georgia, the state-subsidized agricultural insurance program has been in operation since 2014 and covers risks such as hail, storms, excessive precipitation, and early autumn frost. The state-subsidized program implemented since 2014 has made a significant contribution to the establishment of a risk management system in the sector and to raising farmers' awareness.

The main challenges remain the low coverage of the program, the insufficient number of meteorological stations, and the geographical concentration of insured land plots in high-risk regions. This trend creates the risk of adverse selection and limits the even nationwide dissemination of the agricultural insurance program.

Overcoming these challenges requires close cooperation between the public and private sectors, the harmonization of agricultural insurance policy and practice, the introduction of a unified damage assessment methodology, and the strengthening of farmer awareness and information. In addition, it is advisable to develop new insurance products and financial incentives, taking regional specificities into account, which would encourage the involvement of small and medium-sized farmers in low-risk regions as well.

Keywords: *insurance, agricultural insurance, risk agriculture, state, private sector.*

In Georgia, a subsidized agricultural insurance program based on cooperation between the public and private sectors has been in operation since 2014 and aims to ensure farmers' financial stability and the sustainability of agriculture.

Due to the specific geographical location of Georgia's territory and its complex relief, various types of natural hydrometeorological processes frequently occur, among which hail is particularly significant. In this regard, the Kakheti region stands out, where hail often causes damage to the region. The damage caused by hail amounts to millions of GEL annually. Accordingly, it is natural that among the named risks covered under the agricultural insurance program, hail represents one of the most important types of coverage. It should be noted that more than half of the insured plots are concentrated in the Kakheti region. According to 2024 data, within the framework of the agricultural insurance program, 79% of insured land plots are insured in Kakheti, while 69% of insured plots are vineyards.

Within the framework of the program, insurance coverage, in addition to hail, includes such major risks as storms, excessive precipitation, and early autumn frost (only for citrus crops).

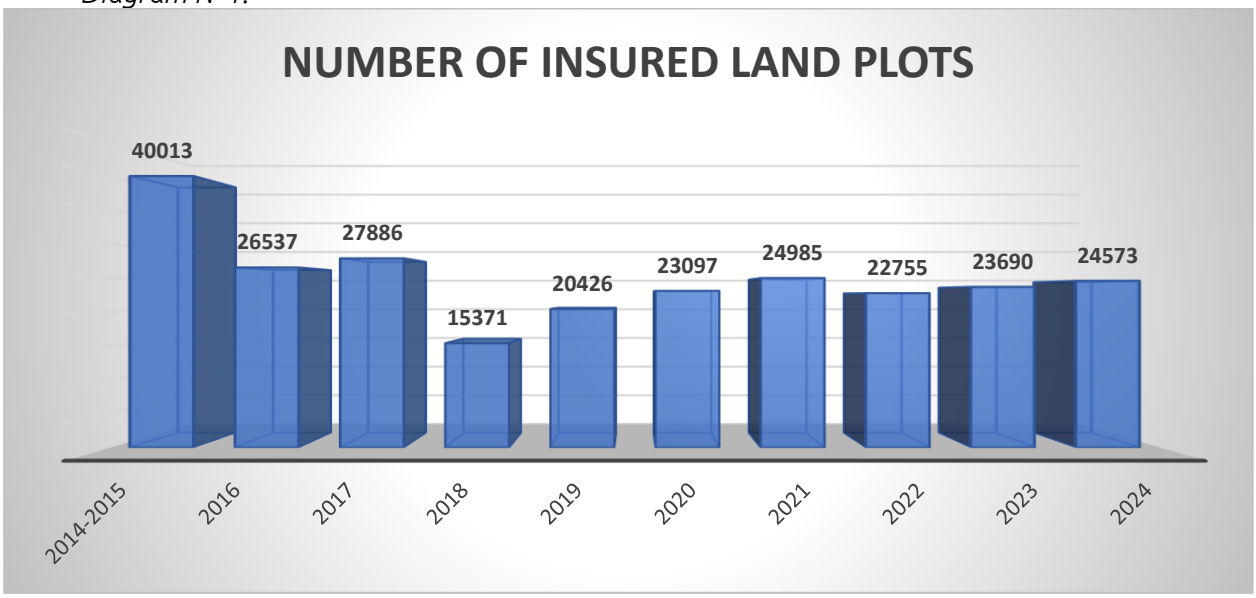
Based on the program's outcomes, its conditions are refined and clarified, and changes are implemented almost every year. The definition of the deductible (franchise) has been clarified; a unified damage assessment standard (for certain crops) has been developed for all insurance companies participating in the project; reporting procedures and deadlines have been improved; normative yields, tariffs, and the co-financing percentage have been reviewed and specified; and three-year insurance for perennial crops has become possible. In addition, continuous video recording and audio recording using body-worn cameras during the process of describing an insured event have been made mandatory.

Despite the progress achieved, the agricultural insurance system continues to face significant challenges. Although the share of agricultural insurance in the insurance market has been increasing from year to year, it remains very small and in 2024 accounted for only 1.57% of the total insurance market.

Low coverage remains one of the main challenges of Georgia's agricultural insurance system and significantly limits the effectiveness of the program. Despite the fact that the state-subsidized agricultural insurance program has been operating since 2014 and provides farmers with the opportunity to protect their crops against various types of risks, its geographical and sectorial coverage remains limited. The number of insured plots constitutes only a small share of the country's total agricultural land, indicating both a lack of information and low farmer motivation to participate in the program. One of the reasons for low coverage is the insufficient meteorological infrastructure—specifically, the limited number of meteorological stations—and issues related to the accuracy of the data obtained from them.

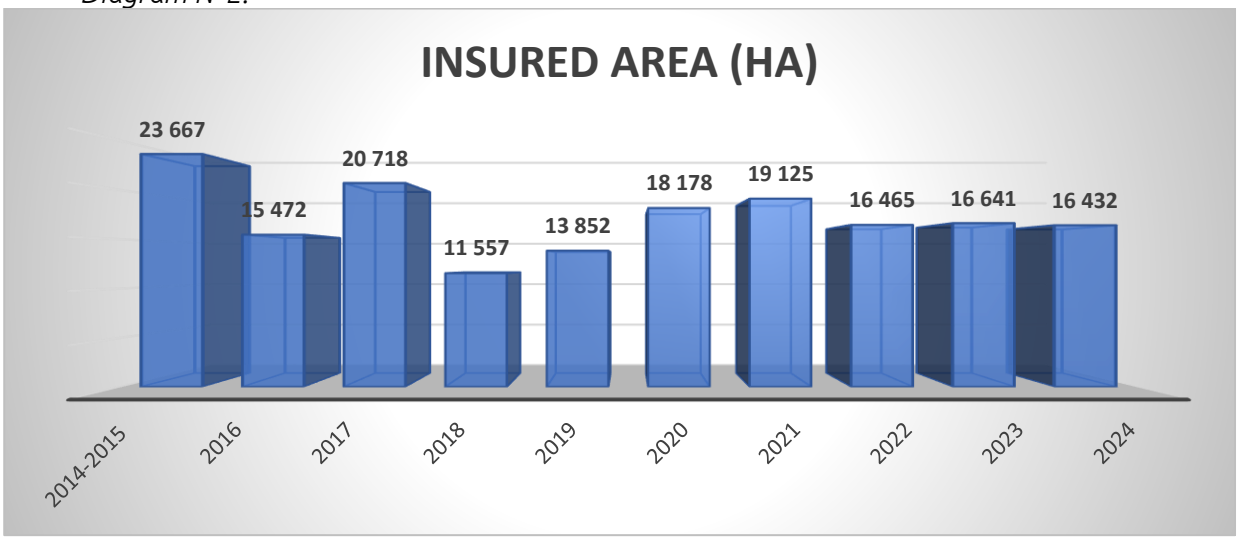
Accurate meteorological data form the foundation of the agricultural insurance system, as damage assessment directly depends on such data. From the launch of the program through 2024, the number of insured plots is distributed as follows.

Diagram №1.



The amendment implemented in 2018, according to which only land plots registered with the National Agency of Public Registry were eligible for insurance, resulted in a 45% decrease in the number of insured land plots.

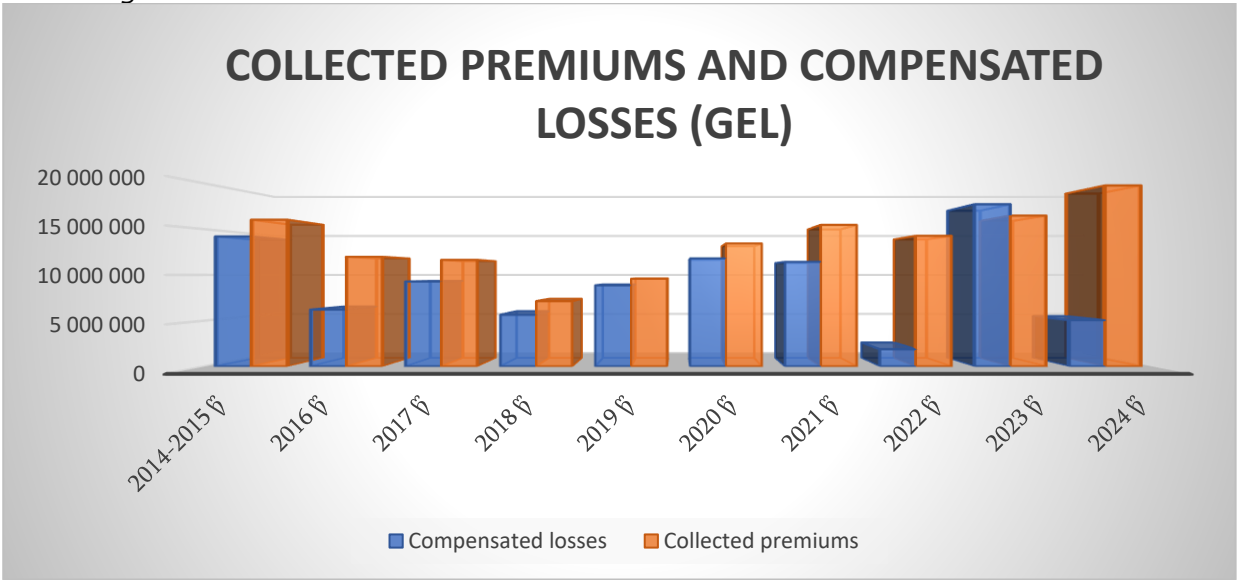
Diagram №2.



Adverse selection remains a significant challenge. One of the most illustrative examples of adverse selection in Georgia's agricultural insurance program is the uneven geographical distribution of insured plots. According to available data, more than half of the insured plots are concentrated in only three regions—Kakheti, Shida Kartli, and Kvemo Kartli—out of Georgia's 12 regions. This fact clearly indicates that interest in agricultural insurance is predominantly expressed by farmers operating in high-risk areas, where hail, strong winds, and excessive precipitation are frequent and the probability of crop damage is high. Consequently, in lower-risk regions, such as Imereti, farmers' interest in insurance is significantly lower, which disrupts the spatial balance of the program and increases the risk of adverse selection. This trend underscores the need for the state and the private sector, through close cooperation, to develop additional incentives and mechanisms that would encourage farmers in low-risk regions to participate in the agricultural insurance system as well, thereby ensuring geographical diversification of the program and promoting the sustainable development of the sector.

Since the inception of the program and up to 2024, insurance companies have compensated losses totaling over 92 million lari, while aggregate gross premiums during the same period exceeded 135 million lari.

Diagram №3.



Agricultural insurance in Georgia represents one of the key mechanisms for ensuring the sustainable development of agriculture, the financial stability of farmers, and social protection. The agricultural insurance program, introduced by the state in 2014, has played a significant role in establishing a risk management system within the agricultural sector and raising farmers' awareness. Despite the results achieved, the program is still in a developmental stage and requires improvement at administrative, technical, and institutional levels. One of the main challenges remains low coverage and the limited number of meteorological stations. In addition, insured plots are primarily concentrated in a few high-risk regions, particularly Kakheti, where hail and other natural disasters are frequent. Such geographical imbalance has increased the risk of adverse selection—farmers in low-risk regions show less interest in insurance, which disrupts the equitable and effective distribution of the program nationwide. In this context, it is advisable, taking regional specificities into account, to develop new insurance products and mechanisms, which requires close cooperation between the public and private sectors. It also necessitates strengthening informational, technological, and financial mechanisms. Only through these measures will it be possible to enhance the agricultural insurance system, ensure farmers' economic protection, and increase the competitiveness of the agricultural sector in the face of global climatic and economic changes, which, ultimately, forms the foundation for the country's economic sustainability.

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THE AUTHORITY OF A MANAGER IN A MODERN INNOVATIVE COMPANY

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Abstract

It is generally accepted that the effectiveness of management activities depends on the authority of the manager. The view that a person automatically acquires authority as a result of being appointed to a certain position is truly erroneous.

Authority is the influence a person has on a work group/team through his own labor. Authority is created by a combination of organizational skills, professional knowledge, and skills in working with people. Authority is the deserved trust that a manager enjoys among his employees, superiors, and colleagues. Authority is the recognition of a person; it is the team's assessment of the compliance of the manager's subjective qualities with objective requirements. Authority can be considered as a system of human relationships, values, and work results. Therefore, a manager must combine management and leadership functions in himself in order for positional authority to correspond to personal authority. Leadership is a process of psychological influence based on free relationships, mutual understanding and voluntary subordination. The power of influence over an employee is directly related to the authority of the Manager.

Keywords: *Manager, Authority, Modern, Innovative, Company.*

Management is the process of legitimate influence exercised by a manager on the basis of the power granted to him by society or a collective/team. Power attitudes, decree, social control, the use of disciplinary practices are the very principles on which leadership is based. The authority of a manager has two sources:

- *Personal, which is manifested in the skills and leadership influences of the individual;*
- *Public, which is manifested in the possession of official prestige and the power of the manager.*

Authority is formed on the basis of respect, the will and conscious execution of the instructions of the manager by employees. It is also necessary to take into account that caring for the authority of a manager is not only his personal business, but also the business of higher management and especially of any employee, who must protect, elevate and strengthen this authority. They should take from him an example of conscientious attitude to work/business, organization, honesty and restraint. Authority can be considered as a factor that facilitates management and increases its effectiveness.

Authority depends on the psychological state of a person. A manager who is not confident in his own abilities and actions will never become an authority for his talents; however, unfounded self-confidence will not increase his authority among employees either. The corresponding psychological state is always created as a result of awareness of one's own abilities and competence, which is confirmed by real facts; by understanding what others demand from the manager; by understanding the importance of one's rights and duties, privileges and activities. Quite often, managers associate their authority with personal value. As a result, the growth of authority is perceived by them as a personal victory, while its loss turns into a personal tragedy. It can be said that this assumption is partly true. Any manager must possess authority, otherwise he is automatically considered a bad leader/manager. However, even an authoritative manager can make mistakes. Psychologists advise that if the manager's authority has been violated/decreased among employees for some reason, there is no need to perceive this as tragic. In such a case, it is necessary for the manager to change the forms of management and interpersonal relations (sometimes even cardinally). The relationships between the manager and human resources determine his authority, which is formed on the basis of what Management style the Manager uses in a particular situation.

The unconditional support of employees is the basis of effective management. Positive relationships with talents already mean good management. The human resources that a manager manages have a true idea of his management style. The success and failure of a manager also explains

how he looks in the eyes of his employees. They perfectly understand the difference between bad and good management. Under the conditions of a good manager, the work of human capital becomes more interesting, and the achieved successes are reinforced by a sense of professional pride. With ineffective management, the employee loses interest in the work and, accordingly, labor productivity decreases.

A high culture of relationships, which is expressed in the norms of professional ethics, affects the authority of the manager. The culture of relationships includes: the manager's democracy with talents, colleagues, attentiveness, accuracy, creation of an atmosphere of trust, politeness, organization and clarity. The manager's authority and the degree of trust in the work team increase due to his constant relationship with employees.

There is also a false authority that is created by the manager using artificial methods. For example:

Aloofness/Distance Authority - the manager is sure that if he keeps himself away from his employees and is extremely formal, his authority will increase.

Kindness Authority - the manager believes that in order to increase his authority, he must always be kind in his relations with Human Resources. Often, such kindness reduces demandingness and leads to negative results.

Pedantry Authority - in this case, the manager cares about the little things and strictly defines all stages of the task, thereby stifling the initiative and creativity of talents.

Arrogance Authority - the manager is extremely ambitious and always looks "from above"; constantly boasts of his own achievements and merits; tries to attract the attention of employees and is sure that such behavior ensures his authority.

Insulting authority - quite often the manager instills fear in his own talents and uses intimidation methods. He mistakenly thinks that such an attitude will strengthen his authority; however, this can become the reason for the loss of self-confidence and initiative in human resources, which logically results in distortion of relationships, negative emotions, unhealthy confrontation and differences of opinion.

In general, caring for the authority of a manager is not only his personal business, but, first of all, the superior leadership. Therefore, we should consider authority as a factor that will facilitate management and increase its effectiveness.

Conclusion: Thus, gaining authority in a team, as well as management, can be compared to some level of art. Perhaps this is the reason why researchers have not been able to develop a unified theory of "gaining authority" to date. The main thing for a manager is to choose a more or less acceptable management style, one that matches his personal characteristics and dispositions. The style of a Manager is directly related to the work situation. The authoritative style of a manager, in any case, should become a flexible tool for effective Management of the organization.

KEY FEATURES OF RISK MANAGEMENT IN ORGANIZATIONS

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Introduction

In the contemporary global business environment, organizations operate in conditions characterized by uncertainty, volatility, and increasing complexity. Economic instability, technological disruption, globalization, and regulatory pressures create numerous risks that may affect organizational stability and performance. As a result, risk management has become a fundamental component of strategic management and corporate governance.

Risk management refers to a structured and systematic process of identifying, assessing, and responding to uncertainties that may affect the achievement of organizational objectives. Modern approaches emphasize that risk management should not only focus on preventing losses but also on enhancing opportunities and supporting informed decision-making processes. According to international standards, risk management aims to create and protect value by improving organizational performance and supporting strategic objectives (Purdy, 2010).

In recent decades, organizations have increasingly adopted integrated risk management approaches such as Enterprise Risk Management (ERM), which address risks across the entire organization rather than within isolated departments. ERM frameworks enable organizations to integrate risk considerations into strategic planning, operational management, and decision-making processes (Lam, 2014).

This thesis examines the key features of risk management in organizations. It focuses on the conceptual foundations of risk management, its strategic role in modern organizations, and the major characteristics that determine the effectiveness of risk management systems.

Conceptual Foundations of Risk Management

Risk management has evolved significantly over time. Traditional risk management approaches focused mainly on financial risks, insurance, and loss prevention. However, contemporary organizations face more complex risks that include operational, technological, reputational, environmental, and strategic risks. Consequently, modern risk management frameworks emphasize a holistic and integrated approach.

Enterprise Risk Management (ERM) is one of the most widely adopted frameworks for managing organizational risks. ERM integrates risk management practices across organizational functions and aligns them with strategic objectives. The Committee of Sponsoring Organizations of the Treadway Commission (COSO) defines ERM as a process effected by an entity's board of directors, management, and other personnel, applied in strategy setting and across the enterprise to identify potential events that may affect the organization (COSO, 2017).

Another influential framework in risk management is the ISO 31000 standard developed by the International Organization for Standardization. This standard provides internationally recognized guidelines for implementing risk management systems across different sectors and organizations. ISO 31000 emphasizes that risk management should be integrated into all organizational processes and should support decision-making at every level of management.

The ISO 31000 framework is built on three major components: principles, framework, and process. These components ensure that risk management activities are structured, systematic, and embedded within organizational governance and operational activities.

The adoption of structured frameworks enables organizations to manage uncertainties more effectively, improve governance, and strengthen their resilience against potential disruptions.

Key Features of Risk Management in Organizations

Strategic Integration of Risk Management

One of the most important characteristics of effective risk management is its integration with organizational strategy. Risk management should not function as an isolated activity performed only by compliance departments. Instead, it must be embedded within the strategic planning and decision-making processes of the organization.

Strategic integration ensures that managers evaluate potential risks when formulating organizational strategies. By identifying uncertainties in advance, organizations can allocate resources

more effectively and avoid strategic failures. Research shows that organizations that integrate risk management into strategic planning are better prepared to address market volatility and environmental uncertainty (Hillson, 2017).

Moreover, strategic risk management supports long-term organizational sustainability by enabling organizations to balance risk and opportunity in their decision-making processes.

Systematic Identification and Assessment of Risks

Another essential feature of risk management is the systematic identification and assessment of risks. Organizations face a wide range of risks including financial risks, operational risks, reputational risks, technological risks, and legal risks.

The process of risk identification involves detecting potential events that may negatively or positively affect organizational objectives. Once risks are identified, they must be analyzed in terms of their probability and potential impact. This assessment allows organizations to prioritize risks and focus their attention on the most significant threats.

International standards emphasize that risk management should be structured and systematic in order to ensure consistency and comparability in risk evaluation processes.

Various analytical tools are used in this process, including risk matrices, probability-impact analysis, scenario analysis, and simulation models.

Establishment of a Risk Management Framework

An effective risk management system requires the establishment of a comprehensive organizational framework. The framework defines policies, responsibilities, procedures, and reporting mechanisms for risk management activities.

According to ISO 31000, the framework should support the integration of risk management into governance structures, organizational culture, and management systems.

Leadership commitment plays a critical role in this process. Senior management and boards of directors must actively support risk management initiatives and ensure that adequate resources are allocated for their implementation.

Furthermore, risk management frameworks must be tailored to the specific context of the organization. Different industries and sectors face different types of risks; therefore, frameworks must be flexible and adaptable to organizational needs.

Continuous Monitoring and Improvement

Risk management is a dynamic process that requires continuous monitoring and evaluation. Organizational environments are constantly changing due to technological innovation, economic shifts, regulatory developments, and global events.

Continuous monitoring allows organizations to detect emerging risks and respond promptly. Regular reviews of risk management processes help organizations evaluate the effectiveness of risk mitigation strategies and improve their risk management systems.

International standards highlight continuous improvement as a key principle of risk management. Organizations are encouraged to learn from previous experiences, identify weaknesses in risk management practices, and adapt their systems accordingly.

Through continuous improvement, organizations can maintain the relevance and effectiveness of their risk management processes.

Organizational Culture and Risk Awareness

Risk management effectiveness largely depends on the organizational culture. A strong risk culture encourages employees at all levels to recognize potential risks and report them openly.

Organizations with well-developed risk cultures promote transparency, accountability, and responsible decision-making. Employees are encouraged to communicate risks without fear of negative consequences.

Human and cultural factors are recognized as critical components of effective risk management systems. Organizational behavior, leadership attitudes, and employee awareness significantly influence how risks are perceived and managed.

Therefore, organizations must invest in training programs and awareness initiatives that strengthen employees' understanding of risk management principles.

Stakeholder Engagement and Communication

Effective risk management also requires the involvement of multiple stakeholders. Stakeholders such as employees, investors, regulators, suppliers, and customers can provide valuable insights into potential risks.

Transparent communication ensures that risk information is shared effectively across the organization. This communication supports collaboration and improves the quality of decision-making processes.

Inclusive risk management processes enable organizations to benefit from diverse perspectives and reduce the likelihood of overlooking important risks. According to international standards, stakeholder participation enhances the relevance and effectiveness of risk management systems.

Use of Data and Analytical Technologies

In recent years, digital technologies have significantly transformed risk management practices. Organizations increasingly rely on data analytics, artificial intelligence, and predictive modeling to identify and evaluate risks.

These technologies allow organizations to process large volumes of data, identify patterns, and forecast potential risks more accurately. Data-driven risk management improves decision-making processes and enhances organizational resilience.

Advanced analytical tools also enable organizations to perform scenario analysis and stress testing, which help evaluate potential outcomes under different conditions.

Benefits of Effective Risk Management

Organizations that implement effective risk management systems experience numerous benefits. First, risk management improves strategic decision-making by providing managers with better information about uncertainties and potential consequences.

Second, risk management enhances organizational resilience by enabling organizations to anticipate potential disruptions and develop appropriate response strategies.

Third, effective risk management strengthens corporate governance and compliance with regulatory requirements. It also improves stakeholder confidence and organizational reputation.

Finally, risk management contributes to sustainable organizational growth by helping organizations balance risks and opportunities.

Conclusion

Risk management has become an essential element of modern organizational management. In an environment characterized by uncertainty and rapid change, organizations must adopt systematic approaches to identify, evaluate, and manage risks that may affect their objectives.

The key features of effective risk management include strategic integration, systematic risk identification and assessment, establishment of structured frameworks, continuous monitoring and improvement, development of strong risk cultures, stakeholder engagement, and the use of data-driven analytical tools.

Organizations that successfully implement these features are better equipped to manage uncertainty, protect their assets, and achieve sustainable competitive advantages. As global risks continue to evolve, the importance of comprehensive risk management systems will continue to increase in both private and public sector organizations.

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PROSPECTS FOR THE DEVELOPMENT OF AGRITOURISM IN THE SAMTSKHE-JAVAKHETI REGION

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Abstract

The article examines the main aspects of sustainable development of agritourism as a sector of the economy that plays an important role in the sustainable growth of the world economy and is one of the most powerful drivers. Today, travel and tourism have grown significantly both economically and socially and have become the fastest growing economic sector in most developed and developing countries. The positive role of the tourism industry in the economy is especially important in terms of employment and attracting investment. Tourism is one of the leading industries in the world, which consistently creates jobs every year. However, it is also possible that:

- *Many developing countries have limited choice of development sectors, and often tourism is one of the few opportunities for development;*
- *Many developing countries lack sufficient capital to develop tourism and need to import capital;*
- *Import "flows" are very high in many developing countries. Tourism offers many opportunities to reduce these "flows" in areas such as food supply, construction, souvenir production and others;*
- *Not all countries can benefit from tourism, but those with potential should care about the quality of tourism growth and its sustainability. In addition to the above, it is necessary to involve local authorities and increase public participation, regulate land use and zoning, protect the environment, etc. Given all this, tourism can become an important source of growth with a serious impact on the economy.*

Keywords: *agritourism, sustainability, sustainable economy, diversification, dynamics*

In different countries of the world, tourism, unlike other sectors, is constantly expanding and diversifying, becoming one of the most dynamic and rapidly developing economic sectors, so experts recognize it as an economic phenomenon of our time. In particular, carefully planned and regulated tourism activities can make a significant contribution to improving all three components of sustainable development (economic, social and environmental). This ensures the creation of jobs, the expansion of opportunities in the field of trade and the attraction of foreign currency to countries. The main goal of the 2012 UN Conference on Sustainable Development and the 2017 UN Assembly is precisely the development of the tourism sector as one of the powerful tools for implementing strategic goals. Its role in the development of community between the peoples of countries and acquaintance with various civilizations is great, since a huge number of tourists annually cross state borders, giving this activity a global character.

In recent years, agritourism has become an important area for the development of ties, as well as tourism potential, as agritourism associations have intensified in many European countries. Among the reasons for active development are economic and social factors. In the economic sphere, agritourism contributes to additional income. Its main goal is to provide a tourist with the opportunity to live in the countryside for a while, like a local resident. Namely, to work in the fields, cultivate the land, relax in a quiet and calm environment and engage in agritourism. The attractiveness of agritourism is determined by a number of advantages:

a) the opportunity to fully get acquainted with a certain region in terms of its historical features;
b) the ability to spend more time resting due to social status.

In Europe, agritourism is well developed. Even the economic crisis does not weaken this sector. Agritourism is also interesting and beneficial because it is not hindered by the change of seasons. Often agritourist farms are created near historical and cultural monuments. You can organize such tourist and entertainment events as horse riding, winemaking, climbing churches, visiting museums, etc. This is what attracts the tourist, because he himself is involved in the process.

In terms of increasing sustainable development of tourism potential, agritourism is one of the most attractive destinations. All countries are aware of the growing attractiveness of agritourism: Italy, Spain, Poland, Norway, Belarus. What agritourism has to offer: hospitality, local traditions, natural resources and adequate accommodation. Tourism is one of the most powerful drivers of sustainable economic growth. With appropriate investment, it will be an ever-growing sector for at least the next decade and

contribute to employment development and economic growth. This encourages society to pay attention to the preservation of natural, historical and cultural values. This problem affects the whole world, but the rapid development of tourism and mass visits can have negative consequences, since improper management can lead to higher prices and economic instability.

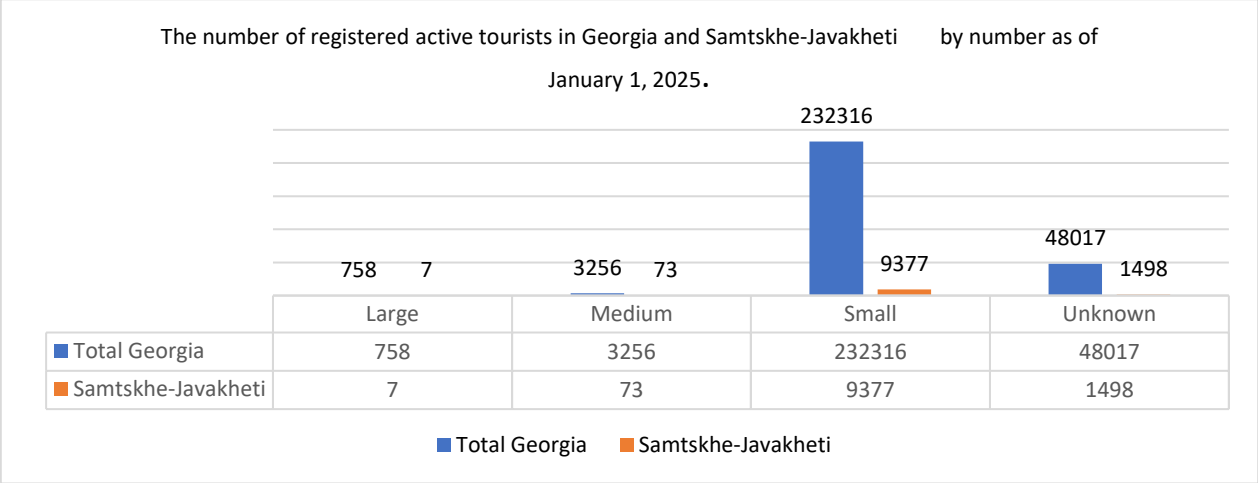
Samtskhe-Javakheti region is located in the southern part of Georgia and includes six administrative-territorial units with an area of 6413 square meters. km and a population of 160,504 people. This is a pronounced agrarian region, where the share of agriculture in the total value added is the largest (32%). Most of the human resources are employed in this sector. Agriculture in the region is represented by households and trading farms. More than 90% of production is concentrated in small households. 73% of households produce agricultural products mainly for their own consumption, and for the remaining 27%, agriculture is a source of income. The level of agricultural commercialization in the Samtskhe-Javakheti region is high across the country in both crop and livestock production. Based on the above, the region is agrarian, and, accordingly, the development of tourism in this direction will significantly increase both economic growth and attractiveness for foreign tourists.

Agricultural tourism is the production of food by locals in rural areas, the management of tourist sites, which creates jobs and provides direct economic benefits from tourist spending. Successful development of rural tourism does not require large investments, although the local population must undergo special training to maintain facilities. In particular, to obtain technical advice, small loans and, most importantly, to maintain an optimal level, so as not to create environmental and social problems. If necessary, build new objects. Agritourism in Spain reacted very quickly to the desire of tourists. Throughout the country, residential areas, hotels have been transformed, village owners offer tourists historical and local legends, sights, folklore, traditional holidays. Income from agritourism in France exceeded millions of dollars. In particular, the program includes various types of recreation. Income is received from visiting castles, wine cellars, horseback riding.

To analyze the prospects for agritourism in Georgia and the state of the industry as a whole, let's consider the tourism potential of our country. Georgia has a fairly large tourist potential: 102 resorts, 182 resort towns, 2,400 mineral springs, 12,000 historical and architectural monuments, 3 of which are included in the UNESCO World Heritage List, 11 national parks, 41 natural monuments, 2 protected landscapes, etc. Based on the existing resource potential, the development of agritourism in our country will be promising. Currently, agritourism in Georgia is at the development stage. In recent years, foreign tourists come to Georgia mainly to relax in mountain and sea resorts, visit historical and cultural monuments, although Georgia, as a country with rich agricultural traditions, has opportunities for the development of agritourism here. Agritourism is already firmly established in our country. Hopefully more tourists will come in the future to see the diverse nature, culture and attractions. However, we also have weaknesses in this area. The main one is the lack of appropriate infrastructure in rural areas. Nevertheless, if agritourism develops, small farmers can benefit and turn small farms into profitable commercial enterprises. Several travel companies and guest houses already offer agritourism to foreign and local tourists, which includes participation in grape harvesting, grape pressing, churchkhele harvesting, cheese and honey production. The historical region of Samtskhe-Javakheti has many terraced villages. In particular, in the village of Chobareti, a local resident restored a three-hundred-year-old ode, which currently receives an average of 400 visitors a month, delighted with the local cuisine. Tourists can also take a tour and take part in baking traditional Meskhetian bread, making cheese and baking kadi. The company employs 15 people. A cheese factory is under construction, which was funded by a grant project in the amount of 28 thousand. There are many such small but promising entrepreneurs in the region who play an important role in the development of agritourism. However, in my opinion, agritourism in our country can be developed more broadly, which will also contribute to the development of agriculture.

In recent years, tourism and the development of tourism infrastructure have become very relevant for attracting investors. Based on the above, the municipalities of Samtskhe-Javakheti region have a fairly significant resource for investors interested in the tourism business. The region is distinguished by its ancient and richest history. The region is rich in historical and cultural monuments, among which it is worth mentioning the restored Akhaltsikhe-Rabati fortress, the Vardzia monastery complex, the Tmogvi, Khertvisi, Rabati fortresses, the Zarzmi and Sapar monasteries, as well as several popular resort areas, the Borjomi-Kharagauli national park and the protected areas of Javakheti. Currently, the region is developing mainly cultural, recreational and adventure tourism. This is just a small list of those that can attract quite large investments. The number of entities currently active in tourism in Georgia (Diagram N1), including Samtskhe-Javakheti, is as follows:

Diagram N1



Source: National Bureau of Statistics of Georgia 2025

Over the past 5 years, according to Geostat, the number of hotels and other accommodation facilities in the Samtskhe-Javakheti region has increased by 40%. The number of tourists in the region also increased by 45%. At the moment, 138 hotels are registered in the region, of which 78 are family-type. If in 2010 the total turnover of hotels in the region amounted to 7.3 million GEL, then in 2024 this figure increased both in the number of tourists and in the number of excursion trips (903.2 million GEL). Accordingly, income also increased: the income of tourists in the region amounted to 1354.8 thousand. GEL, of which 3.6% is in the Samtskhe-Javakheti region. Foreign tourists in the region come mainly from Armenia, Russia, Germany, Israel and the United States. In 2011, 27,850 tourists visited Samtskhe-Javakheti, of which 8,415 were foreigners. In 2024, this figure amounted to 16,354.8 thousand US dollars. And in 2025 it increased to US $4.6 billion, representing an annual increase of 4.9%. The bulk of this income comes from income from Iranian tourists. The growth rate may decrease, since at this stage the tourism sector will be affected by the unstable political situation in Iran. An equally significant share of the income belongs to tourists from Russia, who spent about 700 million US dollars in Georgia, although this is 18% less than in previous years. Traveller revenues from European Union countries increased by almost 16% to US $660 million. Based on the above, the decline in income was mainly due to the pandemic, to which disorganized infrastructure was added, although Georgia is probably the only country where prices for goods and services are low, which is acceptable for any tourist with a limited budget.

Agritourism will become the leading sector of the region, since there are recreation and recreation areas, but it is already important to introduce tourist service facilities, information centers, since tourists visiting the region need to provide high-quality services with qualified personnel. It is equally important to provide infrastructure, create safe conditions for vacationers and improve the ecological condition of recreation areas and forests. The region has such key strategic development potential as the offer of innovative tourist packages to consumers. In particular, this is the opening of high-quality catering enterprises, trade in crafts, mountaineering, sailing, fishing, the organization of extreme tourism in the Trialeti gorge, the use of the potential of the protected area of Javakheti, the launch of a balneological resort in Akhaltsikhe. In general, the development of agritourism, with proper planning and management, can become a powerful tool for improving the prospects for employment and well-being of the local population, preserving the cultural and natural heritage of society and the territory.

Stable growth in tourism and, therefore, agritourism means not only an increasing dependence on financial income, but also the need to strengthen infrastructure, improve the quality of services and long-term strategic planning. However, at this stage, the country still faces a choice: how to maintain environmental balance and ensure the sustainable development of the region against the backdrop of rapid growth. However, the effectiveness of the tourism sector will depend on how much the country can maintain positive dynamics through innovation, quality improvement and integration of regional diversity.

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SUSTAINABLE DEVELOPMENT AND INNOVATION FACTORS IN THE GREEN ECONOMY

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Abstract
A Green Economy is one of the foundations of sustainable development. The primary goal of a green economy is to improve the well-being of current and future generations through the most efficient use of existing non-renewable resources, their replacement with environmentally friendly resources, and the preservation and development of natural capital. A Green Economy is one that improves long-term human well-being and reduces inequality so that future generations can avoid significant environmental risks and environmental degradation. The definition of a green economy places a primary emphasis on improving Human well-being, as the preservation, protection and improvement of nature contribute to increased Human well-being.

Keywords: Natural Resources; Ecological Economics; Green Architecture; Environmentally Friendly Products.

Sustainable development is a system of social development that, while taking into account Economic development and environmental protection, ensures human well-being, an improved quality of life, and the right of future generations to enjoy natural resources and the environment, protected to the maximum extent possible from irreversible quantitative and qualitative changes.

Sustainable development implies a form of Economic growth that ensures the well-being of society in the short, medium, and, most importantly, long term. It is based on the principle that today's needs must be met without compromising the well-being of future generations. Sustainable development implies creating conditions for long-term economic development with maximum consideration for environmental protection.

The world faces serious challenges: on the one hand, it must meet growing consumption, while on the other, it must care for its planet. We may think of the Earth on one side of the scale, and a growing population on the other. However, such ideas are misguided; in reality, the scales do not exist. There is a simple path that eliminates this choice: sustainable development. By adhering to the principles of sustainable development, we can produce more energy, food resources, and so on, while simultaneously minimizing our harmful impact on the environment. The development of a green economy, one of the foundations of sustainable development, also plays a vital role in achieving this goal.

A Green Economy is a model of Economic development that places particular emphasis on minimizing the risks of environmental problems. A green economy is one that improves long-term human well-being and reduces inequality so that future generations can avoid significant environmental risks and impoverishment. The definition of a green economy places a primary emphasis on improving human well-being, as preserving, protecting, and enhancing nature contributes to improving human well-being.

Sustainable development equally encompasses the economic, environmental, and social spheres. A green economy encompasses all three, but its primary focus is on the efficient use of resources and the conservation and development of nature. In this context, the greatest role in improving Human well-being is played by the challenges of living and working in an environmentally sound environment, both now and in the future. The primary goal of a green economy is to improve the well-being of current and future generations through the most efficient use of existing non-renewable resources, their replacement with environmentally friendly resources, and the preservation and development of natural capital. The green economy encompasses six key sectors: renewable energy, clean transportation, water management, waste management, green construction, and land use. The development of each sector is crucial in addressing environmental challenges.

The main advantage of renewable energy is its inexhaustibility, unlike fossil fuels (oil, coal, etc.). Furthermore, renewable energy production is less harmful to the environment, making it possible to meet growing energy demand with minimal environmental impact. Renewable energy sources include: hydropower; wave energy; solar energy; wind energy; geothermal energy; and biomass energy.

There is not a single country in the world that does not face waste management challenges. Particularly in large countries with large populations, household and industrial waste reaches enormous volumes. Landfills occupy vast areas, polluting the soil, atmosphere, and water resources, often causing various diseases and epidemics. A proper approach to waste management is essential to avoiding many problems. In 2005, the 3R (reduce, reuse, recycle) concept emerged in Japan, with the primary goal of proper waste management. The 3Rs are a combination of the first letters of three words: Reduce, Reuse, and Recycle. In modern literature, two more principles have been added to the 3Rs, making them even more comprehensive: the first is Energy Recovery, which processes waste using specialized technologies to recover energy; the second is Disposal, which involves disposing of waste on the earth's surface under special control.

Green architecture is a conceptual approach to construction that reduces the harmful impact of construction on human health and the environment. The goal of ecological architecture is to minimize the negative impact on the environment. Furthermore, green architecture allows for more efficient use of resources in terms of energy consumption. For example, such buildings are designed to better retain heat, as well as cool the building in hot summer weather, etc. Improving energy efficiency in the housing and utilities sector is achieved primarily through the use of innovative energy-efficient technologies.

Energy savings in the transport sector are achieved by encouraging the public to purchase fuel-efficient vehicles, upgrading aircraft and rail locomotive fleets, and switching to innovative electric vehicles. The European Commission has proposed banning the use of gasoline-powered cars in cities by 2050. Some European countries have already adopted this ban as early as 2030.

Innovation plays a crucial role in the development of a green economy. Today, 40% of global innovation is related to the green economy, 50% of which is related to energy conservation and energy efficiency, key factors in a green economy. Furthermore, in developed countries, innovation currently encompasses not only the creation and improvement of new products but also the development of new technological complexes (i.e., the creation of new production facilities altogether), as well as the rebuilding of existing but temporarily lost (primarily in post-Soviet countries) production facilities on a new technological basis, and much more. All of this is implemented through the use of national innovation systems and economic mechanisms (R&D, technology transfer, innovation commercialization, public and private financing of innovation, etc.). In this regard, the "green" economy can be considered an integral part of the innovation economy, gradually occupying an increasingly important place within it. The following general key areas for the development of the "green" economy can be identified:

1. General ecosystem Management – waste Management, water and air pollution control, land (soil) restoration and rational use, reforestation and reforestation;

2. Implementation of renewable Energy sources;

3. Reducing the energy intensity of GDP and increasing energy efficiency (construction of buildings and structures, housing and utilities, industry, transport, agriculture);

4. Development of electric transport;

5. Organic farming in agriculture;

6. Development of Ecotourism.

Conclusion: *A Green Economy is a way of life that embraces environmental stewardship and protection, as well as shared responsibility, resulting in clean air, clean water, and high-quality food. Ultimately, this means a healthy environment and a strong, competitive Economy.*

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Geographical sciences

ANALYSIS OF CLIMATE CHANGE IN THE KABARDINO-BALKARIAN REPUBLIC DURING THE COLD PERIOD

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Abstract

The aim of this study is to investigate changes in key climate characteristics at two meteorological stations in the Kabardino-Balkarian Republic (Nalchik and Prokhladnaya) during the cold season of 1961-2024. The Kabardino-Balkarian Republic is located in the southern part of the temperate climate zone, shielded from the south and southwest by the Greater Caucasus Mountains and exposed to the north and northwest by cold air masses from the Arctic. To assess climate change, three key meteorological factors were analyzed: average air temperature, total precipitation, and relative humidity for the months of the cold season at two meteorological stations located in different climatic zones of the republic.

Data analysis revealed that the average temperature at both meteorological stations does not exceed the climatic norm, with the exception of November. Precipitation totals also do not exceed the climatic norm in all months of the cold season, except for January and February in Nalchik. Relative humidity exceeded the climatic norm in all months except January.

The study revealed a statistically significant increase in average monthly air temperature from January to March at both weather stations. Precipitation showed both statistically insignificant positive and negative trends. The linear trend coefficient for relative humidity was statistically significant only in February and March at both weather stations.

Keywords: *average temperature, precipitation, relative humidity, cold period, climatic norm, linear trend.*

In recent decades, climate change due to global warming has become one of the most pressing and debated topics. It is an undeniable fact that the average global surface temperature is rising. This fact has been noted previously and is currently confirmed in numerous studies by Russian and international scientists [1-6]. Researchers, citing the results of the Intergovernmental Panel on Climate Change (IPCC), note that the observed warming will lead to an increase in the frequency of extreme natural events, increased precipitation intensity, sharp fluctuations in air temperature, and an increase in the number of droughts [7-8].

Climate change is a global phenomenon that is felt everywhere, affecting every corner of the Earth and influencing our daily lives. Understanding these processes requires detailed study both globally and at the level of individual regions. Global warming is particularly noticeable in Russia: between 1900 and 2010, temperatures in the country increased by 1.2°C, significantly exceeding the global average of 0.74°C. Increases in average annual air temperature have been recorded in all Russian regions. However, given the country's vast size and the diversity of its natural zones, climate shifts manifest themselves differently depending on the specific territory and time of year.

Climate change studies conducted in the North Caucasus region, and in particular the Kabardino-Balkarian Republic (KBR), have shown a statistically significant increase in average annual temperatures, against a background of a statistically insignificant decrease in annual precipitation [9, 10].

Annual and seasonal values of climate variables are most often used to analyze climate change, but for some applications, the seasonal division of meteorological parameters into warm and cold periods is of interest rather than the seasonal division. This paper presents an analysis of climate indicators for the cold period (CP) (november-march) in the period from 1961 to 2024 at two meteorological stations (MS) of the KBR.

The Nalchik weather station is located in the foothills at an altitude of 500 meters above sea level, between the Pastbishchny and Tersky mountain ranges. The station, with WMO index 37212, has been operating since 1892. Its coordinates are 43°22' north latitude, 43°24' east longitude.

The Prokhladnaya weather station is located in the flatlands at an altitude of 198 meters above sea level, at the junction of the Tersko-Kuma Lowland and the Tersky mountain range. The station, with WMO index 37144, has been observing since 1873. Its coordinates are 43°74' north latitude, 44°06' east longitude.

The average, maximum, and minimum values of average temperature (°C), precipitation (mm), and relative humidity (%) for five months of the cold period (November–March) were analyzed, along with the slope coefficient of the linear trend (SCLT), which indicates the rate of change in climate parameters. The highest and lowest average values for meteorological stations over the entire period were determined, along with the dates of their occurrence.

Climate change was also assessed using standard climate normals, which characterize average values of climate parameters calculated over 30-year periods, consistent with recommendations of the World Meteorological Organization (WMO). Climate normals are generally accepted criteria for assessing climate anomalies, climate variability, and long-term climate change. A standard reference period from 1991 to 2020 was used to analyze climate change trends.

The obtained quantitative data are presented in Table 1 and allow us to identify trends and characteristics of climate processes in the study area during the cold period.

Table 1

Statistical characteristics of average temperature (°C), precipitation (mm) and relative humidity (%) for the cold period 1961-2024 based on data from Nalchik and Prokhladnaya stations

Characteristics (period) 1961-2024	Month				
	November	December	January	February	March
NALCHIK					
Average temperature, °C / normal (1991-2020), °C	4.3/4.0	-0.4/-0.3	-2.6/-1.8	-1.7/-1.1	3.2/4.1
Maximum of average, °C	8.7(2010)	4.5(2010)	2.3(2007)	5.2(2002)	8.6(2008)
Minimum of average, °C	-5.5(1993)	-7.2(2002)	-12.5(1972)	-9.9(1976)	-2.8(1985)
SCLT, °C/10 years / D, %	0.1/0.5	0.27/6.0	**0.58/16.0**	**0.58/10.0**	**0.58/18.0**
Total precipitation, mm / normal (1991-2020), mm	31.2/33.6	25.9/26.5	21.9/21.5	23.0/22.3	39.2/39.4
Maximum of average, mm	90.2(1992)	79.0(2001)	54.0(1966)	59.1(1978)	94.6(2018)
Minimum of average, mm	6.0(2010)	4.0(2011)	4.8(1999)	4.0(2017)	4.9(1979)
SCLT, mm/10 years / D, %	0.94/1.0	-1.27/3.0	-0.49/0.7	-0.69/1.3	0.43/0.2
Relative humidity, % / normal (1991-2020), %	83.9/83.7	86.0/85.3	84.7/84.9	83.3/82.5	80.3/78.1
Maximum of average, %	93.0(1968)	94.0(1966)	94.0(1966. 1981. 1996)	93.0(2013)	93.0(1987
Minimum of average, %	70.0(2015)	74.0(2015)	68.0(2007)	70.0(1998. 2002. 2017)	64.0(1990)
SCLT *, %/10 years / D %	-0.37/1.0	-0.29/1.0	-0.19/0.0	-0.82/6.0	**-1.24/12.0**
PROKHLADNAYA					
Average temperature, °C / normal (1991-2020), °C	4.4/4.0	-0.3/-0.3	-2.6/-1.8	-1.6/-1.0	3.9/4.8
Maximum of average, °C	8.0(2023)	4.7(2017)	2.1(2005)	4.5(2002)	10.2(2019)
Minimum of average, °C	-5.3(1993)	-8.1(2002)	-13.1(1972)	-9.6(1976)	-2.5(1985)
SCLT, °C/10 years / D %	0.04/0.0	0.26/5.0	**0.58/14.0**	**0.52/9.6**	**0.59/20.0**
Total precipitation, mm / normal (1991-2020), mm	27.2/30.5	25.9/26.6	20.7/22.8	21.0/22.4	30.6/33.8
Maximum of average, mm	87.0(1993)	70.0(1992)	50.5(2016)	51.0(1992)	88.6(2018)
Minimum of average, mm	3.0(1972)	2.0(2011)	4.0(1999)	2.3(2017)	2.0(1986)
SCLT, mm/10 years / D, %	1.53/2.7	-0.54/0.5	0.57/1.1	0.27/0.2	1.14/1.5
Relative humidity, % / normal (1991-2020), %	87.3/87.2	88.9/88.0	86.7/87.2	85.3/84.4	80.4/78.6
Maximum of average, %	95.0(1968)	97.0(2020)	94.0(1981. 2018)	92.0(1962. 2018)	90.0(1969. 1988)
Minimum of average, %	77.0(2015)	77.0(2017)	60.0(1961)	73.0(2017)	65.0(1990)
SCLT, %/10 years / D, %	-0.12/0.0	-0.40/3.0	0.28/1.0	**-0.78/12.0**	**-1.19/17.0**

An analysis of the temperature regime during the cold period showed that the average temperature at Nalchik and Prokhladnaya meteorological stations was only above the climatic norm in November, while in the remaining months (December through March) it did not exceed the norm. As can be seen from Table 1, the maximum average temperatures were observed after 2000, and the minimum

before 2000, with the exception of December, where the minimum values of -7.2°C and -8.1°C were observed in 2002 at Nalchik and Prokhladnaya meteorological stations, respectively.

The slope coefficients of the linear trends demonstrate a consistent positive change in average monthly temperatures in January, February, and March at both weather stations, with the largest monthly increase noted in March at a rate of 0.58°C/10 years with a D of 18% at Nalchik meteorological station and 0.59°C/10 years with a D of 20% at Prokhladnaya meteorological station.

Precipitation totals at Nalchik MS were above the climatic norm in January and February, while in the remaining months of the period, they were below the climatic norm. At Prokhladny MS, all average precipitation totals for the studied months were below the climatic norm. Analysis of changes in the SCLT revealed both positive and negative SCLT values, but all were statistically insignificant.

With regard to humidity, the situation is different: humidity below the climatic norm was observed only in January, and only slightly so – by 0.2% in Nalchik and by 0.5% in Prokhladny. The slope coefficients of the linear trend at Nalchik MS are negative in all months of the period, but are statistically significant only in March. At Prokhladny MS, there is one positive trend (January), but it is statistically insignificant. Significant negative SCLT values were observed only in February and March, with values of -0.78%/10 years, with D=12%, and -1.19%/10 years, with D=17%, respectively.

Also of interest is an analysis of climate change over the entire cold period from 1961 to 2024. A statistical analysis was conducted, and graphs of changes in these characteristics were plotted.

A statistical analysis of the climate characteristics during the cold period showed that, at the two stations under consideration, the average temperature and precipitation for the cold period were below the climatic norm, while the average relative humidity was above the norm. The results are presented in Table 2.

Table 2

Statistical characteristics of the cold period

№ n/n	Statistics	Temperature, °C	Precipitation, mm	Humidity, %
		NALCHIK		
1	Mean (standard error), $\bar{x}$	0.6 (0.2) °C	141.8(4.5) mm	83.7(0.377) %
2	Standard deviation, σ	1.6°C	36.4 mm	3.01 %
3	Minimum, min	-3.6°C (1972)	83 mm (1986)	76.6 % (2003)
4	Maximum, max	3.5°C (2023)	246.9 mm (1992)	90.4 % (1987)
5	Range, R	7.1°C	164 mm	13 %
6	Median	0.6	135	83
7	Confidence interval for the mean (lower-upper bounds)	0.168-0.944	132.7-150.9	82.9-84.4
8	Skewness, As	-0.425(0.299)	0.747(0.299)	0.051(0.299)
9	Kurtosis, E	-0.378(0.590)	0.170(0.590)	-0.542(0.590)
10	Normal distribution, P≥0,05	0.103>0.05 normal	0.090 >0.05 normal	0.102 >0.05 normal
11	Climate norm (1991-2020), N	1.0 °C	143.3 mm	82.9 %
12	T-test Sig. ≥0,05	0.026<0.05 are not equal	0.740≥0.05 equal	0.049<0.05 are not equal
13	Extremes	no	1 extremum ≥ 247 mm in 1992	no
		PROKHLADNAYA		
1	Mean (standard error), $\bar{x}$	0.8 (0.2) °C	125.7(4.0) mm	85.7(0.314) %
2	Standard deviation, σ	1.6°C	32.4 mm	2.5 %
3	Minimum, min	-3.8°C (1972)	64 mm (1975)	81.2 % (1961)
4	Maximum, max	3.5°C (2023)	227.2 mm (2018)	90.6 % (2018)
5	Range, R	7.3°C	163 mm	10 %
6	Median	0.8	125.0	86.0
7	Confidence interval for the mean (lower-upper bounds)	0.372-1.149	117.6-133.8	85.11-86.36
8	Skewness, As	-0.491(0.299)	0.576(0.299)	0.150(0.299)
9	Kurtosis, E	-0.035(0.590)	0.735(590)	-0.769(0.590)
10	Normal distribution, P≥0,05	0.120>0.05 normal	0.098>0.05 normal	0.130>0.05 normal
11	Climate norm (1991-2020), N	1.1°C	136.0 mm	85.1 %
12	T-test Sig. ≥0,05	0.086≥0.05 equal	0.013<0.05 are not equal	0.048<0.05 are not equal
13	Extremes	no	1 extremum ≥ 227 mm in 2018	no

Table 2 shows that the average temperature over the CP has a left-sided asymmetry with a negative excess As=-0.425 and E=-0.378 for Nalchik meteorological station and As=-0.491 and E=-0.035 for Prokhladnaya meteorological station; therefore, there is a flat peak of the distribution curve. For the amount of precipitation over the CP at Nalchik and Prokhladnaya meteorological stations, there is a right-sided asymmetry (As=0.747 and As=0.735), positive excess (E=0.170 and E=0.735) and normal distribution (0.09>0.05 and 0.098>0.05). For the relative humidity at Nalchik and Prokhladny meteorological stations, there is a slight right-sided asymmetry As=0.051 and As=0.150 and a negative excess E=-0.542 and E=-0.769. All climate characteristics exhibit a normal distribution with a P>0.05.

At the meteorological stations under consideration, only one extreme value was detected for precipitation totals ≥247 mm in 1992 in Nalchik and ≥227 mm in 2018 in Prokhladnaya.

Extreme values were also detected for each month of the period. It turns out that at the Nalchik station there is 1 extreme average monthly temperature in November (≤ -5.5°C in 1993), December (≤ -7.2°C in 2002) and February (1 extreme ≤ -7.2°C in 2002) and 3 extreme values ≤ -8.6°C in January (-8.6°C in 1969, -12.5°C in 1972, -10.1°C in 1977).

At the Prokhladny meteorological station, two extreme values ≤ -0.3°C were recorded (-5.3°C in 1993, -0.3°C in 2011), one extreme value ≤ -8.1°C in December 2002, and six extreme values ≤ -7.6°C in January: -7.6°C in 1964, -8.1°C in 1969, -13.1°C in 1972, -7.8°C in 1973, -10.7°C in 1977, and -8.5°C in 2008.

In terms of precipitation, extreme values were recorded in all months at both meteorological stations. At Nalchik MS, 10 extreme values of precipitation amounts were recorded: in November, 2 extremes ≥ 79 mm (79 mm in 1995 and 90 mm in 1992), in December, 2 cases ≥ 57 mm (57 mm in 1992 and 79 mm in 2001), in January, 1 extreme ≥ 54 mm (54 mm in 1966), in February, 2 extremes ≥ 53 mm (59 mm in 1978 and 53 mm in 1992) and in March, 2 extreme values ≥ 94 mm (94 mm in 1977 and 95 mm in 2018). Ten extreme precipitation totals were also recorded at Prokhladny MS: November had one extreme ≥ 87 mm (87 mm in 1993), December had two instances of exceeding the 68 mm threshold (71 mm in 1977 and 89 mm in 2018), and January and February were similar in their "extremeness," with each month having two extremes ≥ 49 mm (49 mm in January 2010 and February 1978, and 51 mm in January 2016 and February 1992). March had the absolute highest number of extreme values, exceeding the 71 mm mark three times: exactly 71 mm fell in 1977, 75 mm in 2002, and 89 mm in 2018. Regarding relative humidity, the Nalchik weather station has recorded only two extreme values below the threshold: ≤ 68% in November 2007 and ≤ 70% in December 1998. The situation is different at the Prokhladnaya meteorological station. Here, extreme values of relative humidity below the threshold (79%) were observed more frequently: twice in November – 79% in 1978 and 77% in 2015; three times in December – 79% in 2013, 78% in 2015, and 77% in 2016; and one extreme in January (≤ 60% in 1961) and March (≤ 65% in 1990). The only month without extreme values of relative humidity in Prokhladny is February. Figure 1 shows the course of change in average temperature, precipitation and relative humidity for the entire cold period (November-March) 1961-2024 with linear trends.

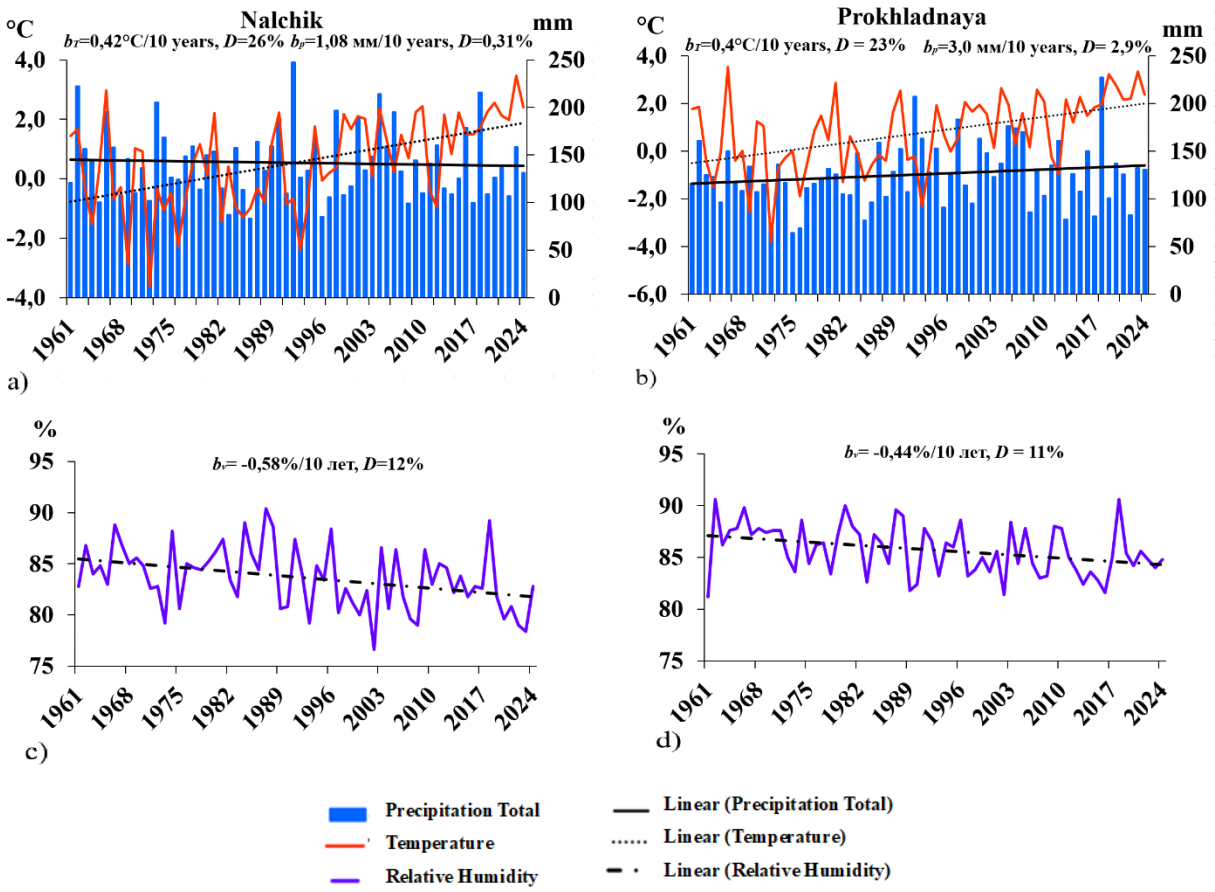

Figure 1. Average temperatures, precipitation totals, and relative humidity for the cold season

As Figure 1a and 1b show, the slope of the linear trend for average temperature during the cold season at the Nalchik and Prokhladnaya weather stations is positive and statistically significant. The increase rate was b=0.42°C/10 years, D=26%, and b=0.4°C/10 years, D=23%, respectively. This confirms a significant and consistent upward trend in average temperature during the cold season. For precipitation totals, the trends are statistically insignificant at both stations. Nalchik shows a slight negative trend (b=1.08 mm/10 years, D=0.31%), while Prokhladnaya shows a positive trend (b = 3.0 mm/10 years, D=2.9%). Relative humidity at both stations showed a statistically significant decrease (b=-0.58%/10 years, D=10%) at Nalchik MS (Fig. 1c) and (b=-0.88%/10 years, D=9%) at Prokhladny MS (Fig. 1d).

Conclusion: *This study identified trends and characteristics of climatic processes by month of the cold period and for the entire period from 1961 to 2024 in the study area.*

The average temperature at both MS does not exceed the climatic norm, with the exception of November. An analysis of the maximum and minimum average temperatures shows that the maximums occurred after 2000, while the minimums occurred before 2000, with the exception of December, where the minimum at both stations occurred in 2002. Precipitation totals at Nalchik and Prokhladny stations did not exceed the climatic norm in all months of the cold period, with the exception of January and February in Nalchik. Relative humidity was slightly below the climatic norm in January, but exceeded the norm in the remaining months of the cold period.

A study of changes in these climatic characteristics at Nalchik and Prokhladny stations revealed an increase in average monthly air temperature at both stations, but this increase was statistically significant only in January, February, and March. This was not the case for precipitation totals, where statistically insignificant positive and negative linear trends were observed. For relative humidity, significant SCLT were found only for February and March at both stations. For the average values of the entire cold period, the slope of the linear trend in average temperature was found to be positive and statistically significant at both meteorological stations. For precipitation totals, the trends were statistically insignificant, with a slight negative trend in Nalchik and a positive trend in Prokhladnaya. Changes in relative humidity showed a statistically significant decrease at the studied weather stations.

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Medical sciences

IMPETIGO HERPETIFORMIS IN A PREGNANT WOMAN WITH ICHTHYOSIS VULGARIS- CASE REPORT

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Abstract

Introduction: *Impetigo Herpetiformis (IH) is a rare pregnancy dermatosis considered to be a variant of Pustular Psoriasis. It typically manifests in the third trimester with generalised pustules, serious systemic alterations and placenta insufficiency, which can lead to maternal or fetal death. Differential diagnosis comprises Subcorneal Pustulosis of Sneddon-Wilkinson, Acute Generalized Exanthematous Pustulosis (AGEP), Pemphigoid Gestationes and Dermatitis Herpetiformis during pregnancy.*

Case Report*: We report the case of a 31-year-old female, 18 weeks pregnant. She was referred to the dermatology department* ***presenting these symptoms:*** *high fever, chills, malaise, and a widespread eruption consisting of erythematous, edematous plaques with innumerable non-follicular pustules (distinct and confluent). In her childhood she was diagnosed with a rather severe form of Ichthyosis Vulgaris, for which she had periodically undergone courses of systemic Acitretin. Based on clinical findings, laboratory results, and histopathology the diagnoses of Impetigo Herpetiformis (IH) was concluded. Corticosteroid therapy was started which was gradually tapered, along with systemic antibiotics, parenteral fluids, antipyretics, topical antiseptics and emollient creams. At 29 weeks gestation, the pregnancy ended in stillbirth and we concluded that IH might have potentially contributed to the fatal outcome.*

Conclusion: *This case highlights the severity of IH during pregnancy and its potential to contribute to poor pregnancy outcomes, including stillbirth. Early diagnosis, aggressive treatment, and multidisciplinary management (dermatology, obstetrics, and neonatology teams) are critical in such cases to optimize maternal and fatal outcomes.*

Keywords: *impetigo herpetiformis, pregnancy, ichtiosis vulgaris.*

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

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Abstract

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

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

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

ultrasound diagnostics occupies a leading position both in diagnostics and for monitoring [1-4].

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

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

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

In comparison, patients referred because of an solid pseudopapillary neoplasm (SPN) on

examination and for CS identified nodules on 55% and 39% of ultrasounds, respectively. Patients with MS had a nodule on ultrasound 43% of the time. Among those referred for high-risk factors, 57% had a nodule present. Patients referred for combined indications had nodules on 42% of ultrasounds. Analysis of variance (ANOVA) indicated the difference in nodule detection rate between indications was statistically significant ($p < 0.05$). Only 27% of ultrasounds identified a thyroid nodule that was recommended for biopsy. Those referred from incidental imaging had the highest percentage of biopsy-recommended nodules (55%). This was followed, in order, by patients referred for physical examination of a palpable thyroid nodule (21%), high-risk factors (20%), combined indications (16%), MS (10%), and CS (6%). The overall mean maximum diameter of identified thyroid nodules was 1.9 cm (SD 1.3 cm). Of note, 32 radiology reports identified a thyroid nodule but did not record size and were, therefore, excluded from this specific analysis. Patients referred for incidentally found thyroid nodules had the largest mean nodule size at 2.4 cm (SD 1.2 cm). All other groups had a mean nodule size between 1.2 and 1.8 cm. The difference in average size of nodule was statistically significant ($p < 0.05$). A logistic regression model evaluated the association of patient age, sex, ethnicity, CCI, insurance status, and referral indication with identification of a nodule on ultrasound. Compared with patients referred for an SPN on examination, those with incidental nodules were over 10 times more likely to have a nodule found on ultrasound (odds ratio [OR] = 10.6 [confidence interval (CI) 7.0–16.0]). Conversely, patients referred for CS were half as likely to have an identifiable nodule compared with those referred for physical examination findings (OR = 0.5 [CI 0.4–0.7]). In addition, the odds of finding a nodule increased with age, especially for those aged 65 years and above (vs. age <45 OR = 3.6 [CI 2.2–5.9]). Finally, females were twice as likely to have a nodule found on thyroid ultrasound (OR = 2.0 [CI 1.5–2.6]). Results were similar when evaluating only biopsy-recommended nodules. Compared with patients referred for an SPN on examination, those referred for incidental findings were significantly more likely to have a biopsy-recommended nodule (OR = 4.7 [CI 3.5–6.3]), while those referred for CS were significantly less likely to have a biopsy-recommended nodule on ultrasound (OR = 0.3 [CI 0.1–0.5]. There was no difference in identifying biopsy-recommended nodules between sexes (female vs. male OR = 1.2 [CI 0.9–1.6]). In conclusion, the authors emphasize that only a quarter of dedicated thyroid ultrasounds yielded a nodule recommended for biopsy, and 39% did not have a nodule present at all. Moreover, only half of ultrasounds performed to evaluate a suspected nodule on physical examination actually identified one. Ultrasound referrals for symptoms had the lowest diagnostic yield, with fewer than 10% identifying a biopsy-recommended nodule. These findings suggest that re-evaluation of guidelines on thyroid ultrasound referral may be necessary to decrease the overutilization of thyroid ultrasound and the downstream consequences of detection of small potentially irrelevant nodules [6].

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

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

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

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

branches, which was in line with the actual situation. This shows that SMI technology has a good imaging effect on nodular blood vessels [7].

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

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

The researchers piloted and applied an extraction form to collect patient demographics and the specialty of the clinician who conducted the physical exam. From the physical exam documentation, they extracted the types of findings (solitary nodule, multinodular goiter, enlargement without nodularity, normal thyroid, and an "other category" for patients with indeterminate findings such as thyroid asymmetry). Additionally, study's authors documented the precise locations (right lobe, left lobe, isthmus or bilateral) where these findings were encountered, whenever the data was accessible. In a similar fashion, researchers carefully extracted the TUS findings (solitary nodule, multinodular goiter, enlargement without nodularity, no finding, and "other category" to group patients who had thyroiditis without the presence of nodules or lymphadenopathy) and noted the corresponding locations of the

described findings. When there was a nodular finding in the ultrasound, authors extracted the largest diameter from the largest nodule. Given that the accuracy of thyroid physical exam may be affected by previous knowledge of thyroid-related symptoms, our colleagues also documented whether there was presence of symptoms associated with thyroid nodules or masses (e.g., neck fullness, dysphagia, odynophagia, choking, etc). The authors summarized continuous variables using means and standard deviations, and categorical variables using frequencies and percentages. Using the TUS findings as the reference standard, they calculated the accuracy of the findings noted from the thyroid palpation. First, our colleagues calculated the sensitivity, specificity, accuracy, and positive predictive value (PPV) and negative predictive value (NPV) of the thyroid palpation in the identification of any abnormal thyroid findings (any abnormality yes/no in thyroid palpation compared with any abnormality yes/no in thyroid ultrasound). Then, study's authors estimated the accuracy of the physical exam in detecting thyroid nodules (single thyroid nodule [yes/no] detected by thyroid palpation compared to thyroid nodule [yes/no] detected on confirmatory thyroid ultrasound), and multinodular goiters (multiple nodules [yes/no] found by thyroid palpation compared to multiple nodules [yes/no] identified on a thyroid ultrasound). Additionally, they calculated the accuracy and PPV of the thyroid physical exam to determine the location (e.g., right lobe, left lobe, isthmus or bilateral) of the thyroid findings when data was available in the medical records. Finally, authors calculated the proportion of 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 >2cm), 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 thyroxin (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 abovementioned three linear dimensions (ellipsoid equation with a correction factor: V (ml) = L (cm) × A-P (cm) × W (cm) × 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 mUI/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 ± 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 (x2-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 [x2(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 [x2(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, [x2(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 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 ± 0.05012and 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 articifial 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 10 s. 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 sulphuhexafluoride 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 ml±5 ml (27 to 69 ml). All echo-poor, irregularly vascularized, inhomogeneously indurated lesion > 1 cm were identified as highly suspicious for malignancy with early wash out kinetics and were also confirmed surgically. The 13 cases of histologically confirmed thyroid carcinoma (8 papillary, 2 medullary, 2 microfollicular, 1 anaplastic carcinoma) with a mean size of 15 mm±6 mm (9–21 mm) were correctly evaluated by TI-RADS IV based on irregular shape, induration > 2.5 m/s or > 30 kPA and appositional wash-out kinetics using CEUS (TI-RADS V). Tumor lymph nodes could be correctly detected preoperatively only in one case of medullary carcinoma according to the surgical findings, based on irregular vascularization with UMA in roundish shape with cortex > 4 mm with a transverse diameter up to 11 mm. In 25 cases of inhomogeneous nodular goiter, evaluation with TI-RADS III was performed in 31

cases, evaluation with TI-RADS IV was performed in 4 cases with incomplete marginal contour, partial marginal vascularization with UMA and partial wash out with indurations up to 2.5 m/s or 30 kPA, and surgical excision was performed for nodular goiter. In 12 cases of adenomas with diameters of 1.7 to 3.5 cm, mean 26 cm±0.5 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 thyroxin, provides a comprehensive picture of the functional state of the thyroid gland.

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

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

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

of complications and/or radiation exposure, and make it possible to conduct targeted, specialized treatment for these patients.

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Pedagogical sciences

TEACHER REFLECTION AS A TOOL FOR PROFESSIONAL DEVELOPMENT IN ENGLISH LANGUAGE EDUCATION

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Abstract

Teacher reflection has become an essential component of professional development in contemporary English language education. Reflective practice enables teachers to critically analyze their teaching methods, classroom interactions, and instructional strategies, which contributes to the improvement of pedagogical effectiveness and student learning outcomes. The purpose of this study is to examine the role of reflective practice as a tool for enhancing professional competence among English language teachers. The research is based on the analysis of recent studies on reflective teaching and professional development in English as a Foreign Language (EFL) contexts. The findings indicate that systematic reflection—through teaching journals, peer observation, and collaborative discussions—helps educators identify strengths and weaknesses in their instructional practices. Furthermore, reflective activities promote continuous learning, pedagogical innovation, and greater teacher autonomy. Recent research also highlights the role of collaborative reflection and digital technologies in supporting reflective teaching practices in modern educational environments. The study concludes that reflective practice is a significant mechanism for improving teaching quality and fostering sustainable professional development among English language educators.

Keywords: *teacher reflection, reflective teaching, ELT, professional development, English language education*

Introduction

In recent decades, the role of teachers in English language education has changed significantly due to globalization, technological advancement, and the growing demand for effective communication in English. Teachers are no longer expected to simply deliver knowledge; instead, they are required to continuously evaluate and improve their instructional practices. In this context, teacher reflection has become an important component of professional development in English language teaching. Reflective practice allows educators to analyze their teaching experiences, understand classroom challenges, and develop more effective pedagogical strategies.

Reflective teaching is commonly understood as the process through which teachers critically examine their classroom practices in order to improve the quality of instruction and student learning outcomes. According to Riyanti (2021), reflective practice encourages teachers to analyze their own experiences, identify areas for improvement, and develop new teaching strategies that better meet the needs of learners. Through reflection, educators become more aware of their teaching methods and are able to make informed decisions about instructional approaches.

In the field of English as a Foreign Language (EFL), reflective practice plays a particularly important role because teaching contexts are often dynamic and culturally diverse. Teachers frequently encounter challenges related to student motivation, language proficiency levels, and classroom interaction. Reflective activities such as maintaining teaching journals, conducting peer observations, and engaging in professional discussions help teachers better understand these challenges and adapt their teaching practices accordingly (Lap et al., 2024). As a result, reflective practice contributes not only to improved classroom management but also to the development of more effective learning environments.

Recent studies have also highlighted the importance of collaborative reflection, where teachers share their experiences and insights with colleagues. Collaborative reflective practices allow educators to exchange ideas, learn from each other's experiences, and develop innovative teaching strategies. Research by Rozimela, Fatimah, and Fudhla (2025) demonstrates that both individual and collaborative reflection can significantly enhance teachers' professional competence and promote continuous

professional growth. Similarly, Yukselir and Ozer (2025) emphasize that reflective dialogue between teachers and researchers can strengthen the connection between theory and classroom practice.

Furthermore, modern educational environments increasingly integrate digital technologies, which also influence reflective teaching practices. Digital tools, online platforms, and intelligent assessment systems can provide valuable feedback that helps teachers evaluate their teaching effectiveness and identify areas for improvement (Alam et al., 2024). These technological developments create new opportunities for reflective learning and professional development among language educators.

Despite the growing recognition of reflective teaching in professional development, many teachers still face difficulties in implementing systematic reflection in their daily practice. Time constraints, lack of institutional support, and limited awareness of reflective methods may hinder teachers from fully engaging in reflective activities. Therefore, understanding the role of reflection as a professional development tool remains an important area of research in English language education.

The purpose of this study is to explore the role of teacher reflection as a tool for professional development in English language education. The paper analyzes recent research on reflective teaching practices and discusses how reflection can contribute to the improvement of teaching quality and the professional growth of English language educators.

Literature review

Reflective practice has become a central concept in teacher professional development, particularly in the field of English language education. The idea that teachers should critically examine their teaching practices in order to improve instructional quality has been widely discussed in educational research. Reflective teaching encourages educators to evaluate their classroom experiences, identify challenges, and implement strategies that enhance student learning outcomes. As English language education continues to evolve in response to globalization and technological change, reflective practice has gained increasing importance as a tool for continuous professional growth (Ferreiro, 2025; Erbilgin & Robinson, 2025; Lap et al., 2024).

One of the main benefits of reflective teaching is its role in helping teachers become more aware of their instructional strategies and classroom dynamics. According to Riyanti (2021), reflective teaching enables educators to analyze their own teaching experiences and recognize both strengths and weaknesses in their instructional practices. This process encourages teachers to think critically about their pedagogical decisions and adjust their teaching methods in order to better meet the needs of learners. Reflection therefore contributes to the development of more effective and responsive teaching approaches in English language classrooms.

In English as a Foreign Language (EFL) contexts, reflective practice is particularly valuable because teachers often work with students who have diverse linguistic and cultural backgrounds. Lap et al. (2024) emphasize that reflective teaching helps EFL educators evaluate their classroom practices and identify ways to improve language instruction. Their research shows that teachers who regularly engage in reflective activities, such as self-evaluation and teaching journals, tend to develop a deeper understanding of their teaching processes. As a result, reflective practice promotes greater teacher autonomy and professional awareness.

Another important aspect of reflective teaching is the role of collaborative reflection. Rather than reflecting individually, teachers can benefit from discussing their experiences with colleagues and participating in professional learning communities. Rozimela, Fatimah, and Fudhla (2025) highlight that both individual and collaborative reflective practices contribute significantly to teacher professional development. Their study demonstrates that when teachers share their experiences and teaching challenges with peers, they gain new perspectives and develop innovative instructional strategies. Collaborative reflection therefore helps create a supportive professional environment where teachers can learn from one another.

Teacher collaboration can also take the form of partnerships between teachers and researchers. Yukselir and Ozer (2025) describe how reflective dialogue between teachers and academic researchers can support professional learning and bridge the gap between theory and classroom practice. Through such collaborations, teachers are able to examine their teaching experiences more systematically and apply research-based insights to their classroom activities. This process not only strengthens teachers' professional competencies but also encourages continuous improvement in teaching practices.

Another factor influencing reflective practice in modern education is the integration of technology. Digital tools and online platforms increasingly support teachers in evaluating their teaching performance and monitoring student progress. Alam et al. (2024) argue that technological developments, particularly intelligent computer-assisted assessment systems, provide new opportunities for reflective teaching.

These systems generate valuable feedback that allows teachers to assess their instructional methods and identify areas that require improvement. As a result, technology can enhance reflective practice by providing more data-driven insights into teaching effectiveness.

Professional development programs also play an important role in promoting reflective teaching among educators. For instance, Erbilgin and Robinson (2025) demonstrate that structured professional learning environments, such as lesson study programs, encourage teachers to reflect on their instructional practices and collaborate with colleagues. Such programs allow teachers to observe classroom lessons, discuss teaching strategies, and jointly analyze student learning outcomes. This collective reflection fosters professional growth and helps teachers continuously refine their pedagogical approaches.

Similarly, research focusing on pre-service and early-career teachers shows that reflective practice is essential for developing teaching competence. Rakhimova (2025) examined the perceptions of pre-service English teachers regarding reflective practice and professional development. The findings indicate that reflective activities help novice teachers gain confidence and improve their understanding of effective teaching methods. By reflecting on their experiences during teaching practicum, future educators can better prepare themselves for real classroom challenges.

Reflective teaching also plays an important role in teacher education programs. Ferreiro (2025) emphasizes that reflective practice during teaching practicum allows student teachers to critically analyze their classroom experiences and connect theoretical knowledge with practical teaching skills. Through reflection, future educators can evaluate their instructional decisions and develop strategies for improving student engagement and learning outcomes.

Overall, the literature suggests that reflective practice is a key element in teacher professional development within English language education. Reflection allows educators to critically examine their teaching practices, adapt to diverse classroom contexts, and continuously improve their instructional methods. Both individual and collaborative forms of reflection contribute to professional growth, while technological tools and professional learning programs further support reflective teaching practices. Therefore, reflective practice can be considered an essential mechanism for enhancing teaching quality and supporting the ongoing professional development of English language teachers.

Methodology

Research Design

This study employed a qualitative research design in order to explore teachers' perceptions of reflective practice as a tool for professional development in English language education. Qualitative research is particularly suitable for investigating participants' experiences, opinions, and attitudes toward specific educational practices. In this study, a qualitative approach allowed the researcher to gain deeper insights into how English language teachers understand and apply reflective practices in their professional activities.

Participants

The participants of the study consisted of ten English language teachers working in secondary schools and language centers. The participants were selected through convenience sampling, as they were easily accessible to the researcher. The teachers had varying levels of teaching experience, ranging from two to ten years in English language education. This diversity of teaching experience allowed the study to capture different perspectives on reflective practice and professional development. All participants voluntarily agreed to take part in the study.

Data collection

Data were collected through a semi-structured questionnaire consisting of open-ended questions related to teachers' experiences with reflective practice. The questionnaire was designed to explore participants' understanding of reflective teaching, the methods they use to reflect on their instructional practices, and the perceived impact of reflection on their professional development. The questions also focused on possible challenges teachers face when engaging in reflective activities.

Examples of the questions included: how often teachers reflect on their teaching practices, what strategies they use for reflection (such as teaching journals, peer observations, or discussions with colleagues), and how reflective practice contributes to improving their teaching effectiveness. The use of open-ended questions allowed participants to express their opinions and experiences freely, providing richer and more detailed responses.

Data Analysis

The collected data were analyzed using thematic analysis. First, all responses were carefully reviewed in order to identify recurring ideas and patterns. After the initial reading, similar responses were

grouped into broader categories and themes related to reflective teaching and professional development. This process helped to identify the most common perceptions and experiences shared by the participants. The analysis focused on highlighting key themes that illustrate how reflective practice supports teachers' professional growth and contributes to improving teaching practices in English language education.

Discussion

The analysis of the participants' responses revealed several important themes related to the role of reflective practice in teachers' professional development. Thematic analysis allowed the identification of recurring patterns in teachers' perceptions and experiences with reflective teaching. The results indicate that reflective practice plays a significant role in improving teaching effectiveness, supporting professional growth, and promoting collaboration among educators.

Reflection as a Tool for Improving Teaching Practice

One of the most frequently mentioned themes in the responses was the role of reflection in improving teaching practices. Many participants reported that reflecting on their lessons allowed them to evaluate their teaching methods and identify aspects that needed improvement. Teachers noted that reviewing their classroom experiences helped them better understand students' needs and adjust their instructional strategies accordingly.

Several participants mentioned that after reflecting on their lessons, they were able to modify activities, improve explanations, and adopt more effective classroom management techniques. These findings support the argument that reflective practice encourages teachers to critically analyze their teaching experiences and continuously improve their instructional approaches (Riyanti, 2021). By engaging in reflection, teachers become more aware of their pedagogical decisions and their impact on student learning.

Reflection and Professional Development

Another important theme that emerged from the analysis was the connection between reflective practice and professional development. Participants emphasized that reflection helped them evaluate their professional progress and identify areas where further development was needed. Some teachers reported that maintaining reflective journals or reviewing their lessons after teaching allowed them to recognize their strengths and weaknesses as educators.

These findings are consistent with previous research suggesting that reflective practice plays an essential role in supporting teachers' continuous professional learning (Lap et al., 2024). Through systematic reflection, educators can develop a deeper understanding of their teaching practices and improve their professional competence. Reflective activities also encourage teachers to adopt innovative teaching methods and remain open to new pedagogical approaches.

Collaborative Reflection

The importance of collaboration in reflective practice was also highlighted by several participants. Teachers reported that discussing teaching experiences with colleagues helped them gain new perspectives and develop alternative strategies for addressing classroom challenges. Informal discussions with other teachers, peer observations, and participation in professional meetings were mentioned as valuable opportunities for collaborative reflection.

This finding aligns with the research of Rozimela et al. (2025), who emphasize that collaborative reflection allows teachers to learn from each other and develop more effective teaching practices. Similarly, Yukselir and Ozer (2025) highlight that collaborative dialogue between educators can strengthen professional learning and help teachers connect theoretical knowledge with practical classroom experience.

Challenges in Reflective Practice

Although participants recognized the benefits of reflective teaching, some challenges were also identified. Several teachers reported that limited time and heavy workloads often prevented them from engaging in regular reflective activities. In addition, some participants mentioned that they lacked formal training on how to conduct systematic reflection on their teaching practices.

These findings are consistent with the observations of Erbilgin and Robinson (2025), who note that institutional support and structured professional development programs are important for encouraging teachers to engage in reflective practice. Providing teachers with opportunities for professional collaboration and reflection can therefore enhance the effectiveness of reflective teaching in educational settings.

Overall, the results of this study suggest that reflective practice is a valuable tool for improving teaching quality and supporting the professional development of English language teachers. Reflection

allows educators to critically examine their teaching experiences, collaborate with colleagues, and continuously develop their pedagogical skills.

Conclusion

This study explored the role of reflective practice as a tool for professional development in English language education. The findings indicate that reflective teaching allows educators to critically analyze their instructional practices, identify areas for improvement, and develop more effective teaching strategies. The results of the qualitative analysis show that reflection supports teachers' professional growth, enhances their awareness of classroom practices, and encourages collaboration with colleagues. These findings are consistent with previous research highlighting the importance of reflective practice in improving teaching quality and promoting continuous professional learning.

However, the study has several limitations. First, the number of participants was relatively small, which may limit the generalizability of the findings. In addition, the data were collected through self-reported responses, which may reflect participants' subjective perceptions of their teaching practices.

Despite these limitations, the study provides practical implications for English language education. Educational institutions should encourage reflective teaching by providing professional development opportunities, collaborative learning environments, and structured reflection activities. Supporting teachers in engaging in reflective practice may contribute to improving teaching effectiveness and fostering sustainable professional development among English language educators.

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Appendix A

The following questions were used to collect data about teachers' experiences with reflective practice and professional development in English language education.

1. *How do you understand the concept of reflective teaching in your professional practice?*
2. *How often do you reflect on your teaching after conducting a lesson?*
3. *What methods do you usually use to reflect on your teaching practice? (For example: teaching journals, self-evaluation, peer observation, discussions with colleagues.)*
4. *Can you describe a situation when reflecting on your teaching helped you improve your lesson or teaching strategy?*
5. *In your opinion, how does reflective practice contribute to your professional development as an English language teacher?*
6. *Do you discuss your teaching experiences with colleagues or participate in collaborative reflection? If yes, how does it help you improve your teaching?*
7. *What challenges do you face when trying to reflect on your teaching practices?*
8. *What strategies or support could help teachers engage more actively in reflective practice?*

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ENHANCING PEDAGOGICAL COMMUNICATIVE COMPETENCE FOR EFFECTIVE CONTENT AND LANGUAGE INTEGRATED LEARNING IMPLEMENTATION

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Abstract

Content and Language Integrated Learning (CLIL) has become a prominent educational approach for integrating subject content and language learning in multilingual and internationalized educational contexts. While previous research has extensively explored learners' linguistic and academic outcomes in CLIL settings, considerably less attention has been paid to the development of teachers' pedagogical communicative competence, particularly within preservice teacher education. This study addresses this gap by examining how participation in a structured CLIL-oriented professional development programme influences preservice teachers' pedagogical communicative competence. Adopting a mixed-methods research design, the study investigates both measurable changes in preservice teachers' pedagogical communication skills and their perceptions of professional and transformative learning experiences. Quantitative data were collected through performance-based assessments focusing on classroom discourse, scaffolding strategies, subject–language integration, and lesson planning, while qualitative data were obtained through reflective journals and semi-structured interviews. The findings indicate that targeted CLIL training contributes to significant improvements in preservice teachers' ability to communicate subject content clearly, manage classroom interaction, apply language-sensitive teaching strategies, and integrate the Language Triptych into instructional practice. Furthermore, qualitative findings reveal that participants experienced increased professional confidence, enhanced reflective awareness, and greater readiness to implement CLIL in real classroom contexts. The study underscores the central role of pedagogical communicative competence in effective CLIL implementation and highlights the importance of systematic, practice-oriented training within teacher education programmes. The results offer valuable implications for CLIL teacher education, curriculum design, and professional development in multilingual educational contexts.

Keywords: Content and Language Integrated Learning (CLIL); pedagogical communicative competence; preservice teacher education; CLIL teacher training; classroom discourse; language-sensitive pedagogy

Introduction

Content and Language Integrated Learning (CLIL) remains one of the most influential pedagogical frameworks in contemporary education, integrating subject content instruction with the simultaneous development of a foreign or additional language. Initially conceptualized and implemented in European educational systems, CLIL has progressively expanded to diverse global contexts, including primary, secondary, and higher education, due to its potential to foster learners' cognitive, linguistic, and sociocultural competences in an integrated manner [1]. As educational systems increasingly emphasize multilingualism, internationalization, and competence-based learning, CLIL continues to gain strategic relevance worldwide. Recent research consistently emphasizes that the effectiveness of CLIL implementation is closely linked to teachers' professional competences rather than to curricular design alone [2]. While numerous studies have examined learners' linguistic outcomes and academic achievement in CLIL contexts, systematic reviews indicate that pedagogical communicative competence—particularly classroom interaction, instructional discourse, and scaffolding practices—remains comparatively under-researched. This gap is notable given that communication constitutes the core medium through which subject knowledge and language development are jointly constructed in CLIL classrooms. Beyond foundational pedagogical preparation, recent research highlights the importance of innovative instructional approaches within CLIL contexts. Translanguaging practices and multimodal pedagogies have been identified as effective strategies for promoting comprehension, learner confidence, and inclusive participation. By allowing learners to mobilize multiple linguistic and semiotic resources, these approaches contribute to deeper cognitive engagement and facilitate access to complex subject content, particularly in linguistically heterogeneous classrooms. Despite these pedagogical advances, persistent challenges in CLIL implementation continue to be reported across

educational settings. Teachers frequently identify limited institutional support, insufficient opportunities for sustained professional development, and a lack of CLIL-specific assessment literacy as major constraints. Recent scoping reviews underline the urgent need for assessment frameworks that coherently align content mastery with language development, ensuring validity and transparency in CLIL evaluation practices. The research questions guiding this study are:

RQ1: How do subject teachers and foreign language teachers perceive the implementation of Content and Language Integrated Learning (CLIL) methodology and pedagogical strategies in higher education institutions in Kazakhstan?

RQ2: What pedagogical and communicative benefits do teachers associate with the use of CLIL methodology in higher education contexts?

RQ3: What challenges and constraints do teachers identify in implementing CLIL, particularly in relation to pedagogical communicative competence, institutional support, and assessment practices?

Literature Review

Content and Language Integrated Learning (CLIL) is increasingly prevalent worldwide, occurring in primary, secondary, and tertiary educational institutions. CLIL is described as "an educational approach that employs various language-supportive methodologies, resulting in a dual-focused form of instruction where both language and content are emphasized" [3]. Additionally, CLIL serves as an umbrella term encompassing different types of multilingual programs that use a second language (L2) as the medium of instruction for content subjects. Variants of CLIL include Immersion, Content-Based Instruction, and English-Medium Instruction [4]. In this special issue, CLIL is broadly defined as an educational setting where an additional language is used as the medium of instruction for teaching content subjects. This definition covers a range of settings that differ in various aspects, such as their student populations and the balance they place on content and language learning [3]. In the field of education, there has been a tendency to view languages as distinct and separate entities. This perspective has influenced the early definitions of multilingualism, resulting in, paradoxically, promoting the ideology of a monolingual norm. Multilingual individuals were often seen as deficient and lacking language competence, as suggested by concepts like non-native speakers [5] interlanguage [6], and L2 fossilization [7]. These concepts imply that multilinguals exhibit incomplete and incorrect linguistic usage and struggle to achieve the native-speaker standard. However, sociolinguists have criticized this monolingual perspective of multilingualism and offer alternative understandings [8]. As Li [9] argues, rather than perceiving what languages multilinguals know or do not know, researchers should focus on how different languages, and multimodal resources, which are known by multilinguals, can be useful resources for learning. In the past decade, the concept of "translanguaging" has garnered significant attention from scholars researching CLIL classrooms. With contributions from leading scholars in the fields of multilingualism and CLIL, this special issue aims to explore how teachers and students utilize their diverse multilingual and multimodal resources to develop students' learning of discipline-specific knowledge and enhance their ways of thinking within the specific disciplines. These resources include a variety of linguistic repertoires, registers, body language, visuals, and other modes of communication. We initially solicited proposals from scholars worldwide to contribute to this special issue, receiving over 72 submissions from various countries, including Hong Kong (China), the United States, Spain, the United Kingdom, Turkey, Norway, Indonesia, Australia, Canada, Finland, Austria, New Zealand, Germany, Japan, and Mainland China. Ultimately, we accepted 8 research papers for the issue, representing scholars from five countries: the United States, Canada, Australia, Hong Kong (China), and Finland [10]. Nikula et al. [11] examine how unpacking and repacking disciplinary knowledge is achieved multimodally in CLIL Physics and Chemistry classrooms through translanguaging practices. The study integrates multimodal Conversation Analysis and Legitimation Code Theory to highlight the complexity of knowledge construction. The findings reveal that teachers use various multimodal resources, such as depictive gestures, everyday objects, and pedagogical tools like PowerPoint, Prezi presentations, smartboards, and inscriptions, to unpack subject-specific knowledge. The authors argue that these diverse multimodal resources enable teachers to engage in multimodal trans languaging, which facilitates the construction and communication of subject-specific meanings. Wong and Tian's [12] study emphasizes the effectiveness of teacher-researcher collaboration in helping CLIL teachers develop a translanguaging stance, engage in translanguaging designs, and make translanguaging shifts. In their research, they adopted a participatory approach to co-design lessons with two CLIL teachers in a Chinese immersion setting. Aligned with its national language policy in education, Kazakhstan became the first country in Central Asia to introduce Content and Language Integrated Learning (CLIL), which incorporates the use of three languages as mediums of instruction for certain subjects [13]. However, globally, Kazakhstan is ranked

at a "Very Low Proficiency" level according to the The World's largest ranking of countries and regions by English skills. Furthermore, Gimeno [14] concluded that there is a growing global demand for English language acquisition due to its status as the language of the international scientific community, technology, multimedia, and its utility for professional mobility and cultural exchange. This trend underscores the need for further research into the implementation of CLIL, also referred to as ICLHE (Integrated Content and Language in Higher Education), as an effective and appropriate approach for developing the future chemistry teachers' FLPCC in higher education institutions, particularly in the context of the modern job market. A study by Huertas-Abril and Shashken [15] utilized SWOT analysis to assess perceptions of CLIL implementation through open ended questions directed at both CLIL and non-CLIL instructors in Kazakhstan. The findings revealed the strengths, such as CLIL increases student engagement, encourages diversity in task design, enables students to simultaneously acquire linguistic competence and subject knowledge. Among the opportunities, the scholars emphasize that CLIL improves the quality of education, facilitates further development of the CLIL approach. As the weaknesses, they highlight that students' low language proficiency can hinder their ability to grasp subject content and teachers require significant time to prepare lessons in the target language. Furthermore, the reasons of threats they considered lack of dedicated instructional resources and insufficient availability of educational materials. In their study, Winter [16] analyzed the perspectives of participants in Kazakhstani nationwide reform initiative aimed at teaching biology, chemistry, physics, and computer science in English. The study focused on general education school teachers who had begun participating in professional development courses designed to enhance their qualifications for teaching core subjects in English. These findings revealed notable regional differences in teacher expectations regarding their students' learning process and teachers' perspectives on assessments of learning outcomes, and their ability to teach their subjects in English. Kuzembayeva [17] analyzed teachers' reflections on their experiences and challenges in implementing the CLIL approach in Kazakhstani trilingual schools during the pandemic in the context of distance learning. This study classified data based on several factors: preparation for teaching, resources utilized by teachers, student interaction during lessons, and the attitudes of stakeholders toward the approach. The findings underscored some significant challenges in fully implementing CLIL, such as inadequate language proficiency (many students were unprepared to fully engage with content taught in a foreign language, necessitating the occasional use of the native language (L1) during lessons) and insufficient teaching resources (a shortage of CLIL-specific instructional materials and methodological guides hampers effective lesson delivery). Above, we discussed the state of CLIL implementation in Kazakhstani secondary schools. Now, let us turn to the application of CLIL, specifically ICLHE, in universities.

Methods

Research design and participants. The study employed mixed methods of research design, offering detailed insights into specific instances and broader principles [18]. The purpose of this research was to describe the phenomenon from a detailed examination of how preservice CLIL science teachers experienced it after presenting the workshop [19]. Purposive sampling Patton [20] was used, and the participants were 15sophomorepreservice CLIL science students, aged 19 to 20, from the Department of Science Education at a university in Tai wan. The participants included six males and nine females, all native Mandarin Chinese speakers with an intermediate level of English proficiency (defined by their academic records and a pre-test). None of them had previous experience in pedagogical or content knowledge courses for teachers, nor had any of them taught science in a CLIL context prior to the 8-week CLIL science workshops. Ethical considerations stated that participation was voluntary, informed consent was guaranteed, and confidentiality and anonymity were maintained.

Data Collection and Analysis

To evaluate the effects of the CLIL workshop on preservice teachers' pedagogical communicative competence, a mixed-methods approach was employed, combining quantitative and qualitative data sources to provide a comprehensive understanding of teacher learning and skill development. The participants included two groups: an experimental group (n = 20; 16 females, 4 males; English proficiency B1–B2; age 19–20) and a control group (n = 20; 15 females, 5 males; English proficiency B1–B2; age 19–20). Both groups completed pre-workshop assessments to establish baseline equivalence. Pre- and Post-Workshop Microteaching Sessions Participants conducted online microteaching sessions before and after the 8-week CLIL workshop to evaluate changes in their pedagogical content knowledge (PCK) and language teaching skills. Microteaching allowed participants to teach a selected unit from a CLIL science textbook in English or bilingually for 3–5 minutes, explaining their instructional strategies. The post-workshop sessions assessed how participants integrated CLIL principles into their teaching. Sessions were

evaluated using validated rubrics based on Shulman's [21] PCK framework and Coyle's [3] Language Triptych, encompassing dimensions such as content accuracy, clarity of explanations, student engagement, lesson planning, assessment techniques, scaffolding, and the three components of the language triptych. Each dimension was scored on a five-point scale (0 = no evidence; 4 = advanced understanding), following calibration by two experienced CLIL science educators to ensure high interrater reliability (r = 0.85–1.0). Written Tests Pre- and post-workshop written tests assessed participants' knowledge of CLIL PCK and language teaching principles. The tests included 20 multiple-choice and 10 true/false questions, focusing on scaffolding, student engagement, assessment techniques, and the practical application of the language triptych. Test validity was enhanced through expert review and pilot testing with a separate group of preservice teachers. Internal consistency was confirmed using Cronbach's Alpha (pre-test α = 0.867; post-test α = 0.846), indicating strong reliability. Subscales also showed high reliability for PCK (pre = 0.827; post = 0.839) and language teaching (pre = 0.719; post = 0.743). All quantitative data were analyzed using Wilcoxon signed-rank tests to compare pre- and post-workshop results within the experimental group and Mann–Whitney U tests for comparisons with the control group. The alpha level was adjusted for multiple comparisons using the Bonferroni correction (α = 0.003125). Descriptive statistics, skewness, and kurtosis confirmed deviations from normality, supporting the use of nonparametric methods. Qualitative data from microteaching reflections, surveys, and lesson plans were analyzed using thematic coding to identify patterns in the development of PCK, language teaching skills, and reflective practice.

Criterion	Exp Pre (IQR)	Exp Post (IQR)	Z (Wilcoxon)	p	Ctrl Pre (IQR)	Ctrl Post (IQR)	U (Mann–Whitney)	p
PCK	1 (1–2)	4 (4–4)	-4.12	0.000*	1 (1–2)	2 (1–2)	18.0	0.000*
Accuracy of Content	1 (0–1)	4 (3–4)	-4.05	0.000*	1 (1–1)	2 (1–2)	22.0	0.001*
Clarity	1 (1–2)	4 (3–4)	-4.10	0.000*	1 (1–2)	2 (1–2)	20.0	0.001*
Engagement	1 (1–2)	4 (3–4)	-4.08	0.000*	1 (1–2)	2 (1–2)	21.0	0.001*
Lesson Planning	1 (1–1)	4 (3–4)	-4.05	0.000*	1 (1–1)	2 (1–2)	23.0	0.002*
Assessment	1 (0–1)	4 (3–4)	-4.00	0.000*	1 (0–1)	2 (1–2)	25.0	0.002*
Scaffolding	3 (3–3)	4 (4–4)	-4.02	0.000*	3 (3–3)	3 (3–3)	28.0	0.004*
Language of Learning	3 (3–4)	4 (4–4)	-4.05	0.000*	3 (3–4)	3 (3–4)	27.0	0.003*
Language for Learning	3 (3–4)	4 (4–4)	-4.08	0.000*	3 (3–4)	3 (3–4)	26.0	0.003*
Language through Learning	4 (3–4)	4 (4–4)	-4.10	0.000*	3 (3–4)	3 (3–4)	24.0	0.002*

*Note: IQR = interquartile range. *p < 0.05 indicates statistical significance.*

Discussion

The results of this study demonstrate that participation in the 8-week CLIL-oriented workshop significantly enhanced preservice teachers' pedagogical communicative competence compared to a control group. Prior to the intervention, both experimental and control groups exhibited comparable levels of competence, as indicated by median pre-test scores ranging from 1 to 4 across all criteria. This confirms that participants started with similar baseline abilities, ensuring the validity of subsequent comparisons. Following the workshop, the experimental group showed substantial improvements in all evaluated dimensions, including pedagogical content knowledge (PCK), clarity and accuracy of content delivery, student engagement, lesson planning, assessment techniques, scaffolding strategies, and the three components of the Language Triptych. In contrast, the control group displayed minimal gains, reflecting the absence of structured CLIL intervention. Statistical analyses using the Wilcoxon signed-rank and Mann–Whitney U tests confirmed that the differences between pre- and post-test scores in the experimental group, and between experimental and control groups, were statistically significant (p < 0.005). These findings indicate a robust positive effect of targeted CLIL training on both content-specific and language-sensitive teaching skills. The observed improvements align with prior research emphasizing the importance of teacher preparation for effective CLIL implementation [2]. By integrating content and language instruction through practical, workshop-based experiences, participants developed the ability to scaffold learning, manage classroom interactions, and apply language strategies effectively—core elements of pedagogical communicative competence. Furthermore, the development of skills related to the Language Triptych (Language of Learning, Language for Learning, Language through Learning) suggests that CLIL-oriented training not only enhances teachers' methodological knowledge but also strengthens their capacity to support simultaneous content and language development in students [3].

The findings also underscore the value of experiential and practice-oriented teacher education, where preservice teachers can apply theoretical knowledge in simulated classroom environments. As noted by Mezirow [22], such transformative learning experiences foster reflective practice and professional confidence, which are essential for successful CLIL implementation. Additionally, these results are consistent with translanguaging studies, which highlight that integrating multimodal and multilingual resources enables teachers to optimize both linguistic and disciplinary outcomes [4]. In sum, this study provides empirical evidence that structured CLIL training can significantly elevate the pedagogical communicative competence of preservice teachers, equipping them with both the content mastery and language-sensitive strategies required for effective teaching in multilingual and content-integrated learning environments. These findings have implications for curriculum design, teacher professional development, and policy-making in contexts seeking to expand CLIL implementation, such as Kazakhstan and other multilingual educational systems.

Results

The pre-workshop assessment revealed that both the experimental (Exp) and control (Ctrl) groups were at comparable levels across all criteria, with median scores ranging from 1 to 4, indicating initial moderate-to-low pedagogical communicative competence. After the 8-week CLIL workshop, the experimental group demonstrated significant improvements across all assessed dimensions. Overall PCK rose from a median of 1 (IQR 1–2) to 4 (IQR 4–4) in the experimental group (Wilcoxon $Z = -4.12$, $p < 0.001$), whereas the control group showed only modest improvements, from 1 (IQR 1–2) to 2 (IQR 1–2). Similar patterns were observed for accuracy of content, clarity, student engagement, lesson planning, assessment techniques, and the implementation of scaffolding techniques, all demonstrating statistically significant gains in the experimental group compared to the control group.Language-focused competencies, measured via the Language Triptych components, also showed significant increases in the experimental group post-workshop (Z values between -4.05 and -4.10, $p < 0.001$), whereas the control group remained largely stable. Mann–Whitney U tests confirmed that the post-workshop differences between experimental and control groups were statistically significant across all criteria (U values = 18–28, $p < 0.005$), demonstrating that the CLIL intervention had a robust positive effect on preservice teachers' pedagogical communicative competence.

Conclusion

The findings of this study demonstrate the transformative impact of a six-week CLIL science teacher preparation workshop on preservice teachers' PCK and language teaching competencies. This transformation was evident in the significant improvements observed in participants' microteaching sessions, written tests, and survey responses. Participants demonstrated marked progress in key areas such as scaffolding techniques, language integration, and lesson planning, which are central to effective CLIL instruction. These improvements align with Shulman's [21] conceptualization of PCK, emphasizing the integration of subject specific knowledge with pedagogical strategies, and support [3] Coyle language triptych framework for effective language instruction in bilingual contexts. The study confirms that the workshop's design, combining theoretical components with hands-on activities and reflective practices, successfully bridged the gap between theory and practice in CLIL education. For example, the use of practical, interactive tasks like building bird nests or exploring gravity through VR games not only helped participants connect abstract scientific concepts with real-world applications but also facilitated dental language learning (e.g., roots, soil, water drainage). These findings echo Sahin and Yilmaz's [23] emphasis on addressing the inherent complexity of science education in CLIL contexts through innovative approaches and support Turner and Fielding's observation that the spontaneous use of language fosters deeper engagement in CLIL classrooms. Furthermore, the reflective practices embedded in the workshop, such as rubric-based feedback after microteaching, played a pivotal role in participants' professional growth. As suggested by Mezirow [22], critical reflection is foundational to transformative learning, and this study's results indicate that structured reflective activities enabled participants to self-examine and adapt their teaching strategies effectively. Nonetheless, the findings of the surveys showed little advancement in critical reflection and respect for social interaction, indicating cultural interferences in Taiwan's education system, where rote memorization is emphasized [24].

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SOCIO-CULTURAL COMPETENCE THROUGH AUTHENTIC COMICS IN EFL

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ШЕТЕЛ ТІЛІН ОҚЫТУДА ШЫНАЙЫ КОМИКСТЕР АРҚЫЛЫ ӘЛЕУМЕТТІК-МӘДЕНИ ҚҰЗЫРЕТТІЛІКТІ ҚАЛЫПТАСТЫРУ

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Abstract

This article proposes a classroom-ready methodological model for developing learners' socio-cultural competence in EFL through authentic comics – texts produced for real audiences rather than pedagogical simplification. Socio-cultural competence is defined here as an integrated set of cognitive, affective, and behavioral resources that shape how learners notice, interpret, and respond to cultural diversity in communication. In this view, the goal is not to "learn facts about cultures," but to build practical abilities to recognize cultural scripts, manage ambiguity, and choose appropriate communicative actions with awareness and respect.

Authentic comics are conceptualized as sequential art in which meaning emerges from the dynamic interplay of images and words. This multimodal nature makes cultural and pragmatic cues more visible and discussable in the classroom – for example, routines of greeting and leave-taking, interpersonal distance, politeness and register shifts, irony, stereotypes, and implied meanings. Because comics externalize context through visual design, they can help learners track who speaks to whom, with what relationship, and in what situation, supporting deeper comprehension and more informed interpretation. At the same time, authentic comics can sustain engagement and provide a motivating entry point into critical literacy, inviting learners to question perspectives, values, and representations rather than accepting them uncritically.

To translate these advantages into teachable practice, the paper introduces the COMICS model (Curate-Orient-Mediate-Interact-Create-Share/Self-assess). The model integrates: principled text selection guided by authenticity and ethical caution; pre-reading cultural orientation that prepares learners to notice relevant norms and tensions; guided multimodal analysis that links visual choices to pragmatic meaning; mediation-focused interaction in which learners clarify, negotiate, and reframe meanings for others; creative re-voicing tasks that require learners to adapt language and stance to a new audience or context; and portfolio-based assessment aligned with CEFR plurilingual/pluricultural descriptors (e.g., "Building on pluricultural repertoire"). The article concludes with practical assessment guidelines that balance measurability with ethical caution in intercultural evaluation, emphasizing reflective evidence, transparent criteria, and learner agency.

Аңдатпа

Бұл мақала ағылшын тілін шет тілі ретінде оқытуда (EFL) шынайы комикстер арқылы білім алушылардың әлеуметтік-мәдени құзыреттілігін дамытуға арналған, сынып жағдайында қолдануға дайын әдістемелік модель ұсынады. Әлеуметтік-мәдени құзыреттілік мұнда мәдени әртүрлілікті қарым-қатынаста байқау, түсіндіру және соған сай әрекет етуге мүмкіндік беретін когнитивтік, аффективтік және мінез-құлықтық ресурстардың біртұтас жиынтығы ретінде қарастырылады. Демек, мақсат "мәдениет туралы ақпарат жинау" емес, керісінше белгісіздік жағдайын басқару, мәдени сценарийлерді тану және тілдік-қатысымдық таңдауды саналы әрі құрметті түрде жасау сияқты практикалық қабілеттерді қалыптастыру болып табылады.

Шынайы комикстер тізбекті өнер (sequential art) ретінде түсіндіріледі: мағына сурет пен мәтіннің өзара байланысы арқылы құралады. Осындай көпмодальды табиғат сыныпта мәдени әрі прагматикалық ишараларды айқынырақ көрсетіп, оларды талқылауға қолайлы етеді: мысалы, амандасу/қоштасу қалыптары, әлеуметтік арақашықтық, сыпайылық нормалары, регистрдің ауысуы, ирония, стереотиптер және астарлы мағына. Комикстер контекстi визуалды түрде "сыртқа шығаратыны" себепті, оқушы кімнің кіммен, қандай қатынаста және қандай жағдайда сөйлесіп тұрғанын жақсырақ аңғарып, мәтінді тереңірек түсінуге және мағынаны дәлірек интерпретациялауға мүмкіндік алады. Сонымен бірге шынайы комикстер

қызығушылықты сақтап, сыни сауаттылыққа кіріспе бола алады: оқушылар бейнелеу тәсілдерін, көзқарастарды, құндылықтарды және репрезентацияларды талдап, оларды сын тұрғысынан бағалауға үйренеді.

Осы артықшылықтарды жүйелі оқыту тәжірибесіне айналдыру үшін мақала COMICS моделін (Curate-Orient-Mediate-Interact-Create-Share/Self-assess) ұсынады. Модель келесі құрамдастарды біріктіреді: мәтінді таңдаудың қағидалы өлшемдері (шынайылық және этикалық сақтық); оқуға дейінгі мәдени бағдарлау (назар аударуға тиіс нормалар мен "шиеленіс нүктелерін" белгілеу); көпмодальды талдауды бағыттау (визуал шешімдер мен прагматикалық мағына байланысы); медиацияға негізделген өзара әрекет (мағынаны нақтылау, келісу, қайта тұжырымдау); "қайта дауыстау" шығармашылық тапсырмалары (аудитория/контекст өзгергенде тіл мен ұстанымды бейімдеу); және CEFR-дің плюрилингвалды/плюрикультуралық дескрипторларымен (мысалы, "плюрикультуралық репертуарға сүйену") үйлесетін портфолиоға негізделген бағалау. Мақала мәдениетаралық бағалауда өлшенімділік пен этикалық сақтықты тең ұстауға көмектесетін нұсқаулықтармен аяқталады: рефлексиялық дәлел, ашық критерий және білім алушының агенттілігі негізгі орын алады.

Keywords: *comics; multimodality; pragmatic cues; mediation; EFL methodology; critical literacy; CEFR; portfolio assessment.*

Кілт сөздер: *комикстер; көпмодальдылық; прагматикалық ишаралар; медиация; EFL әдістемесі; сыни сауаттылық; CEFR; портфолио арқылы бағалау.*

1. Introduction

EFL classrooms increasingly face a double challenge: helping learners develop linguistic accuracy while also preparing them to use language in socially and culturally appropriate ways in real encounters. The Council of Europe's guidance on the intercultural dimension argues that language education should aim to develop learners' intercultural competence alongside linguistic competence and support them in understanding and accepting people from other cultures as individuals with distinctive perspectives and values.

Yet socio-cultural competence is often addressed indirectly – through isolated "culture facts," short textbook readings, or occasional holiday lessons. Such approaches risk treating culture as static and external, while learners actually need procedural abilities: noticing cultural cues, interpreting ambiguity, comparing viewpoints, and mediating meaning when misunderstandings arise. This is where authentic comics offer an underused but powerful methodological resource.

2. What "Socio-Cultural Competence" Means in This Paper

From "culture knowledge" to intercultural mediation

In intercultural language education, competence is not framed as becoming a native speaker but as becoming an intercultural speaker/mediator – someone who can relate perspectives and help build shared meaning. The Council of Europe guide explicitly states that the "best" teacher is the one who helps learners see relationships between their own and other cultures and develop curiosity about otherness.

Components: attitudes, knowledge, skills, values

The same document identifies intercultural competence as a combination of knowledge, skills, and attitudes, complemented by values tied to social identities. This view is compatible with more general syntheses of intercultural competence that emphasize cognitive, affective, and behavioral dimensions in how people understand and interact with diversity.

CEFR alignment: pluricultural repertoire and mediation

The CEFR Companion Volume strengthens the "social agent" perspective and expands descriptors for mediation and plurilingual/pluricultural competences. In its mediation section, the CEFR describes learners acting as social agents who create bridges and help construct or convey meaning in social, pedagogic, cultural, and linguistic contexts.

Crucially for classroom assessment, the CEFR provides a scale for "Building on pluricultural repertoire," which includes descriptors such as identifying differences in sociolinguistic/pragmatic conventions, interpreting cultural assumptions and stereotypes, coping with ambiguity, and reacting constructively with cultural appropriateness.

3. Why Authentic Comics?

Comics as "sequential art" and cultural meaning-making

Will Eisner defines sequential art as an art/literary form that arranges images and words to narrate a story or dramatize an idea. For language teaching, this matters because cultural meaning is rarely

carried by words alone: facial expressions, spatial distance, clothing, setting details, panel pacing, and visual metaphors often encode what is "normal," "rude," "funny," or "dangerous" in a community.

Authenticity: why "real audience texts" matter

Authentic materials research emphasizes that "authentic" often refers to cultural artifacts such as books, newspapers, broadcasts, websites, and other real-world texts (not originally designed for teaching).

Importantly, Gilmore warns that outcomes depend not only on the text itself but on task design and how effectively the teacher mediates between materials and learners. This is a direct methodological call: if teachers want socio-cultural learning, they must design mediation-rich tasks rather than simply "bring comics to class."

Multimodality, engagement, and comprehension

Comics can support learners who struggle with dense prose. A recent framework paper argues that comics' inherent multimodality can reduce cognitive load while boosting motivation and engagement, helping learners access figurative language and subtle cultural nuance. Empirical work with Saudi EFL learners also reports positive effects of reading a graphic novel on reading comprehension and highlights positive teacher/student perceptions.

From a critical literacy angle, Chun shows how graphic novels can deepen reading engagement and develop learners' critical literacies by inviting multiple interpretations and discussion of representation. This matters for socio-cultural competence because learners must learn not just what a culture "is," but how cultural narratives are constructed, whose voices are centered, and how stereotypes operate.

4. The COMICS Model: A Methodological Model for EFL Classrooms

The proposed model is intentionally procedural (what teachers and learners do) rather than declarative (what culture is). It includes six phases that can be used as a full unit (2–6 weeks) or as a repeatable cycle for short lessons.

Phase 1 – C: Curate (Select authentic comics ethically and strategically)

Goal: choose texts that are authentic and teachable.

Selection criteria (practical checklist):

1. Authentic communicative purpose: created for real audiences (webcomic, strip, graphic memoir excerpt, etc.), not a language-learning worksheet.

2. Socio-cultural density: visible cultural scripts (greetings, turn-taking, politeness, humor, taboo topics, workplace/school norms).

3. Multimodal clarity: panels allow inference (facial expressions, settings, contextual clues).

4. Ethical safety: avoid hate speech and dehumanization; if trauma topics appear (e.g., war memoirs), frame with care and alternatives.

5. Learner fit: linguistic load manageable with scaffolding; culturally relevant without exoticizing.

Teacher move (core): identify 2–3 target socio-cultural "micro-skills" for the text (e.g., "noticing pragmatic softeners," "interpreting irony," "explaining stereotypes"). Align them with CEFR pluricultural descriptors at the class level (e.g., B1–B2).

Phase 2 – O: Orient (Build cultural and interactional readiness)

Goal: prevent "culture shock" in miniature and activate comparison.

The Council of Europe emphasizes that intercultural development involves attitudes and emotions, and learners may experience discomfort when encountering unexpected values or behaviors. Therefore, orientation is not trivia; it is affective and cognitive scaffolding.

Tasks (10–15 minutes):

- *Culture-guess warm-up: show one panel without text. Ask: "What relationship do they have? What is the mood? What clues tell you?"*
- *Norms prediction: learners predict what "counts as polite" in this situation in their culture (L1 allowed), then list what might differ in another context.*
- *Key vocabulary as cultural categories: teach 6–10 items that carry cultural weight (e.g., "small talk," "personal space," "sarcasm," "deadline," "apology").*

Sociocultural rationale: orientation creates a zone of proximal development for interpretation—learners can do more with guidance than alone, and guided performance becomes independent capability over time.

Phase 3 – M: Mediate (Guide multimodal reading and meaning-making)

Goal: teach learners how to read culture in a multimodal text.

The CEFR frames mediation as building bridges and helping convey meaning in social and cultural contexts. In comics-based lessons, mediation happens through guided noticing and interpretation.

Three-layer "Zoom" routine (repeatable):

1. Zoom-in on language: speech acts, politeness markers, hedges, discourse markers ("well…," "actually…," "I mean…"), humor cues.

2. Zoom-in on visuals: facial expressions, gestures, distance, clothing, setting symbols, panel size/pacing.

3. Zoom-out to cultural meaning: What value is implied? What is considered normal/awkward/rude? What stereotype might be present?

Micro-activity: Pragmatics vs. literal meaning Learners rewrite one speech bubble in a "too direct" way, then in a "more polite" way, and discuss what changes socially.

Phase 4 – I: Interact (Turn interpretation into intercultural dialogue)

Goal: practice socio-cultural competence as interaction, not only comprehension.

The Council of Europe's intercultural aim includes preparing learners for interaction and helping them see it as enriching.

Interaction formats (choose one):

- *Mediation circle: Student A explains the cultural meaning of a scene to Student B who "missed the joke." Student B asks clarifying questions; Student A must adjust explanation to the listener (mediation skill).*
- *Perspective swap: learners argue two interpretations: "This is friendly teasing" vs. "This is disrespect." Require evidence from both text and visuals (a core multimodal critical literacy habit).*
- *Ambiguity clinic: identify what is ambiguous cross-culturally (tone, sarcasm, indirect refusal) and propose repair strategies.*

Phase 5 – C: Create (Creative re-voicing to build agency)

Goal: move from decoding to producing culturally appropriate meaning.

Chun argues that multimodal texts can activate learners' imaginations and encourage them to become active producers rather than passive receivers.

Product options (low-tech or digital):

- *Alternative panel: learners add one panel showing a culturally appropriate repair (apology, clarification, softening).*
- *Cultural remix: same plot, different cultural setting (e.g., school corridor in Almaty vs. London). Learners must justify changes in greetings, distance, humor, hierarchy.*
- *Dialogue layering: learners write: (a) what the character says, (b) what the character means, (c) what the listener hears. This reveals pragmatic inference.*

Pedagogical rule: creativity must be evidence-based: learners cite at least two cues from the original (a phrase + a visual cue) that motivated their adaptation.

Phase 6 – S: Share & Self-assess (Portfolio-based assessment with ethical caution)

Goal: document growth without reducing culture to a test of "right attitudes."

6.1. What to assess (aligned to CEFR pluricultural repertoire)

For B1–B2, assessment can target whether learners can:

- *explain how values/behaviors influence views of others;*
- *interpret assumptions/stereotypes and relate them to their own community;*
- *cope with ambiguity and respond appropriately;*
- *identify sociolinguistic/pragmatic convention differences.*

6.2. How to assess (triangulation)

Deardorff's study highlights that assessing intercultural competence is best done with a mix of quantitative and qualitative methods, including interviews, observation, and judgment by self and others. In classroom terms, this becomes:

- *Portfolio artifacts: annotated panels, reflection logs, revised dialogues, creative products.*
- *Observation notes: teacher checklist during mediation circles (clarifying questions, repair strategies, respectful disagreement).*
- *Short reflective interviews: "Describe a misunderstanding and how you repaired it."*
- *Peer feedback: focus on evidence ("Which panel cue supports your interpretation?").*

6.3. Ethical guardrails

Borghetti cautions that intercultural competence has a relational and affective dimension and raises ethical issues about making personal dispositions "provable." So, in COMICS assessment:

• *Do not grade students for "having the correct attitude."*

• *Grade observable practices: evidence-based interpretation, perspective-taking moves, and repair strategies.*

• *Allow opt-out alternatives for sensitive topics.*

5. A Sample 2-Week Mini-Unit (Illustrative)

Week 1:

Day 1: Curate + Orient (panel prediction, norms comparison, key pragmatics)

Day 2: Mediate (Zoom routine; pragmatic softeners; visual cues)

Day 3: Interact (Mediation circle; ambiguity clinic)

Week 2:

Day 4: Create (alternative panel + justification)

Day 5: Share & Self-assess (portfolio submission + short reflective interview)

Evidence claim: If implemented systematically, comics-based work can support comprehension and engagement; studies report positive reading outcomes and learner/teacher perceptions in EFL contexts.

6. Discussion: What Makes This Model Different (and Practical)

• *Not "comics as fun," but comics as mediation training. The model operationalizes the CEFR vision of learners as social agents who mediate meaning.*

• *Authenticity is treated as a task-design problem, not a text label. Gilmore's work implies that teacher mediation and tasks determine whether authentic materials actually work.*

• *Assessment focuses on practices, not personality. This follows both Deardorff's mixed-method assessment logic and Borghetti's ethical cautions.*

7. Conclusion

Authentic comics provide a uniquely efficient pathway to socio-cultural competence because they make cultural meaning visible through multimodal cues while keeping learners engaged. However, the pedagogical value depends on structured mediation and ethically grounded assessment. The COMICS model offers a repeatable cycle for EFL classrooms that connects authenticity research, intercultural education aims, CEFR descriptors, and practical classroom routines into one methodological framework.

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USING CHATBOTS WITH ELEMENTS OF ARTIFICIAL INTELLIGENCE TO IMPROVE THE EFFICIENCY OF TEACHING SPOKEN ENGLISH AT THE B2 LEVEL

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Abstract
This study aimed to investigate how B2-level learners perceive the use of chatbots for improving speaking skills. A total of 40 students participated in an online survey, which included Likert-scale and open-ended questions about frequency of use, purposes, benefits, and challenges. Results showed that learners use chatbots frequently, mainly for translation, grammar clarification, and information retrieval, rather than for speaking practice. Despite limited direct use for oral communication, students reported that chatbots indirectly supported speaking by enhancing vocabulary, confidence, and sentence structure awareness.

Keywords*: Artificial Intelligence, Chatbots, English Language Teaching, Speaking Skills*

In the rapidly evolving global landscape, proficiency in English has become an essential skill for academic success, professional mobility, and intercultural communication. As educational contexts grow increasingly diverse and interconnected, the role of language education has expanded beyond teaching grammar and vocabulary; it now emphasizes communicative competence, digital literacy, and the ability to engage meaningfully in real-world interactions.[1, 28p.] In this environment, English language teaching (ELT) must continuously adapt to meet the needs of learners who require not only linguistic accuracy but also fluency, confidence, and the ability to express complex ideas in various social and professional settings.[2, 178p.] This need is particularly evident at the B2 level, where learners are expected to move from functional communication to more independent, spontaneous, and nuanced language use.

At the same time, technological innovation—especially the rapid development of artificial intelligence (AI)—is reshaping the landscape of language education. AI-powered tools and chatbots have become integral components of modern learning environments, offering personalized instruction, immediate feedback, and flexible practice opportunities beyond the traditional classroom. [3, 87p.] Unlike earlier digital tools, today's conversational AI can simulate natural dialogue, provide context-sensitive responses, and adapt to learners' linguistic needs with increasing precision. These capabilities make AI particularly valuable for speaking practice, an area where learners often face challenges such as limited exposure, anxiety, or lack of interaction opportunities.

AI-driven chatbots are emerging as promising tools for developing speaking skills at higher proficiency levels. They can engage learners in extended dialogues, support role-play scenarios, offer corrective feedback, and help build communicative confidence in a low-pressure environment.[4, 262p.] However, despite the growing presence of such technologies, there is still limited empirical research exploring how chatbot interaction specifically impacts the speaking development of B2-level learners. Understanding this relationship is crucial, as B2 learners require not only increased fluency but also the ability to produce coherent, accurate, and contextually appropriate language.

Therefore, this study aims to investigate the effectiveness of chatbot-assisted learning in enhancing English speaking skills at the B2 level. By examining learner performance, engagement, and perceptions, the research seeks to contribute to the ongoing conversation about how AI can support language education and how educators can integrate these tools meaningfully into pedagogical practice.

This study adopts a descriptive survey research design to explore B2-level English learners' perceptions of using chatbots to improve their speaking skills. A survey design is suitable because it allows the researcher to gather data from a group of learners efficiently without implementing experimental interventions or comparing controlled groups. The purpose of this design is to describe learners' attitudes, perceived benefits, and challenges related to chatbot-assisted speaking practice.

The participants of the study were B2-level English learners enrolled in an English language course at Abay Kazakh National Pedagogical University. A total of 40 students voluntarily took part in the study.

All participants had prior experience using AI chatbots such as ChatGPT or similar tools for speaking or general language practice. Participation was voluntary, anonymous, and based on informed consent.

The questionnaire was distributed online using Google Forms. Before completing the survey, participants were informed about the purpose of the study and assured of anonymity. They were asked to reflect on their use of chatbots for speaking practice over the previous 2–4 weeks. The survey required approximately 5–7 minutes to complete. Responses were automatically recorded and stored securely for further analysis.

Quantitative data from the Likert-scale items were analyzed using descriptive statistics, including frequencies, percentages, and mean scores, to determine general trends in learner perceptions. Qualitative data from the open-ended questions were analyzed using content analysis, where responses were read multiple times, coded, and grouped into emerging themes. These themes helped identify the main perceived benefits, challenges, and suggestions for improving chatbot-based speaking practice.

The results of the survey show that B2-level learners use chatbots very frequently in their daily learning routines. Most participants reported interacting with chatbots almost every day, while the rest use them several times per week. None of the respondents indicated that they use chatbots rarely, suggesting that AI tools have become an established part of their language-learning habits. However, despite this high level of usage, students mainly rely on chatbots for purposes other than speaking practice. The majority of learners stated that they use chatbots to translate words and expressions, check grammar rules, look up information, or correct writing. Only a small portion of participants mentioned that they use chatbots to engage in actual speaking or conversational activities.

Although speaking practice is not the primary reason for chatbot use, some learners still reported indirect benefits for their speaking development. Nearly half of the participants agreed that interacting with chatbots helps them acquire new vocabulary, understand sentence structures, and feel more confident when preparing for speaking tasks. However, fewer students felt that chatbots directly improved their fluency, mainly because they rarely use voice input or conversation modes. Most students prefer typing to speaking, which limits the potential impact of chatbots on oral skills.

The open-ended responses provided further insight into learners' perceptions. Many students described the convenience of receiving immediate explanations and corrections as helpful for preparing for future speaking tasks. They appreciated having access to vocabulary support and noted that using chatbots made them more confident when expressing ideas. At the same time, learners identified several challenges. Some commented that they were unsure how to use chatbots effectively for speaking practice, while others found the interaction to be less natural than real communication. Students also noted that they often choose written interaction because it feels easier and more familiar than speaking out loud.

Learners also offered suggestions for how chatbots could better support speaking skill development. Many expressed interest in structured speaking tasks, real conversation topics, and clearer guidance on how to practice oral communication with AI tools. Some suggested adding voice-based conversation modes with pronunciation or fluency feedback.

Overall, the results indicate that while B2 learners frequently engage with chatbots, they primarily use them for translation, information, and writing support rather than for speaking. However, they acknowledge that chatbot use contributes indirectly to speaking development by building vocabulary, confidence, and grammatical awareness. Learners also show a clear interest in more speaking-focused features, suggesting that chatbots have significant potential to support oral skills if appropriately integrated and designed for communicative practice.

The findings of the study show a noticeable gap between the high frequency of chatbot use and the limited engagement with speaking-specific features. Although students interact with chatbots almost daily, they mainly rely on them for translation, grammar clarification, and information retrieval rather than oral communication. This suggests that learners may not fully understand or utilize the speaking-related functions that chatbots can provide.[5, 35p.] At the same time, the survey results indicate that chatbot interaction indirectly supports speaking development by strengthening vocabulary and confidence. These outcomes align with existing research suggesting that learners often use digital tools for receptive or written support before applying the knowledge in spoken communication.[6, 210p.] The responses also highlight that unfamiliarity with voice-based tools, lack of structured speaking tasks, and concerns about naturalness may limit students' willingness to use chatbots for oral practice. This emphasizes the need for clearer pedagogical guidance and more intuitive AI features designed specifically to encourage speaking.

The study indicates that B2-level learners use chatbots frequently in their language learning routines, but primarily for translation, grammar checks, and information retrieval rather than for speaking practice. While chatbot interaction provides indirect benefits such as vocabulary expansion, increased confidence, and greater awareness of sentence structures, learners rarely engage in oral communication through these tools. This highlights a gap between the availability of AI-supported speaking opportunities and students' actual use of them, suggesting that chatbots' full potential for enhancing speaking skills remains largely underutilized.

To maximize the effectiveness of chatbots in developing speaking skills, educators should integrate structured speaking activities into their teaching, such as role-play tasks, dialogue prompts, and guided conversation exercises specifically designed for chatbot interaction. Additionally, students should be encouraged to use voice-based features and receive clear guidance on how to practice oral communication through AI tools. Developers of educational chatbots could improve user experience by designing more interactive, context-sensitive, and natural conversation modes that provide feedback on pronunciation, fluency, and grammar.

For future research, longitudinal studies could investigate how sustained use of chatbot-assisted speaking practice affects fluency, accuracy, and confidence over time. Comparative studies could explore differences in effectiveness between text-based and voice-based chatbot interactions. Research could also examine how specific features, such as error correction, feedback type, or task design, influence learner engagement and oral development. Overall, this study underscores the potential of AI chatbots as a supplementary tool for language education while emphasizing the need for targeted implementation and further empirical investigation to fully support speaking skill development at the B2 level.

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STUDENTS' PERCEPTIONS OF PODCAST-BASED LEARNING IN DEVELOPING COMMUNICATIVE COMPETENCE

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Abstract

The increasing integration of digital technologies in education has created new opportunities for improving foreign language teaching and learning. Digital tools offer innovative ways to enrich language learning and support the development of students' communicative skills. Among these tools, podcast-based teaching has recently attracted significant interest in the field of language teaching. Podcasts provide authentic linguistic information and allow students to access real-life interactions, which can significantly contribute to the development of English as a Foreign Language (EFL) listening and speaking skills. By introducing students to natural language, different accents, and meaningful communicative contexts, podcasts help create an interactive and engaging learning environment. This study aimed to explore students' perceptions of podcast-based teaching in developing their communicative skills in an EFL context. The study targeted students who participated in English courses that included podcast-based activities to improve listening and speaking skills. The study participants were undergraduate students learning English as a foreign language. A total of 22 students participated in the survey and shared their experiences of podcast teaching activities implemented in their English courses. Data were collected via an online survey that included Likert-scale open-ended questions. The survey aimed to explore students' attitudes towards using podcasts in language learning and to analyze how they perceived their role in improving listening comprehension, speaking confidence, vocabulary development, and, more broadly, communication skills. The collected data were analyzed using descriptive statistics to identify general trends in students' attitudes and perceptions towards podcast learning. The results show that the majority of students have a positive attitude towards this type of learning and consider podcasts to be a useful resource for developing listening and speaking skills. Many participants reported that podcasts helped them to better understand spoken English, identify main ideas during listening exercises, and express their opinions more confidently during class discussions. Students also reported increased motivation and engagement during podcast-based activities. Overall, the results suggest that integrating podcasts into language teaching supports communicative learning and can help creating an interactive, student-centered learning environment in English as a foreign language classroom.

Keywords: *podcast-based learning, communicative competence, EFL, listening skills, speaking skills, student perceptions*

INTRODUCTION

The rapid development of digital technologies has significantly influenced modern approaches to language education. In recent years, various digital tools have been integrated into language classrooms in order to create more engaging and interactive learning environments. Among these tools, podcasts have become increasingly popular as a resource for language learning. Podcasts provide learners with authentic language input, diverse topics, and natural speech patterns, all of which are elements for developing communicative competence.

Communicative competence is widely recognized as one of the main objectives of foreign language education. It refers to learners' ability to use language effectively and appropriately in real communication. According to the principles of communicative language teaching, students should be exposed to meaningful language input and provided with opportunities to interact, express ideas, and participate in communicative activities. In this context, digital audio materials such as podcasts can play an important role in supporting the development of both receptive and productive language skills, particularly listening and speaking.

Podcasts offer several advantages for language learning. First, they expose learners to authentic speech and different accents, helping students become familiar with natural language use. Second, podcasts often include interesting and relevant topics, which can increase students' motivation and

engagement. In addition, podcast-based activities may encourage discussion and interaction among learners, thereby supporting the development of communicative competence in the classroom.

Despite the increasing use of podcasts in language education, research focusing specifically students' perceptions of podcast-based learning for developing communicative competence remains limited. Understanding learners' perspectives can provide valuable insights into how digital tools influence language learning and how they can be more effectively integrated into classroom practice.

Therefore, the present study aims to explore students' perceptions of podcast-based learning in the development of communicative competence in an EFL classroom. The study focuses on learners who participated in lessons that incorporated podcast-based activities and examines their views on how these materials contribute to listening comprehension, speaking confidence, vocabulary development, and overall communicative competence.

LITERATURE REVIEW

The concept of communicative competence has been widely discussed in linguistics and language education. One of the earliest theoretical perspectives on language competence was proposed by Chomsky (1965), who introduced the concept of linguistic competence. According to Chomsky, linguistic competence refers to a speaker's internal knowledge of the grammatical rules of a language that enables them to produce and understand sentences. However, this concept mainly focuses on grammatical knowledge and does not fully explain how language is used in real communicative situations.

In response to this limitation, Hymes (1972) introduced the concept of communicative competence. Hymes argued that knowing a language involves more than mastering grammatical structures; it also includes the ability to use language appropriately in different social contexts. Communicative competence therefore, involves selecting suitable linguistic forms depending on the situation, the participants involved, and the purpose of communication. Later, Canale and Swain (1980) further developed this concept and proposed a model comprising four components: grammatical competence, sociolinguistic competence, discourse competence, and strategic competence. Together, these components enable language learners to communicate effectively and appropriately in real-life situations.

Another important perspective on language learning is provided by Vygotsky's (1978) sociocultural theory. Vygotsky emphasized the crucial role of social interaction in cognitive and language development. According to this theory, learning occurs through interaction with others, particularly through communication with teachers and peers. Vygotsky also introduced the concept of the Zone of Proximal Development (ZPD), the gap between what learners can accomplish independently and what they can achieve with guidance or collaboration. In language classrooms, communicative and collaborative activities can therefore support learners in developing their language abilities within this zone.

The principles of communicative competence and sociocultural learning are closely related to the Communicative Language Teaching (CLT) approach. Richards (2006) notes that CLT emphasizes meaningful communication, authentic language use, and learner interaction in the classroom. Within this approach, students are encouraged to participate in communicative tasks that simulate real-life communication situations. Such activities help learners develop both receptive skills, such as listening, and productive skills, such as speaking.

With the rapid development of digital technologies, new tools have emerged that support communicative language learning. Digital resources such as podcasts have become increasingly popular in language education because they provide authentic language input and flexible learning opportunities. Rosell-Aguilar (2007) points out that podcasts can expose learners to natural speech, different accents, and real-life communication topics. As a result, podcast-based learning can support the development of listening comprehension and encourage learners to engage in communicative activities such as discussions, reflections, and presentations.

In addition to improving language skills, podcasts may also increase learners' motivation and engagement. Authentic audio materials allow students to interact with language in meaningful contexts, thereby enhancing their participation in classroom activities. Therefore, integrating podcasts into language instruction can support communicative language teaching and contribute to the development of communicative competence in English as a Foreign Language (EFL) classrooms.

METHODOLOGY

Participants

The participants of this study were undergraduate students learning English as a Foreign Language (EFL). In total, 22 students participated in the survey. The participants were selected from one intact class that had previously experienced podcast-based activities during their English language lessons. The

students' English proficiency level ranged approximately from B1 to B2 according to the Common European Framework of Reference for Languages (CEFR).

Participation in the study was voluntary. Students were informed about the purpose of the research and assured that their responses would remain anonymous. This approach was used to encourage honest and unbiased answers.

Instrument

The main instrument used in this study was an online questionnaire designed to explore students' perceptions of podcast-based learning and its role in developing communicative competence. The questionnaire consisted of three sections.

The first section included several background questions about students' English proficiency levels and their prior experience with podcast-based learning activities. The second section contained Likert-scale statements aimed to measure students' attitudes toward the use of podcasts in language learning. These statements focused on different aspects of communicative competence, including listening comprehension, speaking confidence, vocabulary development, motivation, and overall communicative ability.

The third section included open-ended questions that allowed students to provide more detailed opinions and reflections about their experience with podcast-based activities.

Procedure

The data were collected through an online survey using Google Forms. The questionnaire was distributed to students after they had participated in several podcast-based activities during their English language lessons. Before completing the questionnaire, students were informed that the survey was conducted for research purposes and that their responses would remain anonymous.

Students were asked to answer the questions honestly based on their own learning experience with podcast-based activities. Once completed, the responses were automatically recorded and stored in the Google Forms system for further analysis.

Data Analysis

The collected data were analyzed using descriptive statistical methods. The responses to the Likert-scale items were calculated as percentages to identify general trends in students' perceptions of podcast-based learning.

The results were presented in tables and figures to clearly illustrate students' attitudes toward the use of podcasts in language learning. In addition, the responses to the open-ended questions were reviewed and categorized into common themes. This qualitative analysis helped identify students' experiences, opinions, and suggestions regarding the use of podcast-based activities in language learning.

RESULTS

A total of 22 students participated in the survey. The results of the questionnaire indicate that students generally have positive perceptions of podcast-based learning in English language classes.

Most respondents reported that podcasts were useful for improving their language skills. In particular, 68.2% of the students agreed that podcast-based lessons were beneficial for their English learning, as shown in Figure 1.

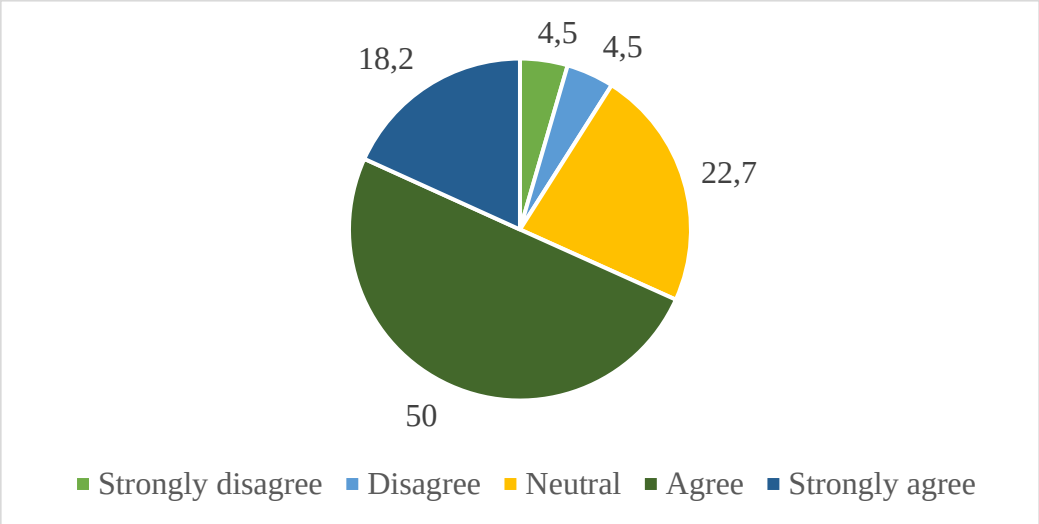

Figure 1. Students' perceptions of the usefulness of podcast-based lessons

In addition, 72.7% of the participants indicated that the podcast topics were interesting and relevant to them, as illustrated in Figure 2.

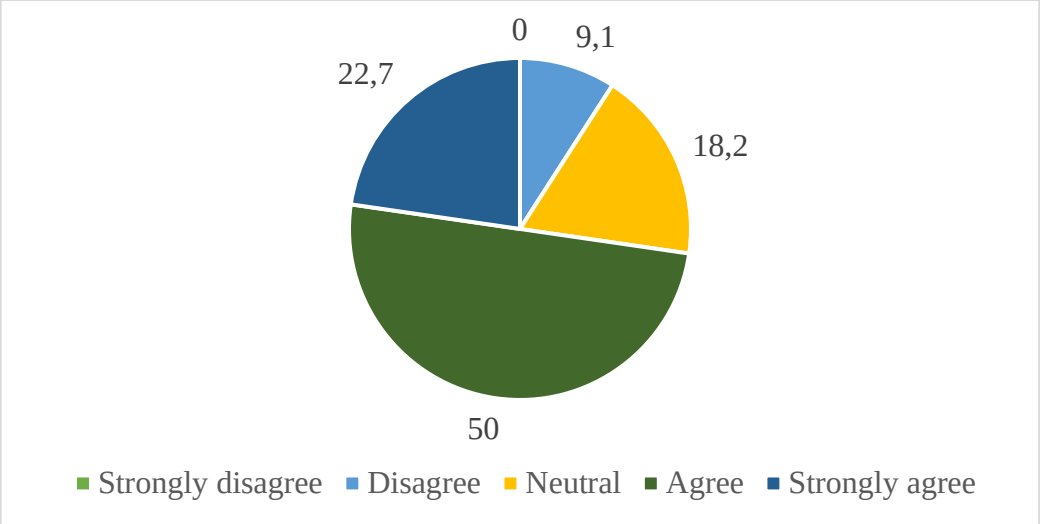

Figure 2. Students' perceptions of podcasts in improving listening comprehension

The findings also show that podcasts contributed to the development of listening skills. A large proportion of respondents (81.8%) reported that podcasts helped them better understand spoken English, as presented in Figure 3, while 86.4% agreed that podcasts helped them identify the main ideas when listening. Furthermore, 72.7% of the participants reported increased confidence when completing listening tasks after participating in podcast-based lessons.

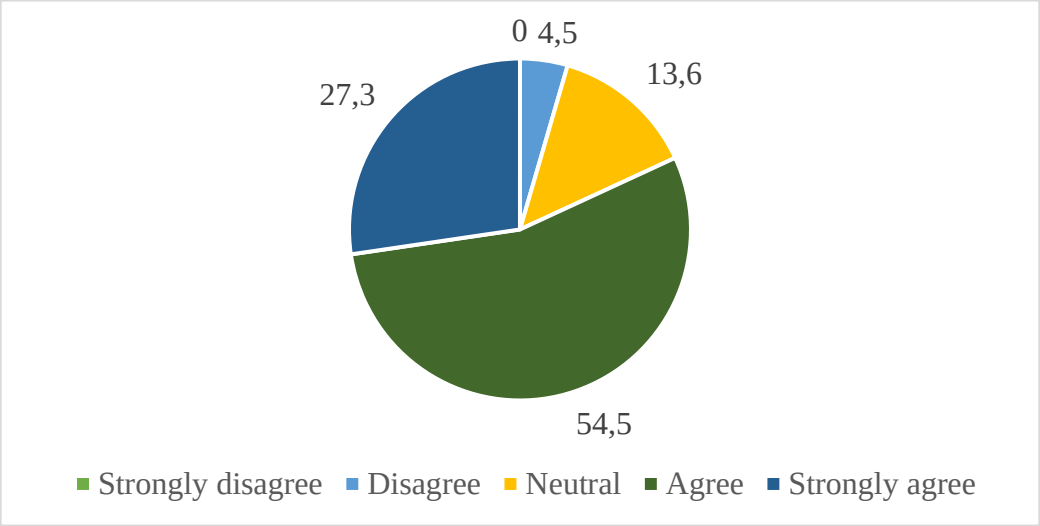

Figure 3. Podcasts and listening comprehension

Podcast-based activities also supported the development of speaking skills. According to the Figure 4, 77.3% of students stated that podcast-based tasks helped them express their ideas more clearly in English. Additionally, 68.2% of respondents reported improvement in their speaking fluency, while 81.8% indicated that podcasts helped them use more appropriate vocabulary and expressions during speaking activities.

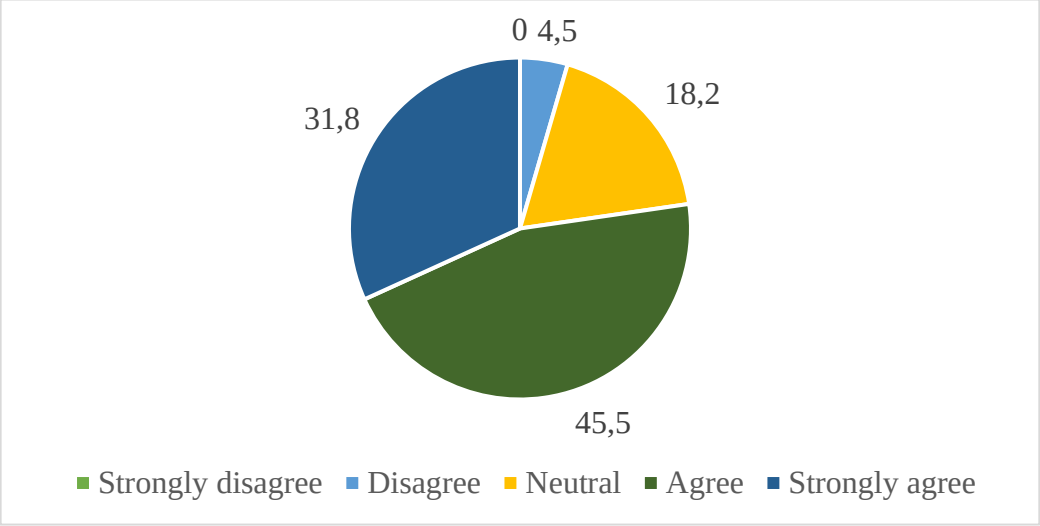

Figure 4. Podcasts and speaking skills development

Interaction after listening was also perceived positively by students. A large majority of respondents (86.4%) reported that discussions following podcast listening helped them communicate more confidently with their classmates. Overall, 77.3% of the participants believed that podcast-based learning contributed to the development of their communicative competence.

The survey results also revealed increased student motivation. As illustrated in Figure 5 approximately 86.4% of respondents reported that podcast-based lessons increased their motivation to learn English. Moreover, 77.3% of the participants expressed their willingness to use podcasts more frequently in English classes.

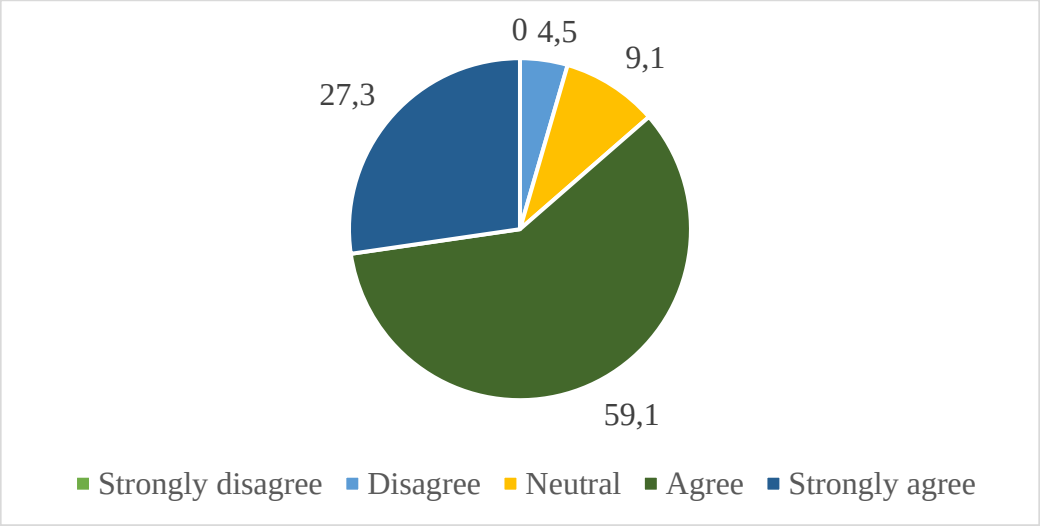

Figure 5. Students' motivation toward podcast-based learning

DISCUSSION

The findings of this study indicate that students generally have positive perceptions of podcast-based learning in English language instruction. Most participants reported that podcast-based activities helped them improve their listening comprehension, speaking confidence, and overall communicative competence. These results suggest that podcasts can be an effective tool for supporting communicative language teaching in EFL classrooms.

One of the most notable findings of the study is the positive impact of podcasts on listening skills. A large majority of students reported that podcasts helped them better understand spoken English and identify the main ideas in listening tasks. This result may be explained by the nature of podcasts, which provide learners with authentic language input. Exposure to authentic speech, different accents, and natural communication situations allows learners to develop listening comprehension skills in a more realistic context than traditional classroom materials.

The results also indicate that podcast-based activities contribute to the development of speaking skills. Many students reported increased speaking confidence and an improved ability to express their ideas during classroom discussions. This finding supports the principles of Communicative Language Teaching, which emphasize meaningful interaction and communication in language learning (Richards,

2006). When students participate in discussions and communicative tasks based on podcast content, they have more opportunities to practice language in authentic communicative situations.

The findings of this study can also be interpreted in relation to Hymes' (1972) concept of communicative competence. According to Hymes, communicative competence includes not only grammatical knowledge but also the ability to use language appropriately in different communicative contexts. Podcast-based activities encourage learners to listen, interpret information, and express their opinions, which contributes to the development of several components of communicative competence.

Furthermore, the results can be explained through Vygotsky's sociocultural theory. Vygotsky (1978) emphasized the role of social interaction in learning processes. In podcast-based lessons, students often engage in discussions, collaborative activities, and group tasks after listening to podcast materials. Such interactions allow learners to exchange ideas, negotiate meaning, and support each other's language development.

Another important finding of the study is the increase in students' motivation and engagement during podcast-based lessons. Many students reported that podcast topics were interesting and relevant, which encouraged them to participate more actively in classroom activities. Authentic and engaging materials can therefore play an important role in maintaining students' interest and motivation in language learning.

Overall, the findings of this study support the idea that integrating podcasts into language instruction can create a more interactive and communicative learning environment. Podcast-based activities provide authentic language input and encourage learners to engage in meaningful communication, which is essential for developing communicative competence.

CONCLUSION

This study explored students' perceptions of podcast-based learning in the development of communicative competence in an English as a Foreign Language (EFL) context. The findings indicate that students generally hold positive attitudes toward the use of podcasts in language learning. Most participants reported that podcast-based activities helped improve their listening comprehension, speaking confidence, vocabulary use, and overall communicative competence.

The results suggest that podcasts can serve as an effective supplementary resource in language instruction. By providing authentic language input and engaging topics, podcasts allow learners to interact with real-life language and participate in meaningful communicative activities. In addition, podcast-based lessons appear to increase students' motivation and engagement, both of which are essential for successful language learning.

From a pedagogical perspective, integrating podcasts into English language teaching can support the principles of communicative language teaching. Teachers can use podcasts as authentic listening materials and design interactive activities, such as discussions, summaries, and collaborative tasks, based on their content. Such activities may help learners develop both receptive and productive language skills, particularly listening and speaking.

However, this study has several limitations. The number of participants was relatively small, and the data were collected from a single student group. Therefore, the findings may not fully represent the perceptions of all EFL learners. Future research could involve larger samples and explore the long-term effects of podcast-based learning on the development of communicative competence.

To conclude, integrating podcasts into language instruction demonstrates considerable potential to enhance communicative language learning. Podcast-based activities can support the development of communicative competence by combining authentic language input with interactive classroom communication.

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STEM EDUCATION

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STEAM education is a pedagogical philosophy that integrates science, technology, engineering, art, and mathematics. This approach views these disciplines as a unified system, mastered through practice-oriented projects.

The primary goal of STEM methodology is to establish connections between academic knowledge and real-world problems, making learning more practical. This fosters a deep understanding of scientific foundations and successful adaptation to the modern information environment. This approach motivates students to actively engage in STEM subjects, developing critical thinking, problem-solving, and teamwork skills. The opportunity to apply acquired knowledge in practice helps students understand the connections between different subject areas, for example, the relationship between mathematics and physics or engineering, emphasizing the value and practical significance of each subject.

STEM education also aims to develop technological literacy and competencies in working with modern tools, which are essential for successful careers in the digital age. The origins of the STEM approach can be traced back to the early 20th century, but it received a significant boost after the launch of the Soviet Union's Sputnik in 1957. This event, known as the "Sputnik crisis," prompted active measures in the United States to improve education in technological fields. The National Defense Education Act of 1958 was a key step, including a significant increase in funding for the natural sciences.

The term "STEM education" itself entered scientific usage at the end of the 20th century. In 1990, American scientist Robert Colwell proposed the acronym STEM, which was subsequently actively supported by the US National Science Foundation, defining it as the integration of these disciplines into the educational process. At the beginning of the 21st century, STEM was declared a national priority in the United States, aimed at preparing specialists for a technological society and developing key skills. Thus, although the prerequisites for the STEM approach arose in the 1950s, its systematic development and recognition occurred in the early 21st century.

The key principles of the STEM approach include:

Project-based learning: Learning through collaborative problem-solving and projects, stimulating communication skills and interest in the subjects.

Practical focus: Emphasis on the applicability of knowledge to real-life situations.

Interdisciplinarity: Integrating knowledge from various subject areas to develop a holistic perspective.

Emphasis on core disciplines: Focus on subjects that form the foundation for future engineers and scientists.

These principles, taken together, contribute to the comprehensive development of students in STEM fields and the development of essential 21st-century competencies.

Key benefits of STEM education:

- Competitive advantage in university admissions and employment.
- Developing complex problem-solving and analytical thinking skills.
- Experience with advanced technologies.
- Stimulating creativity and the generation of innovative ideas.
- Improving career prospects and income levels.
- General improvement of education and a culture of thinking.

Disadvantages of STEM education:

- A shortage of qualified teachers.
- The STEM approach's requirements are inconsistent with the traditional external monitoring and evaluation system.
- Focus on children with pronounced technical potential.

In the context of the growing importance of creative industries (computer technology, design, advertising, etc.), the STEM concept has been transformed into STEAM. The addition of an "Arts" component has allowed for the integration of humanities and creative disciplines (design, architecture, music, literature) alongside traditional STEM subjects. The STEAM approach, while maintaining a project-based, practical, and interdisciplinary approach, teaches a harmonious combination of scientific rigor and creative freedom, developing the ability to find solutions in the face of uncertainty. STEAM ideas are

inspired by the examples of great figures who combined science and creativity, such as Galileo, Leonardo da Vinci, and Einstein.

A comparison with traditional teaching methods shows that the integration of STEM technologies into the educational process differs significantly from classical approaches based on memorization and repetition of educational material. Traditional teaching typically involves the transfer of knowledge from teacher to students through lectures, standardized exercises, and tests, which often leads to passive learning and lack of student motivation. This method is well suited for reinforcing basic knowledge, but often fails to foster the development of critical thinking, creativity, and independent study skills that are essential in the modern world.

In contrast, the use of STEM technologies focuses on student active participation in the learning process through project-based activities, experimentation, group work, and solving practical problems. This approach promotes the development of analytical thinking, the ability to apply knowledge in practice, and teamwork. In STEM education, students not only learn theoretical material but also learn to find solutions to real-world problems, which increases their interest in the subject and stimulates independent learning. As a result, compared to traditional methods, the implementation of STEM technologies promotes a deeper understanding of physics, develops skills necessary for future professional work, and fosters inquiry-based thinking in students.

However, despite these advantages, the implementation of STEM methods is time-consuming and organizationally demanding. In a traditional system, the learning process is more structured and predictable, facilitating planning and monitoring of results. At the same time, the use of innovative technologies and project-based assignments requires teachers to be highly competent, able to organize the learning process while taking into account the individual needs of students, and to provide the necessary technical equipment. Given limited resources and inadequate teacher training, the transition to STEM education can be fraught with difficulties, such as decreased learning effectiveness, if the methods are not implemented systematically and consistently.

Furthermore, traditional teaching methods provide more rigorous assessment of knowledge through standardized exams and tests, allowing for an objective assessment of material acquisition. However, with STEM technologies, assessment becomes more complex, as it involves not only knowledge but also skills, abilities, and creativity. This requires the development of new assessment methods, which poses an additional challenge for teachers and educational institutions.

It's also worth considering that traditional learning often gives students less freedom in choosing topics and methods, which can limit their initiative and interest in the subject. In contrast, STEM methods provide more opportunities for independent information discovery, project selection, and research methods, which fosters initiative and responsibility for their own learning. This approach is more flexible and adaptable to students' individual needs, increasing their motivation and engagement.

However, it is important to emphasize that neither method is a one-size-fits-all solution. Effective learning depends on the appropriate combination of traditional and innovative approaches, as well as the level of teacher training and the technical equipment available in schools. In some cases, especially during the initial phase of introducing new technologies, traditional methods can serve as the basis for reinforcing basic knowledge, while STEM methods can be used to develop skills and abilities. This combined approach maximizes the advantages of both methods and minimizes their disadvantages.

A study [9] examined the comparative characteristics of traditional and STEAM education, highlighting the advantages of project-based learning in "creative spaces." Unlike the classical method, where knowledge is imparted within the curriculum, the STEAM education model is based on the collaborative work of schoolchildren, undergraduates, and graduate students on real-world projects initiated by the community. This approach fosters creativity, initiative, and practical skills, increasing motivation and interest in the subjects. It provides more flexible and integrative learning, allowing participants to apply knowledge in practice and develop interdisciplinary competencies. As a result, STEAM methods foster students' systemic thinking and responsibility for their own development, making the educational process more modern and focused on the real needs of society.

Overall, the comparison shows that the introduction of STEM technologies into physics and other subjects makes the educational process more engaging, practice-oriented, and responsive to the demands of the modern world. However, to achieve sustainable results, it is necessary to consider the challenges and risks associated with the transition to new methods and develop strategic plans for their implementation. It is important to ensure teacher training, develop the necessary equipment and technical resources, and create the conditions for the systematic implementation of innovations to maximize the potential of STEM education and ensure high-quality education for future generations.

This project set and successfully achieved its primary goal: to study the impact of STEM technologies on the effectiveness of physics instruction in secondary schools. All planned objectives were achieved, providing a comprehensive understanding of the current state of the educational process and identifying prospects and areas for the further development of innovative teaching methods.

The first objective of the project was to analyze the current state of physics instruction in schools. To this end, observations of the educational process were conducted, curricula were studied, and data was collected on the teaching methods used and the level of technical equipment in classrooms. The analysis revealed that traditional physics teaching methods based on lectures and standardized problem-solving do not always foster student interest in the subject and do not fully realize the potential of modern technologies and teaching methods. Furthermore, it was noted that student motivation and initiative within the traditional system often remain low, negatively impacting the quality of material acquisition and the development of practical skills.

The second objective was to develop and implement lessons using STEM technologies. To this end, methodological materials were prepared, projects and practical assignments were developed, focusing on the application of interdisciplinary approaches, the use of modern information technologies, and research experiments. Various methods were employed during the implementation process, including project-based learning, research projects, computer simulations and laboratory systems, and interactive teaching methods. An important component was creating conditions for students to work independently, search for information, and select project topics and research methods, which fostered initiative, responsibility, and creativity.

The third objective was to evaluate learning outcomes and compare them with those obtained using traditional methods. This was accomplished through questionnaires, testing, observation of the learning process, and interviews with teachers and students. Data analysis revealed that the introduction of STEM technologies increased motivation for learning physics, developed practical skills, critical thinking, and the ability to apply knowledge in real-world situations. The level of theoretical material acquisition also significantly improved, as confirmed by the results of assessments and tests. Positive dynamics were particularly evident in the completion of project assignments, independent research, and practical experiments, demonstrating that students are developing the systemic knowledge and skills necessary for successful academic performance and further professional development.

The fourth objective was to collect feedback from students and teachers. This was accomplished through questionnaires, interviews, and classroom discussions. The data obtained showed that most participants in the learning process noted increased interest in the subject, improved independent work skills, and the development of creativity and initiative. Teachers also noted that the use of STEM methods requires them to develop new professional competencies, as well as additional preparation and adaptation of curricula. However, most teachers expressed a willingness to further develop their skills and believe that the introduction of innovative technologies makes lessons more engaging and effective.

Upon completion of all the assigned tasks, a set of recommendations was developed for the further development and systematic implementation of STEM technologies in the teaching of physics and other subjects in secondary schools. Specifically, the need for advanced teacher training, the development of material and technical resources, and the creation of conditions for project-based activities and independent information search by students was emphasized. Recommendations were also made for the development of teaching aids and programs that take into account the specifics of implementing innovative methods, as well as organizing an exchange of experiences between teachers.

Summarizing the obtained results, it can be concluded that the systematic implementation of STEM technologies in physics instruction in secondary schools contributes to the development of modern competencies in students necessary for successful adaptation to a rapidly changing world. This approach not only improves the quality of education but also prepares future specialists capable of solving complex engineering, scientific, and technological problems. Going forward, it is important to continue developing innovative methods, expand their application, and create conditions for the continuous professional growth of teachers and the modernization of curricula. Only with a systematic and comprehensive approach can we achieve sustainable positive results and ensure high-quality education for future generations.

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Physical sciences

DIAGNOSTIC CONTROL OF CAR AND TRUCK ENGINES

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Abstract

Increasing the reliability and efficiency of automobiles, as well as their long-term operability, requires extending the service life of the engines in use. For this purpose, it is necessary to conduct certification tests to ensure a high level of engine performance. Therefore, optimizing the requirements for the quality of automobile engines on a scientific basis is of particular importance. Conducting certification tests without sufficiently justifying the quality indicators and using engines that do not meet operational requirements ultimately leads to a decrease in the reliability of automobile engines.

Keywords: Passenger and commercial vehicle engines, internal combustion engine structure, working cycle of an internal combustion engine

Relevance of the Topic

The correct assessment of the quality indicators of automobile engines and the implementation of certification tests at the required level directly depend on the effective resolution of metrological support issues. Metrological support ensures the accuracy and reliability of measurement results. The metrological support of certification tests for automobile engines encompasses the metrological characteristics of the measuring instruments and devices used in these tests, as well as the methods and tools employed for their verification. Certification tests provide extensive opportunities, resources, and a legal framework for verifying and confirming the compliance of products, processes, and services with standards and other regulatory documents. This process enables the adoption of accurate and up-to-date decisions on critical quality issues during production and service provision, as well as the seamless realization of products in domestic and international markets.

Objective of the Research.

The impact of conducting certification tests of automobile engines and the use of engines that do not meet operational requirements on the reliability of automobile engines has been evaluated.

Results of the Research and Their Discussion.

One of the most widespread types of engines is the internal combustion engine, in which fuel burns directly inside the cylinder, and the heat energy released during combustion is converted into mechanical energy. The internal combustion engine is considered one of the main and most important components of an automobile and is often described as the "heart" of the vehicle. Internal combustion engines consist of two main mechanisms and four systems. The mechanisms include the crank-slider mechanism and the valve distribution mechanism, while the systems comprise the cooling, fuel supply, lubrication, and ignition (starting) systems [1]. To ensure long-term and reliable operation of the engine, timely maintenance of its mechanisms and systems according to the requirements of regulatory and technical documents is essential.

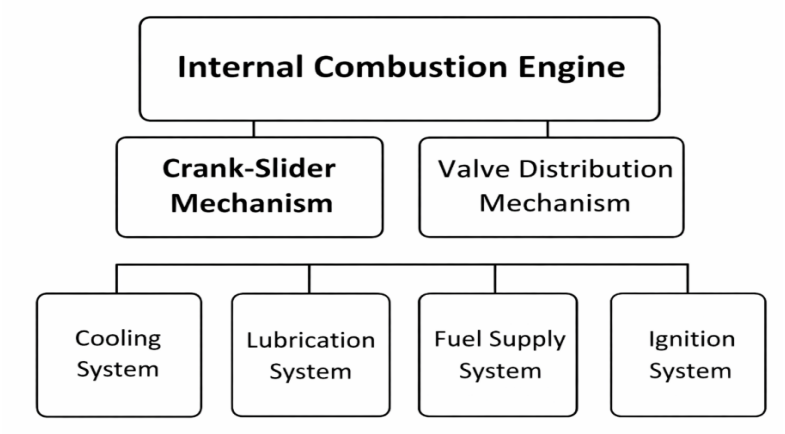
Internal combustion engines differ depending on the type of fuel used and are mainly divided into carburetor engines running on volatile liquid fuel—gasoline—and gas-cylinder engines operating on compressed or liquefied gas stored in cylinders installed in the vehicle [2]. During engine operation, only a part of the heat energy generated is converted into useful mechanical work, while the remaining energy heats the engine components and is expelled along with the combustion products. The average temperature during the working cycle is approximately 800–900 °C. Under such high-temperature conditions, artificial cooling of the engine is necessary. Without cooling, engine components may overheat, oil may burn, pistons may expand and seize, bearings may melt, and other malfunctions can occur. Therefore, a cooling system is crucial for removing heat from the heated parts and ensuring normal engine operation.

The operating principle of a single-cylinder engine is as follows: a piston moves freely inside the cylinder and is connected to the crankshaft via a jointed connecting rod. As the fuel mixture rapidly combusts, the gases in the cylinder expand due to heating, creating high pressure. This pressure moves

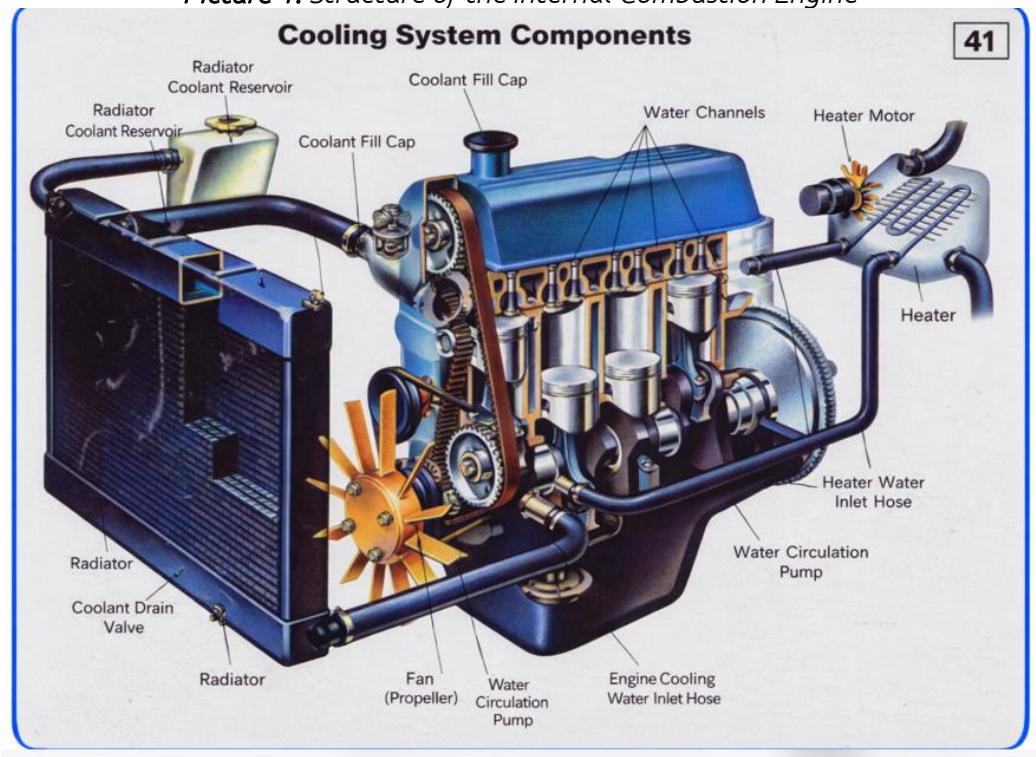
the piston. When the piston moves together with the connecting rod, the crankshaft and the flywheel attached to its end begin to rotate. In this way, the linear motion of the piston is converted into rotational motion of the crankshaft and flywheel through the crank-slider mechanism.

For continuous engine operation, the cylinder must be regularly cleared of burnt gases and supplied with a fresh fuel mixture. To achieve this, a suction port controlled by a valve is located in the cylinder head. The flywheel has a sufficiently large mass to maintain rotation using the speed and inertia generated during fuel combustion, keeping the crank-slider mechanism and piston in motion until the next ignition. When the piston moves upward, the exhaust valve opens, and the burnt gases are expelled from the cylinder. The crankshaft rotation then moves the piston downward, creating a vacuum in the cylinder; this vacuum draws in a new fuel mixture through the intake valve [3].

Igniting the fuel mixture when the piston is at the bottom position is inefficient, as the gas pressure cannot be effectively utilized. Therefore, the piston first moves upward to compress the fuel mixture. The compressed mixture is ignited by a spark, and the resulting gas pressure drives the piston downward again. As the piston moves inside the cylinder, it reaches the upper and lower end positions, where its direction changes; these points are called dead centers. The distance traveled by the piston between these two points is called the piston stroke. During one piston stroke, the crankshaft rotates 180°, completing half a revolution. The process occurring inside the cylinder during one piston stroke is referred to as a cycle [4].



Picture 1: Structure of the Internal Combustion Engine



Picture 2: Automobile engine cooling system devices.

The series of processes that occur in a cylinder in a specific sequence is called the working cycle. Engines in which the strokes repeat every four piston movements, or two revolutions of the crankshaft, are referred to as four-stroke engines. When starting the engine, the crankshaft is rotated by a starting support or a starter to complete the preparation strokes. In a running engine, these strokes occur using the energy accumulated by the flywheel during its working stroke.

In an internal combustion engine, the execution of all processes in the working cycle involves the crank-slider mechanism, the valve distribution mechanism, as well as the cooling, lubrication, fuel supply, and ignition systems. The function of the crank-slider mechanism is to absorb the pressure of the gases during the combustion-expansion stroke and to convert the linear reciprocating motion of the piston into the rotational motion of the crankshaft. The role of the valve distribution mechanism is to timely release a fresh portion of fuel mixture into the engine cylinder and expel the exhaust gases [5].

The cooling system removes heat from the engine components and maintains the engine at an optimal operating temperature. Liquid cooling systems are more widely used. The lubrication system reduces friction between moving parts by supplying oil, partially cooling the components and ensuring the cleaning of the oil. The fuel supply system is responsible for delivering fuel, cleaning and directing air to the carburetor, preparing the fuel mixture, supplying it to the cylinders, and removing exhaust gases. The ignition system generates an electric spark to ignite the fuel mixture in the engine cylinders.

A single-cylinder engine, especially when its size is increased, operates with irregular impulses despite the presence of a flywheel, because only one of the four strokes is a power stroke [6]. Impulse operation causes engine vibration, loosening of fasteners, and excessive wear of components. To reduce irregular operation, multi-cylinder engines—engines with a common crankshaft that essentially combine several single-cylinder engines—are used. Smooth operation of a multi-cylinder engine is achieved by arranging the power strokes in different cylinders in a specific sequence [7].

Cylinder Block. This is the main part of the engine, to which all other mechanisms and components are attached. It is cast from cast iron or aluminum alloy. The engine crankcase and cooling jackets of the cylinders are also cast together with the cylinder block.Piston. During the power stroke, the piston transmits the pressure of the gases to the connecting rod via the piston pin; additionally, the piston performs the preparation strokes.

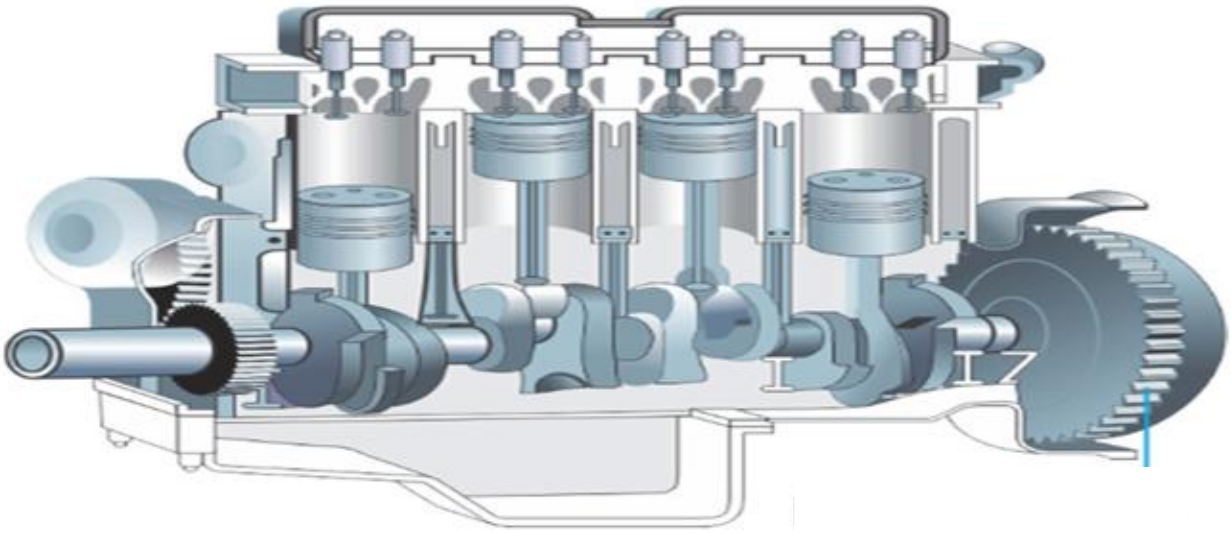
Piston Rings. Depending on their function, the rings are divided into compression rings and oil scraper rings. Compression rings prevent gases from entering the engine crankcase, while oil scraper rings remove excess oil from the cylinder walls. The rings are made of cast iron or steel and have a gap; their elasticity ensures a tight fit against the cylinder wall.

Piston Pin. It connects the connecting rod to the piston in a hinged manner. The pin is made of steel in a hollow cylindrical shape. Its outer surface is hardened by high-frequency current. Spring steel retaining rings placed in the grooves of the piston bosses prevent axial movement of the pin.

Crankshaft. It receives the force transmitted from the pistons through the connecting rods, converts it into torque, and transmits it to the transmission via the flywheel.

Connecting Rod Bearings and Main Bearings. The significant load on the crankshaft journals requires the use of specialized bearings. Bearings are made with thin-walled bimetallic or trimetal liners. The advantage of such liners is high wear resistance, reduced consumption of expensive antifriction alloys, and minimal repair time. Main bearing liners are placed in the crankcase rib seats and walls, while connecting rod bearing liners are placed in the detachable lower heads of the connecting rods. To prevent rotation or displacement, bearings have retaining protrusions that fit into corresponding recesses in the bearing caps and housings.

Flywheel. It reduces irregular engine operation, moves pistons out of dead centers, and facilitates engine starting and vehicle movement. The flywheel is cast from iron in a disc shape, with thickened edges to increase its mass. A toothed ring is mounted along its circumference to enable engine starting with a starter. The flywheel is attached to the crankshaft flange with 4 or 6 bolts..



Picture 3. Nazimcharkh

Conclusion

In order to supply the industry of the Republic of Azerbaijan with automobile fuels and engine oils and to improve their quality to the level of international standards, new technological equipment for the production of engine oils must be installed and put into operation by the state. The operation of engine oils and fuels in automobile engine cooling and ignition systems must comply with regulatory and technical documents. To provide automobile fuels and engine oils with various operational characteristics, it is necessary to organize the production of high-quality additives in the oil industry of the Republic of Azerbaijan. The certification process of engine oils in the Republic of Azerbaijan needs to be further developed. The regulatory and technical framework for the certification process, i.e., national standards, should be established and updated.

Declarations

The manuscript has not been submitted to any other journal or conference.

Educational Limitations

There are no limitations that could affect the results of the study.

Thanks

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Technical sciences

A METHOD FOR SIMULTANEOUS ACQUISITION OF DOPPLER AND ELASTOGRAPHY DATA

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DOPPLEROQRAFIYA VƏ ELASTOQRAFIYA VERILƏNLƏRININ EYNI VAXTDA ƏLDƏ EDILMƏSI ÜSULU

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Abstract

This article examines the principles, applications, and advantages of using Doppler and elastography, two techniques that play an important role in modern medical diagnostics. Doppler ultrasound uses the Doppler effect to assess the velocity and direction of blood flow, while elastography measures the stiffness of tissues. Both methods are non-invasive and provide invaluable information in the diagnosis of various diseases. The article discusses how combining these two techniques increases diagnostic accuracy, especially in the assessment of liver diseases, vascular pathologies and tumors. At the same time, the clinical applications and future prospects of this integrated approach are also reviewed. The application of this method helps doctors make more accurate and comprehensive diagnoses, which leads to the optimization of treatment strategies.

Xülasə

Bu məqalə, müasir tibbi diaqnostikada mühüm rol oynayan doppleroqrafiya və elastoqrafiya üsullarının prinsiplərini, tətbiq sahələrini və bu iki texnikanın eyni vaxtda istifadə edilməsinin üstünlüklərini araşdırır. Doppler ultrasəs, qan axınının sürətini və istiqamətini qiymətləndirmək üçün Doppler effektindən istifadə edərkən, elastoqrafiya toxumaların sərtliyini ölçür. Hər iki üsul da qeyri-invazivdir və müxtəlif xəstəliklərin diaqnostikasında əvəzsiz məlumatlar təqdim edir. Məqalədə, bu iki texnikanın birləşdirilməsinin diaqnostik dəqiqliyi necə artırdığı, xüsusilə qaraciyər xəstəlikləri, damar patologiyaları və şişlərin qiymətləndirilməsindəki rolu müzakirə olunur. Eyni zamanda, bu inteqrasiya olunmuş yanaşmanın klinik tətbiqləri və gələcək perspektivləri də nəzərdən keçirilir. Bu üsulun tətbiqi, həkimlərə daha dəqiq və hərtərəfli diaqnoz qoymaqda kömək edir, bu da müalicə strategiyalarının optimallaşdırılmasına gətirib çıxarır.

Keywords: *Dopplerography, Elastography, Ultrasound, Diagnostics, Tissue Stiffness*
Açar sözlər: *Doppleroqrafiya, Elastoqrafiya, Ultrasəs, Diaqnostika, Toxuma sərtliyi*

Giriş

Müasir tibbi diaqnostikada ultrasəs texnologiyaları qeyri-invaziv, təhlükəsiz və effektiv müayinə üsulları kimi geniş tətbiq olunur. Bu texnologiyalar arasında doppleroqrafiya və elastoqrafiya xüsusi yer tutur. Hər iki üsul da toxumaların və orqanların funksional və struktur xüsusiyyətləri haqqında dəyərli məlumatlar təqdim edir. [1] Doppleroqrafiya, qan axınının dinamik parametrlərini, yəni sürətini və istiqamətini qiymətləndirməyə imkan verir. Bu, damar patologiyalarının, məsələn, stenozların, trombozların və anevrizmaların diaqnostikasında əvəzsizdir. Elastoqrafiya isə toxumaların mexaniki xüsusiyyətlərini, xüsusilə sərtliyini ölçür Toxuma sərtliyindəki dəyişikliklər bir çox xəstəliklərin, o cümlədən fibroz, iltihab və şiş proseslərinin əlaməti ola bilər. Ənənəvi ultrasəs müayinəsi toxumaların morfoloji xüsusiyyətlərini göstərsə də, onların funksional və mexaniki vəziyyəti haqqında məlumat vermir. Bu səbəbdən, doppleroqrafiya və elastoqrafiya kimi əlavə üsulların tətbiqi diaqnostik dəqiqliyi əhəmiyyətli dərəcədə artırır. [2, s. 44–51]

Tədqiqatin Məqsədi, Məsələnin Qoyuluşu

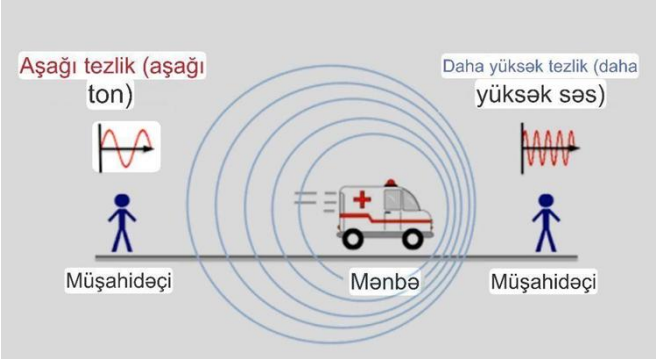
Bu tədqiqatın əsas məqsədi, doppleroqrafiya və elastoqrafiya verilənlərinin eyni vaxtda əldə edilməsi üsulunun klinik əhəmiyyətini, texniki prinsiplərini və diaqnostik üstünlüklərini hərtərəfli

araşdırmaqdır. [3] Məsələnin qoyuluşu ondan ibarətdir ki, bu iki müayinə üsulunun ayrı-ayrılıqda istifadəsi müəyyən məhdudiyyətlərə malikdir. Məsələn, doppleroqrafiya damar patologiyaları haqqında ətraflı məlumat versə də, ətraf toxumaların sərtliyi barədə heç bir fikir vermir. Eyni şəkildə, elastoqrafiya toxuma sərtliyini qiymətləndirsə də, qan axını dinamikası haqqında məlumat təmin etmir. Bu səbəbdən, hər iki üsulun inteqrasiyası, xüsusilə mürəkkəb patologiyaların, məsələn, şişlərin, iltihabi proseslərin və fibrotik dəyişikliklərin diaqnostikasında daha dəqiq və hərtərəfli nəticələr əldə etməyə imkan yaradır. Tədqiqat, bu inteqrasiya olunmuş yanaşmanın hansı klinik vəziyyətlərdə daha effektiv olduğunu və diaqnostik alqoritmlərə necə daxil edilə biləcəyini müəyyənləşdirməyi hədəfləyir.

Məsələnin Həlli Üsulları və Aprobasiyası

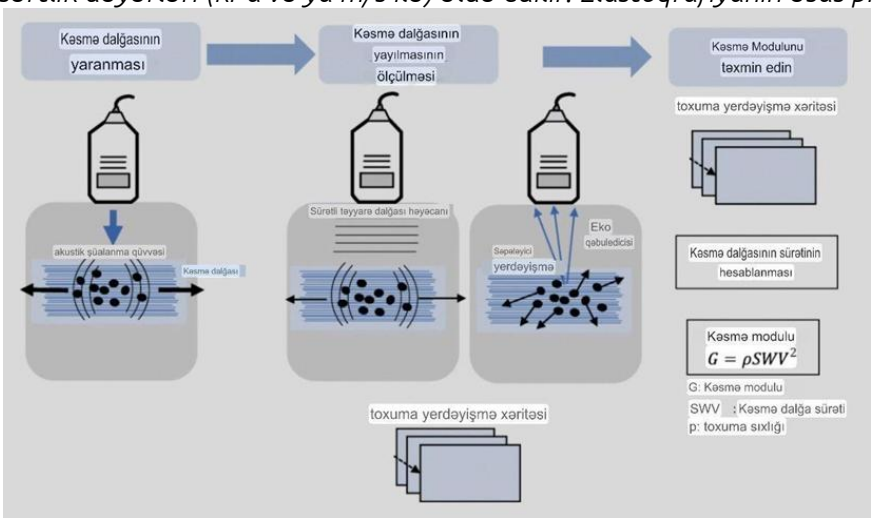
Doppleroqrafiya və elastoqrafiya verilənlərinin eyni vaxtda əldə edilməsi müasir ultrasəs cihazlarında texniki olaraq mümkündür. Bir çox yeni nəsil ultrasəs sistemləri həm Doppler, həm də elastoqrafiya modullarını özündə birləşdirir, bu da həkimlərə bir müayinə seansı zamanı hər iki növ məlumatı əldə etməyə imkan verir. Bu üsulun həlli aşağıdakı prinsiplərə əsaslanır:

Doppleroqrafiya Prinsipləri: Doppler ultrasəs, ultrasəs dalğalarının hərəkət edən obyektlərdən (məsələn, qırmızı qan hüceyrələri) əks olunarkən tezliyinin dəyişməsi (Doppler effekti) prinsipinə əsaslanır. Bu tezlik dəyişikliyi qan axınının sürəti və istiqaməti haqqında məlumat verir. [4] Rəngli Doppler, Power Doppler və Spektral Doppler kimi müxtəlif rejimlər qan axınının vizuallaşdırılması və kəmiyyət analizini təmin edir.



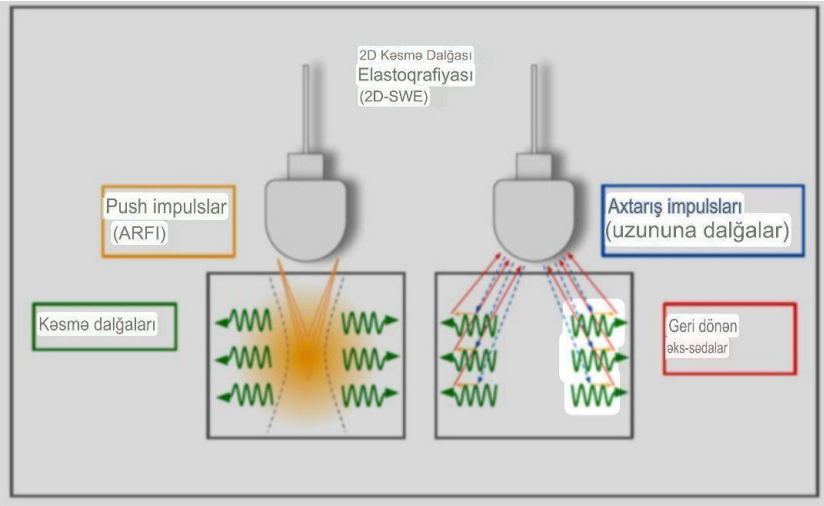
Şəkil 1. Doppler effekti: Səs mənbəyi müşahidəçiyə yaxınlaşdıqda tezlik artır (yüksək ton), uzaqlaşdıqda isə tezlik azalır (aşağı ton).

Elastoqrafiya Prinsipləri: Elastoqrafiya toxumaların sərtliyini ölçmək üçün istifadə olunur. Bu, toxumaya xarici mexaniki təzyiq tətbiq etməklə və ya ultrasəs cihazının özü tərəfindən yaradılan akustik şok dalğaları vasitəsilə həyata keçirilir. Toxumaların deformasiyası və ya kəsmə dalğalarının yayılma sürəti ölçülərək sərtlik dəyərləri (kPa və ya m/s ilə) əldə edilir. Elastoqrafiyanın əsas prinsipləri



Şəkil 2. Elastoqrafiya prinsipləri: Kəsmə dalğası elastoqrafiyası

Eyni Vaxtda Verilənlərin ldə Edilməsi: Müasir ultrasəs cihazları eyni transduserdən istifadə edərək həm B-mod görüntüləməni, həm Doppler analizini, həm də elastoqrafiya ölçmələrini ardıcıl və ya bəzən eyni anda həyata keçirə bilir. Bu, müayinə müddətini qısaltmaqla yanaşı, əldə olunan məlumatların daha dəqiq korrelyasiyasına imkan verir. Məsələn, bir şişin həm qan təchizatı (Doppler), həm də sərtliyi (elastoqrafiya) eyni anda qiymətləndirilə bilər ki, bu da onun xoşxassəli və ya bədxassəli olmasını müəyyənləşdirməkdə kritik rol oynayır. 2D kəsmə dalğası Elastoqrafiya tətbiqinin bir nümunəsi

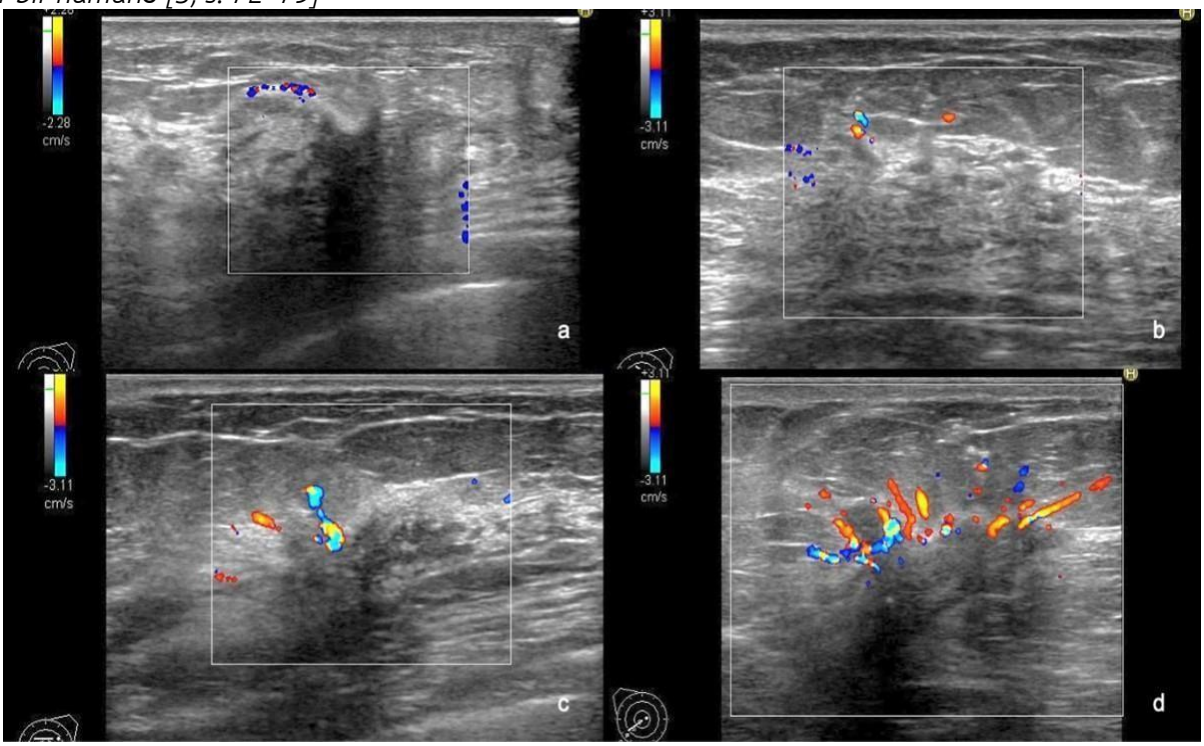


Şəkil 3. 2D Kəsmə Dalğası Elastoqrafiya prinsipi

Aprobasiya: Bu üsulun aprobasiyası müxtəlif klinik tədqiqatlar vasitəsilə aparılmışdır. Məsələn, qaraciyər fibrozunun diaqnostikasında həm Doppler (portal hipertenziyanın qiymətləndirilməsi üçün), həm də elastoqrafiya (qaraciyər sərtliyinin ölçülməsi üçün) birlikdə istifadə olunur. Damar patologiyalarında, məsələn, ateroskleroti̇k lövhələrin qiymətləndirilməsində, lövhənin sərtliyi (elastoqrafiya) və onun qan axınına təsiri (Doppler) eyni anda analiz edilərək daha dəqiq risk qiymətləndirməsi aparılır. Şişlərin diaqnostikasında isə şişin vaskulyarizasiyası (Doppler) və sərtliyi (elastoqrafiya) birlikdə qiymətləndirilərək diferensial diaqnozun qoyulması asanlaşdırılır.

Alınan Nəticələrin Tətbiqi

Doppleroqrafiya və elastoqrafiya verilənlərinin eyni vaxtda əldə edilməsi üsulu tibbin bir çox sahələrində geniş tətbiq imkanlarına malikdir: Qaraciyər Xəstəlikləri: Qaraciyər fibrozunun və sirrozunun diaqnostikasında elastoqrafiya qaraciyər sərtliyini ölçməklə əsas rol oynayır. Eyni zamanda, portal hipertenziyanın qiymətləndirilməsi üçün portal venada qan axınının doppleroqrafik analizi vacibdir. Bu iki məlumatın birləşdirilməsi xəstəliyin mərhələsinin daha dəqiq müəyyənləşdirilməsinə və müalicənin effektivliyinin izlənilməsinə kömək edir. Doppler və elastoqrafiyanın birləşdirilmiş tətbiqinə dair bir nümunə [5, s. 72–79]



Şəkil 4. Doppler və Elastoqrafiyanın Birləşdirilmiş Tətbiqi: Rəngli Doppler və Gərginlik Elastoqrafiya ilə şişin qiymətləndirilməsi.

Damar Patologiyaları: Ateroskleroz, tromboz və venoz çatışmazlıq kimi damar xəstəliklərində Doppler ultrasəs qan axınının pozulmalarını aşkar edir.[6] Elastoqrafiya isə damar divarının sərtliyini və

ya aterosklerotik lövhələrin mexaniki xüsusiyyətlərini qiymətləndirərək, xəstəliyin inkişaf riskini və müalicəyə cavabı proqnozlaşdırmağa kömək edir. Şiş Diaqnostikası: Şiş toxumaları adətən ətraf sağlam toxumalardan daha sərt olur və fərqli vaskulyarizasiya xüsusiyyətlərinə malikdir. Elastoqrafiya şişin sərtliyini ölçməklə onun xoşxassəli və ya bədxassəli olmasını diferensiasiya etməyə kömək edir. Doppler isə şişin qan təchizatını, yəni anjioqenez dərəcəsini qiymətləndirir. Bu iki məlumatın kombinasiyası, xüsusilə süd vəzi, qalxanabənzər vəzi və prostat vəzi şişlərinin diaqnostikasında dəqiqliyi artırır. [7] İltihabi Proseslər: İltihablı toxumalar da sərtlikdə dəyişikliklər göstərə bilər. Eyni zamanda, iltihablı bölgələrdə qan axını artımı (hiperemiya) doppleroqrafiya ilə aşkar edilə bilər. Bu inteqrasiya olunmuş yanaşma, iltihabi xəstəliklərin diaqnostikasında və müalicənin izlənilməsində faydalıdır.

Nəticə

Doppleroqrafiya və elastoqrafiya verilənlərinin eyni vaxtda əldə edilməsi üsulu, müasir tibbi diaqnostikada yeni və perspektivli bir yanaşmadır. Bu inteqrasiya olunmuş texnika, toxumaların həm funksional (qan axını), həm də mexaniki (sərtlik) xüsusiyyətləri haqqında hərtərəfli məlumat təmin edərək, diaqnostik dəqiqliyi əhəmiyyətli dərəcədə artırır. Xüsusilə qaraciyər xəstəlikləri, damar patologiyaları və şişlərin diaqnostikasında bu üsulun tətbiqi, həkimlərə daha dəqiq diaqnoz qoymaqda və optimal müalicə strategiyaları hazırlamaqda kömək edir. Gələcəkdə bu texnikanın daha da təkmilləşdirilməsi və geniş klinik tətbiqi, bir çox xəstəliklərin erkən diaqnostikası və effektiv idarə olunmasında mühüm rol oynayacaqdır. [8, s. 419–431]

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THE IMPACT OF THE REAGENT AND CALIBRATION ERRORS ON BIOCHEMICAL ANALYSIS RESULTS

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REAKTİV VƏ KALİBRASİYA SƏHVLƏRİNİN BİOKİMYƏVİ ANALİZ NƏTİCƏLƏRİNƏ TƏSİRİ

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ВЛИЯНИЕ РЕАКТИВНЫХ И КАЛИБРОВОЧНЫХ ОШИБОК НА РЕЗУЛЬТАТЫ БИОХИМИЧЕСКОГО АНАЛИЗА

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Abstract

Biochemical analyzers are used in medical laboratories, and these high-precision diagnostic devices allow for the assessment of various functional parameters within the human body. The quality of reagents and the proper calibration of the analyzer directly impact the reliability and clinical utility of the results provided by the devices. Our objective is to determine the impact of reagent and calibration errors on laboratory results. Expired reagents, improper storage conditions, and the use of incorrect lots can lead to significant errors [1].

Based on the data obtained from the study, such technical and subjective errors can lead to inaccuracies in the clinical interpretation of laboratory analyses, reduce the quality of diagnostic decisions, and compromise patient safety. The article covers topics such as technical control methods and quality control measures to prevent such errors.

Xülasə

Biokimyəvi analizatorlar tibbi laboratoriyalarda istifadə olunur və bu yüksək dəqiqlikli diaqnostik cihazlar insan orqanizmində müxtəlif funksional göstəricilərini qiymətləndirməyə imkan verir. Reaktivlərin keyfiyyəti və analizatorun düzgün kalibrasiyası cihazların verdiyi nəticələrin etibarlılığı və tibbi tətbiqə yararlılığına birbaşa təsir edir. Məqsədimiz reaktiv və kalibrasiya səhvlərinin laborator nəticələrə olan təsirini müəyyən etməkdir. Rektivlərin son istifadə müddətini aşması, saxlanma şəraitinə uyğun saxlanılmaması, səhf lotlardan istifadə olunması ciddi xətalara səbəb ola bilər [1].

Tədqiqatın nəticəsində əldə olunan məlumatlara əsasən , bu kimi texniki, subyektiv xətalar laborator analizlərin klinik izahında yanlışlıqlara yol açа, diaqnostik qərarların keyfiyyətini azalda və xəstə təhlükəsizliyini risk altına ata bilər. Məqalədə bu kimi səhvlərin qarşısının alınmaq üçün texniki nəzarət metodları və keyfiyyətə nəzarət tədbirləri kimi mövzuları əhatə edir.

Аннотация

Биохимические анализаторы используются в медицинских лабораториях и представляют собой высокоточные диагностические устройства, позволяющие оценивать различные функциональные показатели организма человека. Качество реагентов и правильная калибровка

анализатора напрямую влияют на достоверность получаемых результатов и их клиническую применимость. Целью нашего исследования является определение влияния ошибок, связанных с реагентами и калибровкой, на лабораторные результаты. Просроченные реагенты, несоблюдение условий их хранения, а также использование реагентов с неправильными сериями (lot) могут привести к серьезным ошибкам [1].

На основании данных, полученных в ходе исследования, установлено, что подобные технические и субъективные ошибки могут вызывать неточности в клинической интерпретации лабораторных анализов, снижать качество диагностических решений и создавать риски для безопасности пациентов. В статье также рассматриваются методы технического контроля и меры обеспечения качества, направленные на предотвращение подобных ошибок.

Keywords: *Biochemical analyzer, reagent error, calibration, laboratory diagnostics, result accuracy, technical error, quality control.*

Açar sözlər: *Biokimyəvi analizator, reaktiv səhvi, kalibrasiya, laborator diaqnostika, nəticə dəqiqliyi, texniki xəta, keyfiyyətə nəzarət.*

Ключевые слова: *биохимический анализатор, ошибка реагента, калибровка, лабораторная диагностика, точность результатов, техническая ошибка, контроль качества*

Introduction

Laboratory test results play a crucial role in substantiating clinical decisions within modern healthcare systems. Biochemical analyzers are considered one of the main technical components of the diagnostic process, as they provide automated measurement of chemical parameters in various biological fluids. The accuracy of the obtained results largely depends on the functional condition of reagents and the proper application of calibration mechanisms [2].

Reagent Storage and Identification

Special cooling compartments designed for reagent disks inside the analyzer maintain a stable temperature in the range of 5–15°C, preventing the degradation of chemical components. This stable environment ensures the reproducibility of reactions. At the same time, the automatic barcode scanner integrated into the system minimizes errors caused by the human factor; thus, the type of each reagent, its expiration date, and lot number are automatically recognized and recorded by the system.

Calibration and Photometric Accuracy

To ensure measurement accuracy, the device calculates the corresponding coefficients using calibrator samples. In biochemical analyses that employ the photometric method, recording absorbance values at 49 different points helps eliminate systematic errors and ensures high sensitivity.

Although the device software accelerates the calibration process, errors may still occur in some cases. The main causes of these errors include:

Use of reagents with incompatible lot numbers;

Failure to comply with the storage conditions of calibrators (temperature, light, etc.);

Missing or exceeding the specified calibration intervals.

Significance

The results produced by biochemical analyzers used in clinical laboratories are considered among the most important indicators both for the identification of diseases and for selecting the correct treatment strategy. However, the accuracy of the numerical results provided by these devices depends on many technical conditions and on how properly operational procedures are followed. For instance, deterioration in the composition of chemical substances used for analysis (reagents), failure to comply with proper storage conditions, and the absence of timely device adjustment (calibration) may lead to erroneous results.

In such cases, laboratory findings may be misinterpreted by physicians, which can lead to incorrect decisions regarding the course of a disease. From this perspective, the main issue is to scientifically investigate how reagent-related and calibration-related errors occurring in analyzers affect laboratory results. The importance of this problem lies in the fact that such technical malfunctions not only reduce the quality of laboratory work but also directly endanger patient safety. Therefore, this issue should not be considered merely as a device-related error, but rather as a medical risk. The causes of these errors and the potential consequences they may create must be thoroughly studied.

Research Objective

The main objective of this article is to conduct an in-depth analysis of both the technical causes and the medical consequences of reagent-related and adjustment (calibration) errors encountered in biochemical analyzers. At the same time, the study aims to investigate the capabilities of modern technologies used to prevent such errors and to reveal how these inaccuracies influence laboratory results as well as physicians' clinical decisions.

The primary tasks of the research include, first of all, clarifying the technical characteristics of reagents and identifying the possible types of errors that may arise. In addition, the study analyzes calibration methods and the factors that may lead to errors during this process. Furthermore, it aims to review the quality control systems used within laboratories and to explain, through specific examples, how technical inaccuracies can affect clinical outcomes.

1. Storage of the reagent at an inappropriate temperature.

Example: Reagents used for the ALT (alanine aminotransferase) test must be stored at 5–8°C. However, due to a malfunction in the reagent refrigerator, the reagents were stored at 18°C for 48 hours.

Result: The stability of the enzyme was compromised and the measured activity decreased by 15–20%.

Calculation:

If the normal ALT level should be 70 U/L with a properly functioning reagent and the reagent effectiveness drops to 80%:

Result = 70 × 0.80 = 56 U/L

This may lead to an abnormal interpretation or misdiagnosis.

2. Failure to perform calibration on time

Example: The last calibration of the analyzer for the glucose test was performed more than 10 days ago, while the device software requires daily calibration.

Result: The calibration curve shifts, and the result consistently shows +10 mg/dL higher values.

Calculation:

If the real glucose level is 98 mg/dL:

Reported result = 98 + 10 = 108 mg/dL

This may lead to an incorrect insulin-related diagnosis for the patient.

3. Use of an incorrect reagent lot

Example: For the creatinine test, the analyzer requires R1 reagent with lot code A1234, but lot code B1255 was mistakenly used.

Result: The correction factor of this lot is different, resulting in an error of −15% in the results.

Calculation:

If the real creatinine level is 1.2 mg/dL:

Result = 1.2 × 0.85 = 1.02 mg/dL

This may cause a patient with renal failure to appear within the normal range [6].

Figure 1. Reagent specifications.

2. Errors detectable in biochemical analyzers.

Biochemical analyzers are modern technical devices that automatically perform various laboratory tests. These instruments are indispensable for determining the levels of glucose, creatinine, lipids (fats), liver function indicators, electrolytes, and other substances in blood and other biological fluids. The greatest advantages of such systems are their ability to complete analyses in a short time, operate with high accuracy, and consistently reproduce the same results. In addition, due to automation, human errors

in laboratory procedures are minimized. High-precision diagnostic devices used in modern clinical laboratories enable the automated evaluation of various functional parameters [8].

However, despite all these advantages, the quality of the chemical substances used and the proper implementation of calibration procedures are essential for obtaining accurate results. Otherwise, the results produced may be medically inaccurate, which can lead to incorrect diagnoses. The experiments presented below clearly demonstrate how such technical factors can affect the analytical process.

False elevation of glucose results

If the reagent value is unstable and the analyzer calibration is outdated, glucose results may appear 10% higher than the actual value.

Example: The patient's real glucose level is 105 mg/dL. Due to a calibration error:

Reported value = 105 × 1.10 = 115.5 mg/dL

Medical implication: Although the value is within the normal range, it may be interpreted as a prediabetic condition, which can cause unnecessary psychological and financial burden for the patient.

False decrease in liver enzyme levels

ALT and AST tests are measured using sensitive reagents. If the reagent quality is poor, enzyme activity may appear lower than it actually is.

Example: The patient's real ALT level is 80 U/L. If the reagent stability is compromised and causes a 20% decrease:

Result = 80 × 0.80 = 64 U/L

Medical implication: Since the normal ALT range is 7–56 U/L, this condition may be interpreted as a mild abnormality, whereas the patient may actually have hepatitis.

Incorrect values in electrolyte analysis

Analyses of Na^+, K^+, and Cl^- are performed using ion-selective electrodes. When calibration errors occur, ion concentrations may be measured incorrectly [6].

Example:

Real Na^+ value: 136 mmol/L

Calibration curve shift: +4 mmol/L

Reported value = 136 + 4 = 140 mmol/L

Medical implication: The patient may actually have hyponatremia (low Na^+), but the result appears normal, and the necessary electrolyte balance intervention may not be performed.

These practical examples demonstrate that technical errors can lead to serious inaccuracies in the medical interpretation of laboratory analyses. In particular, proper storage of reagents and timely calibration according to standards are essential conditions for ensuring accurate results.

- *To prevent clinical errors, the following measures are recommended:*
- *Monitoring daily Internal Quality Control (IQC) charts*
- *Automatic verification of calibration intervals*
- *Tracking reagent lot numbers and expiration dates through the LIS system*
- *Providing periodic technical training for laboratory operators.*

3. The impact of reagent and calibration errors on analytical results.

Modern biochemical analyzers utilize various reagents to carry out chemical reactions and determine results mainly based on the absorbance of light (photometric method). These chemical substances are key elements that determine how sensitive and accurate the performed test will be. Failure to follow proper reagent storage conditions, expiration of reagents, contamination with foreign substances, or errors during the preparation stage can seriously affect the accuracy of laboratory analyses. The quality of reagents and their proper storage conditions directly affect the clinical usefulness of the results provided by the analyzer [9].

The most common reagent-related errors encountered in laboratories include:

- *Placement of a reagent that is incompatible with the analyzer or belongs to a different lot (batch);*
- *Use of expired chemical reagents;*
- *Improper regulation of the temperature conditions required for the reaction;*
- *Insufficient or improper mixing of the reagent in its container.*

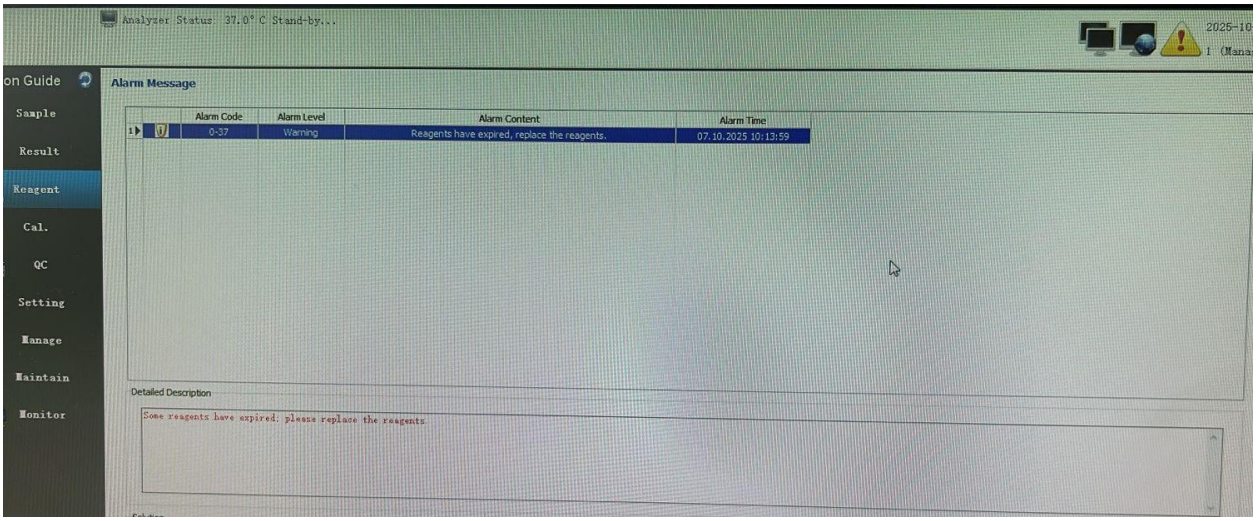

Figure 2. Reagent expiration alarm.

Due to such malfunctions, the analyzer may either display incorrect values or stop functioning completely. In such situations, the final outcome may be an incorrect diagnosis for the patient or the prescription of unnecessary treatments.

Calibration is the process of aligning the measurement system of the device with international standards. During this process, special samples with precisely known composition and concentration (calibrators) are used to properly adjust the device's measurement scale. If this adjustment is not performed correctly, all test results may systematically appear higher or lower than the normal range.

Errors in the calibration process mainly arise from the following reasons:

- *Selection of an incorrect calibrator;*
- *Violation of the storage conditions of calibration samples;*
- *Incorrect entry of calculation coefficients into the device;*
- *Failure to perform calibration within the specified time interval.*

Even the smallest deviation during calibration can cause all laboratory results produced over a long period to become inaccurate, which directly reduces the quality of medical services.

5. Problems and Solutions

The results of the study demonstrate that comprehensive scientific and technical measures must be implemented to prevent reagent and adjustment (calibration) errors. Several important principles play a decisive role in solving this problem. First of all, international quality standards such as ISO 15189 should be implemented in laboratories. Through this system, every stage—from the procurement and storage of chemical substances to calibration schedules and usage procedures—must be systematically monitored and officially recorded.

At the same time, the digitalization and automation of the calibration process are essential. The device software should monitor operations in real time, detect errors immediately through a barcode recognition system, and minimize human intervention as much as possible. Through internal and external quality control procedures (IQC and EQC), the stability and reliability of the analyzer should be tested regularly.

Finally, the professional competence of technical staff must be continuously improved. Providing laboratory personnel with regular training on reagent management and the application of new technologies is essential for the early detection and prevention of potential errors.

Conclusion

Reagent and adjustment (calibration) defects encountered in digital biochemical analyzers are significant factors that directly affect the accuracy of laboratory results and the medical decisions made by physicians. To obtain precise analytical results, the chemical substances used in testing (reagents) must be of high quality, stored under appropriate conditions, and selected according to the correct batch for each specific test. To maintain measurement accuracy in biochemical analyzers, calibration tables must be validated according to international protocols [7].

In addition, proper calibration of the analyzer's measurement system at specified intervals and in accordance with established procedures ensures its reliable operation over a long period of time. The real laboratory cases examined during this study confirmed that deficiencies related to both reagents and calibration can lead to significant deviations in analytical results. Such inaccuracies may ultimately result

in serious consequences, including misdiagnosis of diseases, delays in treatment, or unnecessary medical interventions for patients.

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COMPARATİVE ANALYSİS OF SENSOR TECHNOLOGİES İN ENVİRONMENTAL MONİTORİNG SYSTEMS

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ƏTRAF MÜHİTİN MONİTORİNQ SİSTEMLƏRİNDƏ SENSOR TEXNOLOGİYALARININ MÜQAYİSƏLİ TƏHLİLİ

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СРАВНИТЕЛЬНЫЙ АНАЛИЗ СЕНСОРНЫХ ТЕХНОЛОГИЙ В СИСТЕМАХ МОНИТОРИНГА ОКРУЖАЮЩЕЙ СРЕДЫ

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Abstract

In contemporary times, environmental protection and the assurance of ecological security are considered among the top global priorities. Rapid industrialization, urbanization, and climate change exert serious pressure on the natural environment, and the lack of proper control over these processes may lead to long-term environmental consequences. In this regard, continuous monitoring and assessment of the state of the environment are of great importance. Environmental monitoring systems enable the onepamuве collection of data on the condition of air, water, soil, and living organisms and ensure that management decisions are based on scientific evidence.

Traditional monitoring methods, which mainly rely on laboratory analyses, have limited operational capabilities. In contrast, modern sensor technologies enable real-time data collection and processing. These technologies allow faster detection of environmental changes and early identification of risks. The application of sensors leads to the automation of measurement processes, reduces errors caused by human factors, and increases data reliability.

The main part of the text extensively explains the key directions of environmental monitoring, including air, water, and soil quality monitoring systems. In air monitoring, the measurement of harmful gases and particulate matter in the atmosphere plays an important role in assessing potential risks to human health. In water monitoring, the measurement of physical, chemical, and biological indicators ensures the safety of drinking water resources and contributes to the protection of aquatic ecosystems. Soil monitoring is important for maintaining agricultural productivity, preventing soil degradation, and preserving biodiversity. One of the main challenges in the application of sensor technologies is maintaining their long-term accuracy. Temperature, humidity, pollution, and other external factors may affect sensor measurement results. Therefore, regular calibration of sensors and correction of measurement results are essential. Indicators such as accuracy, precision, repeatability, and reproducibility serve as key criteria for assessing the reliability of sensor data. In addition, communication problems and energy supply difficulties may arise during data transmission from monitoring stations located in remote areas. Such problems can lead to interruptions in real-time data flow and reduce the effectiveness of monitoring. In this context, selecting appropriate communication technologies and properly planning energy sources are important factors that enhance the sustainability of monitoring systems.

Overall, the text comprehensively presents the role of modern sensor technologies in environmental monitoring and the existing challenges in this field. Based on comparative analysis, the strengths and weaknesses of different sensor types are identified, and recommendations for their application areas are proposed. This approach provides a scientific basis for the formation of optimal monitoring models and contributes to improving the efficiency of environmental management processes.

Xülasə

Müasir dövrdə ətraf mühitin qorunması və ekoloji təhlükəsizliyin təmin olunması qlobal miqyasda prioritet istiqamətlərdən biri hesab olunur. Sürətli sənayeləşmə, urbanizasiya və iqlim dəyişiklikləri təbii mühitə ciddi təzyiq göstərir və bu proseslərin nəzarətsiz qalması uzunmüddətli ekoloji fəsadlara səbəb ola bilər. Bu baxımdan, ətraf mühitin vəziyyətinin davamlı şəkildə izlənilməsi və qiymətləndirilməsi böyük əhəmiyyət kəsb edir. Ekoloji monitorinq sistemləri hava, su, torpaq və canlı aləmin vəziyyəti haqqında operativ məlumatların toplanmasına imkan yaradır və idarəetmə qərarlarının elmi əsaslara söykənməsini təmin edir.

Ənənəvi monitorinq üsulları əsasən laboratoriya analizlərinə söykəndiyi üçün operativlik baxımından məhdud imkanlara malikdir. Müasir sensor texnologiyaları isə real vaxt rejimində məlumatların toplanması və emalına şərait yaradır. Bu texnologiyalar ətraf mühitdə baş verən dəyişikliklərin daha tez aşkar olunmasına və risklərin erkən mərhələdə müəyyən edilməsinə imkan verir. Sensorların tətbiqi nəticəsində ölçmə prosesləri avtomatlaşdırılır, insan faktorundan irəli gələn səhvlər azalır və məlumatların etibarlılığı yüksəlir.

Mətnin əsas hissəsində ətraf mühitin monitorinqinin əsas istiqamətləri olan hava, su və torpaq keyfiyyətinə nəzarət sistemləri geniş şəkildə izah olunur. Hava monitorinqi zamanı atmosferdə olan zərərli qazların və hissəciklərin ölçülməsi insan sağlamlığı üçün yarana biləcək risklərin qiymətləndirilməsində mühüm rol oynayır. Su monitorinqində fiziki, kimyəvi və bioloji göstəricilərin ölçülməsi içməli su ehtiyatlarının təhlükəsizliyini təmin edir və su ekosistemlərinin qorunmasına xidmət edir. Torpaq monitorinqi isə kənd təsərrüfatı məhsuldarlığının qorunması, torpaq deqradasiyasının qarşısının alınması və biomüxtəlifliyin saxlanılması baxımından əhəmiyyətlidir. Sensor texnologiyalarının tətbiqi zamanı yaranan əsas problemlərdən biri onların uzunmüddətli dəqiqliyinin qorunmasıdır. Temperatur, rütubət, çirklənmə və digər xarici amillər sensorların ölçmə nəticələrinə təsir göstərə bilər. Bu səbəbdən, sensorların mütəmadi kalibrlənməsi və ölçmə nəticələrinin korrektə edilməsi vacibdir. Dəqiqlik, presizlik, təkrarlanma və reproduksiya kimi göstəricilər sensor məlumatlarının etibarlılığını qiymətləndirmək üçün əsas meyarlar kimi çıxış edir. Bununla yanaşı, uzaq ərazilərdə yerləşən monitorinq stansiyalarından məlumatların ötürülməsi zamanı rabitə problemləri və enerji təminatı çətinlikləri yarana bilər. Bu cür problemlər real vaxt rejimində məlumat axınının fasilələrlə ötürülməsinə səbəb olur və monitorinqin effektivliyini azalda bilər. Bu baxımdan, uyğun rabitə texnologiyalarının seçilməsi və enerji mənbələrinin düzgün planlaşdırılması monitorinq sistemlərinin dayanıqlığını artıran mühüm amillərdir.

Ümumilikdə, mətn müasir sensor texnologiyalarının ətraf mühitin monitorinqində oynadığı rolu və bu sahədə mövcud problemləri əhatəli şəkildə təqdim edir. Müqayisəli təhlil əsasında müxtəlif sensor növlərinin üstün və zəif tərəfləri müəyyən edilir və onların tətbiq sahələri üzrə tövsiyələr irəli sürülür. Bu yanaşma optimal monitorinq modellərinin formalaşdırılması üçün elmi əsas yaradır və ekoloji idarəetmə proseslərinin səmərəliliyinin artırılmasına xidmət edir.

Аннотация

В современную эпоху охрана окружающей среды и обеспечение экологической безопасности считаются одними из приоритетных направлений в глобальном масштабе. Быстрая индустриализация, урбанизация и изменение климата оказывают серьёзное давление на природную среду, а отсутствие надлежащего контроля над этими процессами может привести к долгосрочным экологическим последствиям. В этой связи постоянный мониторинг и оценка состояния окружающей среды имеют большое значение. Системы экологического мониторинга обеспечивают оперативный сбор данных о состоянии воздуха, воды, почвы и живых организмов и способствуют принятию управленческих решений на научной основе.

Традиционные методы мониторинга, в основном основанные на лабораторных анализах, обладают ограниченными возможностями с точки зрения оперативности. Современные сенсорные технологии, напротив, позволяют осуществлять сбор и обработку данных в режиме реального времени. Эти технологии обеспечивают более быстрое выявление изменений в окружающей среде и раннее обнаружение экологических рисков. Применение сенсоров приводит

к автоматизации процессов измерения, снижает ошибки, обусловленные человеческим фактором, и повышает надёжность данных.

В основной части текста подробно рассматриваются ключевые направления экологического мониторинга, включая системы контроля качества воздуха, воды и почвы. При мониторинге воздуха измерение вредных газов и взвешенных частиц в атмосфере играет важную роль в оценке потенциальных рисков для здоровья человека. В мониторинге воды измерение физических, химических и биологических показателей обеспечивает безопасность источников питьевой воды и способствует сохранению водных экосистем. Мониторинг почвы имеет важное значение для поддержания сельскохозяйственной продуктивности, предотвращения деградации почв и сохранения биоразнообразия. Одной из основных проблем при применении сенсорных технологий является обеспечение их долговременной точности. Температура, влажность, загрязнение и другие внешние факторы могут влиять на результаты измерений сенсоров. Поэтому регулярная калибровка сенсоров и корректировка результатов измерений являются необходимыми. Такие показатели, как точность, прецизионность, повторяемость и воспроизводимость, выступают ключевыми критериями оценки надёжности сенсорных данных. Кроме того, при передаче данных с мониторинговых станций, расположенных в удалённых районах, могут возникать проблемы со связью и энергоснабжением. Подобные трудности приводят к перебоям в передаче данных в реальном времени и снижают эффективность мониторинга. В этом контексте выбор соответствующих коммуникационных технологий и грамотное планирование источников энергии являются важными факторами, повышающими устойчивость систем мониторинга.

В целом, текст всесторонне раскрывает роль современных сенсорных технологий в экологическом мониторинге и существующие в этой области проблемы. На основе сравнительного анализа выявляются преимущества и недостатки различных типов сенсоров, а также предлагаются рекомендации по областям их применения. Данный подход формирует научную основу для создания оптимальных моделей мониторинга и способствует повышению эффективности процессов экологического управления.

Keywords: *Environmental monitoring, sensor technologies, environmental safety, air quality, water quality, soil quality, data accuracy and reliability*

Açar sözlər: *Ətraf mühitin monitorinqi,* ***sensor texnologiyaları,*** *ekoloji təhlükəsizlik, hava keyfiyyəti, su keyfiyyəti, torpaq keyfiyyəti, məlumatların dəqiqliyi və etibarlılığı*

Ключевые слова: *Экологический мониторинг, сенсорные технологии, экологическая безопасность, качество воздуха, качество воды, качество почвы, точность и надёжность данных*

Introduction

In contemporary times, environmental protection and the assurance of ecological security have emerged as pivotal global priorities. Rapid industrialization, urbanization, and climate change exert profound impacts on the natural environment, necessitating advanced monitoring systems for the precise assessment of these processes. Environmental monitoring facilitates the continuous observation of ecological conditions, the early detection of potential hazards, and the formulation of management decisions based on scientific evidence. In recent years, advancements in sensor technologies have initiated a qualitatively new phase in this field. Various categories of sensors—designed to measure atmospheric, aquatic, soil, and biosphere parameters—enable real-time data collection and analysis. These technologies not only supersede traditional laboratory methods but also ensure the acquisition of data in a more prompt and reliable manner [1].

Currently, environmental monitoring systems based on diverse technological approaches are implemented in numerous countries worldwide. The strengths and weaknesses of each system vary depending on its intended purpose, geographical conditions, and economic capacities. Consequently, a comparative analysis of sensor technologies is of paramount importance for evaluating their effectiveness and identifying optimal application areas. Extant research demonstrates that appropriately selected sensor systems not only enhance the precision of ecological data but also ensure the agility of management processes. In this regard, the objective of the study is to conduct a comparative investigation into the characteristics of various sensor technologies and to determine their application potential in environmental monitoring.

In recent years, global climate change, the proliferation of industrial waste, and the degradation of ecosystems have exerted a profound impact on the state of the environment. Consequently, the precise tracking and analysis of ecological processes have become increasingly critical in the present day. Traditional monitoring methods often possess limited capabilities in terms of operational efficiency and data accuracy. In contrast, modern sensor technologies enhance the effectiveness of environmental oversight by enabling real-time data collection, processing, and analysis. These technologies facilitate the monitoring of environmental conditions at both local and global scales. A comparative analysis of sensor technologies establishes a significant scientific foundation for the formation of optimal monitoring models by identifying their respective strengths and weaknesses. This, in turn, serves to strengthen the scientific basis of decision-making processes in ecological management.

1. Research Objective and Significance

Environmental monitoring constitutes the observation and assessment of the state of natural resources and ecological characteristics, such as air, water, soil, and biodiversity. These monitoring systems collect and measure data to comprehend current environmental conditions, detect temporal changes, identify potential risks, and forecast future scenarios. For instance, a governmental agency may utilize environmental monitoring instruments to track water quality parameters in a river, including indicators such as temperature, acidity, and the presence of pollutants. Continuous monitoring facilitates the detection of abrupt escalations in pollutants—such as those resulting from industrial discharge—thereby enabling the resolution of issues and the mitigation of environmental damage.

2. Problem Statement and Related Work

Maintaining the long-term accuracy of sensors used in environmental monitoring against fluctuating factors such as temperature, humidity, and contamination remains a significant challenge. These variables can affect the calibration stability of sensors, thereby potentially diminishing the reliability of the results. In this context, the question of "which methods can stabilize sensor accuracy during long-term monitoring processes" persists as a crucial research inquiry. Furthermore, the continuous and reliable transmission of sensor data in remote areas with poor infrastructure is a pressing issue. Network interruptions and power constraints create gaps in data flow, bringing to the fore the question of "which communication technologies are more effective for ensuring the continuity of real-time monitoring." Additionally, to enhance data precision, the concept of reproducibility in sensor data will first be addressed. Sensor data reproducibility is utilized to evaluate the quality of data obtained from low-cost sensors. Air quality monitoring systems implemented for measuring pollutants in urban and industrial areas provide a range of advantages. These systems offer reliable solutions for policymakers and air quality researchers to bridge existing knowledge gaps.

3. Organization of Environmental Monitoring

Environmental monitoring assists organizations in gathering critical data that can be utilized to safeguard public health, preserve sensitive ecosystems, formulate ecological policies and regulations, and enhance operational efficiency. The benefits of environmental monitoring include the following [2]:

- *Detection of pollution levels;*
- *Preservation of the ecosystem;*
- *Disaster preparedness and risk management;*
- *Regulatory compliance;*
- *Operational efficiency.*

Organizations utilize various types of environmental monitoring to assess different aspects of the natural surroundings. Common types of environmental monitoring include:

- *Air quality monitoring;*
- *Water quality monitoring;*
- *Soil quality monitoring;*
- *Salinity monitoring;*
- *Biodiversity monitoring;*
- *Pollution monitoring.*

Let us examine the three most fundamental types of these environmental monitoring systems.

3.1. Air Quality Monitoring

Air monitoring measures pollutants such as ozone, particulate matter, sulfur dioxide, and nitrogen dioxide in the atmosphere. These pollutants can induce significant health issues in humans, including cardiovascular diseases and respiratory ailments. Furthermore, they contribute to the formation of acid rain, which can adversely affect sensitive ecosystems such as lakes and forests. Organizations frequently

monitor air quality by employing sensors to capture atmospheric samples. These samples are subsequently analyzed to determine the presence and concentration of pollutants, along with other meteorological factors such as temperature and humidity. Geographic Information System (GIS) models—computer systems that create interconnected visualizations of geospatial data—aid researchers in tracking air quality levels and pollutant concentrations within specific regions. GIS has the capability to display diverse data types, such as streets, buildings, and vegetation, on a single map. This enables stakeholders to visualize, analyze, and comprehend specific patterns and correlations more effectively (Figure 1).

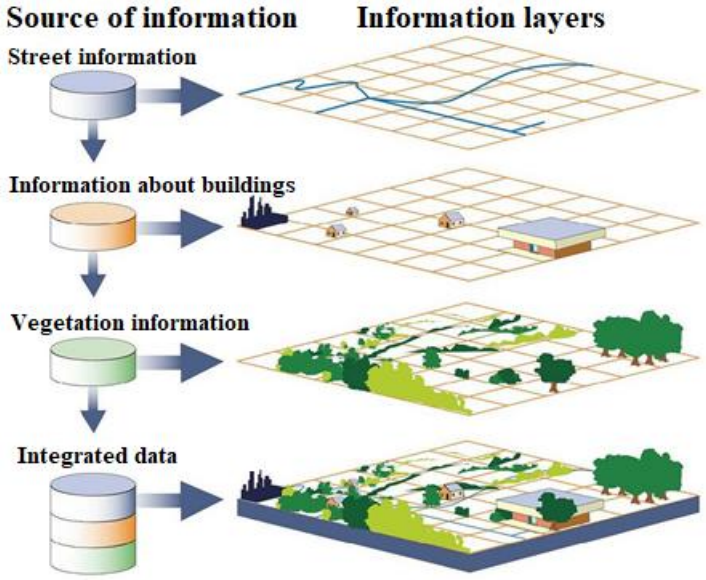

Figure 1. Geographic Information System (GIS) Models

3.2. Water Quality Monitoring

Water monitoring analyzes the physical, chemical, and biological properties of water to ensure its safety for both human consumption and aquatic ecosystems. Microbiological analysis and conductivity testing are considered core components of water monitoring. Microbiological analysis detects harmful microorganisms, such as viruses, bacteria, and fungi, within water supplies. Conductivity testing assesses the electrical conductivity of water, which serves as an indicator to identify the presence of pollutants such as industrial waste, sewage discharge, or agricultural runoff. Water quality sensors measure the chemical, physical, and biological characteristics of water. The following sensors play a pivotal role in determining whether water meets the required quality standards for its intended use [3]:

• ***Dissolved Oxygen (DO) Sensor:*** *These sensors measure the concentration of dissolved oxygen in water. This parameter is vital for aquatic ecosystems, as it directly influences the health of fish and other aquatic organisms. DO sensors are extensively utilized in environmental monitoring, wastewater treatment, and aquaculture (Figure 2).*

Figure 2. Dissolved Oxygen (DO) Sensor

• ***pH Sensor:*** *These sensors measure the acidity or alkalinity of water. The pH level is one of the fundamental parameters affecting chemical reactions in water and the behavior of pollutants (Figure 3).*

Figure 3. pH Sensor

3.3. Soil Quality Monitoring

Soil monitoring facilitates the identification of factors that pose threats to plant development, biodiversity, agriculture, and other ecosystem components. To comprehend soil quality, researchers observe and analyze variables such as soil texture, color, nutrient content, microbiological activity, and root health [4]. Each sensor type—Time Domain Transmissometry (TDT), Time Domain Reflectometry (TDR), and Watermark Sensors—possesses distinct advantages and limitations regarding accuracy, cost, ease of installation, and compatibility with various soil types, characterized by the following:

- *Time Domain Transmissometry (TDT) Sensors: These sensors utilize high-frequency signals to measure the travel time of a pulse through the soil, which serves to determine the soil's dielectric constant (Figure 4).*

Figure 4. Time Domain Transmissometry (TDT) Sensor

- *Time Domain Reflectometry (TDR) Sensors: TDR sensors operate similarly to TDT sensors: an electromagnetic pulse is transmitted along a probe, and the duration of its reflection from the soil is measured. This data enables the highly accurate determination of soil moisture levels.*
- *Watermark Sensors (Granular Matrix Sensors): These sensors determine soil water tension or matric potential by measuring changes in electrical resistance within the soil matrix.*

4. Provision of Sensor Technologies

To ensure the reproducibility of sensor data, a consensus is achieved through meticulous analysis of the device's performance. For instance, when exposed to a zero concentration of a target gas, the sensor must provide consistent readings across multiple measurements. Conducting these evaluations both in laboratory settings and at the deployment site ensures robust calibration and enhanced precision. From a scientific perspective, consensus is a critical parameter for data transmission, fostering a sense of reliability for both policymakers and the general public. In a broader context, this refers to the acceptance of a specific hypothesis by domain experts following extensive investigation. This concept assists in determining whether experiments conducted under diverse conditions yield similar results, thereby facilitating the elimination of errors stemming from subjective bias. Initially, air sensors may deviate from reference monitors by overestimating or underestimating pollutant concentrations due to their sensitivity to fluctuating environmental parameters such as temperature and relative humidity. However, the calibration process and the application of correction parameters mitigate these discrepancies, thereby improving data accuracy.

*As an introduction to the evaluation of sensor data, the parameters of **accuracy**, **precision**, **repeatability**, and **reproducibility** constitute the fundamental aspects for determining data reliability. These concepts will be elucidated within the specific context of air quality monitoring systems (Figure 5).*

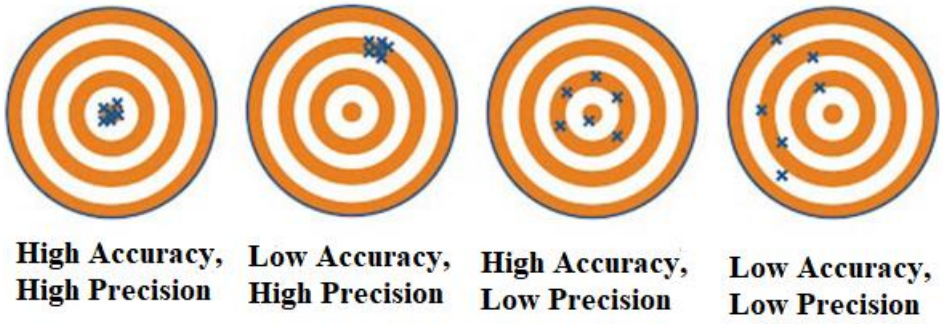

Figure 5. Concepts of Precision and Accuracy for Multiple Measurements

Precision *evaluates the deviations between consecutive sensor readings. The proximity of multiple measurements conducted under identical conditions determines the precision of the measurement. Precision tests do not account for the actual true value; that is, if a system consistently yields similar results, it possesses high precision.*

Accuracy *expresses how closely measurements align with the real or reference value. In other words, the lower the variance between the mean of the measurements and the true value, the higher the accuracy. For instance, in an environment with 4000 ppb SO_2, a reading of 4002 ppb is considered more accurate than 4300 ppb.*

Reproducibility *is often used synonymously with* ***repeatability****; however, subtle distinctions exist in their definitions. When calculating the repeatability coefficient, factors that should not influence measurements—such as the device or location—must remain constant. Conversely, for reproducibility, results must remain consistent even when measurements are conducted under diverse external conditions.*

Repeatability *indicates the proximity between two independent test results obtained under the same conditions. According to scientific literature, the Normalized Root Mean Square Error (NRMSE) value is utilized for the quantitative assessment of repeatability.*

Reproducibility *is a parameter used for the verification of measurements. It determines the sensor's ability to consistently repeat multiple measurements under varying conditions. Utilizing several identical units provides a more reliable indication of the level of reproducibility. The accuracy of sensors can be more precisely evaluated by calculating the standard deviation of multiple tests. The ISO 5725 standard further emphasizes the applicability of these methods for enhancing data reliability.*

One of the most critical strategies for ***maintaining sensor performance*** *is selecting the correct sensor for the specific application. Different sensors possess diverse characteristics, such as sensitivity, range, resolution, linearity, response time, and robustness. These attributes determine how accurately the sensor can measure a given variable and how it withstands environmental changes. Therefore, sensor selection must align with the requirements of the control system and the anticipated environmental conditions. For example, if temperature measurement is required in harsh conditions, using a thermocouple rather than a thermistor is more appropriate, as thermocouples are more resistant to high temperatures and physical damage.*

Another strategy for ***maintaining sensor performance*** *is the regular* ***calibration*** *of the sensor. Calibration is the process of comparing the sensor output with a known standard to eliminate any errors or deviations. Calibration enhances the accuracy and consistency of sensor measurements while mitigating the effects of drift, aging, and wear. Depending on the sensor type and the design of the control system, calibration can be performed manually or automatically. For instance, some sensors feature internal calibration functions that can be activated via a signal or command, while others require manual intervention and adjustment. The third strategy for* ***maintaining sensor performance*** *is* ***compensating for environmental factors*** *that influence sensor output. Compensation is the process of correcting or adjusting the sensor output based on the measurement or estimation of environmental factors. Compensation reduces errors and uncertainties in sensor measurements and enhances the quality of feedback. For example, some sensors possess internal compensation circuits that adjust output based on temperature and pressure changes, while others rely on external compensation algorithms that estimate environmental factors through additional sensors or models.*

The fourth strategy for ***maintaining sensor performance*** *is* ***filtering*** *the sensor output to reduce or eliminate noise and interference. Noise and interference are unwanted signals that distort the sensor output and affect control system performance. These can originate from various sources, such as electrical devices, mechanical vibrations, or radio waves. Filtering is the process of removing or*

attenuating noise and interference components through mathematical operations or devices applied to the sensor output. Filtering increases the signal-to-noise ratio and measurement clarity, preventing false feedback. Filtering can be performed in either analog or digital forms.

Conclusion

Monitoring the environment in accordance with modern requirements is one of the fundamental conditions for ensuring environmental safety. The application of sensor technologies enables more accurate and onepamuвe tracking of ecological processes and facilitates the early identification of environmental risks. This allows decisions related to environmental protection to be made in a timely and well-substantiated manner. Modern sensor systems not only complement traditional laboratory methods but, in many cases, also replace them. The acquisition of real-time data enables the rapid identification of pollution sources, more flexible responses to emergency situations, and the formation of a more comprehensive understanding of the state of the environment. This, in turn, enhances the effectiveness of the activities of management structures and relevant institutions.

On the other hand, issues related to data transmission and storage also have a direct impact on the efficiency of monitoring systems. Particularly in remote areas with weak infrastructure, interruptions in data transmission can disrupt the continuity of the monitoring process. To address these challenges, the selection of appropriate communication technologies and the use of alternative energy sources are of great importance. The use of statistical indicators and international standards in the analysis of sensor data increases the reliability of results. Taking into account concepts such as accuracy, precision, repeatability, and reproducibility facilitates the development of scientifically grounded monitoring models. This approach forms a reliable data base for both researchers and decision-making bodies.

Overall, the comparative analysis of sensor technologies enables the development of more efficient and sustainable systems in the field of environmental monitoring. The proper application of these technologies makes a significant contribution to strengthening environmental safety, protecting natural resources, and achieving sustainable development goals.

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