ACTUAL PROBLEMS OF MODERN SCIENCE, EDUCATION AND TRAINING

KHOREZMSCIENCE.UZ

CONTENTS

UDC: 82(575.1)-1

ERKIN VOHIDOV READINGS: THE CREATOR'S INNER WORLD AND CONTEMPORARY LITERARY THOUGHT

Samandarova Lola Sultanovna
Senior Lecturer (PhD), Alfraganus University
Lolaxonsamandarova1971@gmail.com

Saitqulova Muqaddas Anorboy Kizi
Master's Student, Alfraganus University
SaitqulovaM2001@gmail.com

Annotastiya. Ushbu maqolada o'zbek adabiyotining yirik vakili Erkin Vohidovning jamiyatdagi o'rni va ma'naviy merosi tahlil qilinadi. Shoirning ijodida vatanparvarlik, milliy o'zlik, ma'naviyat, insonparvarlik kabi g'oyalar ustuvor o'rin egallagani yoritiladi. Shuningdek, uning ma'rifiy faoliyati, tarjimachilikdagi hissasi, jamiyat taraqqiyotidagi o'rni hamda "O'zbegim" she'rining milliy ruhni mustahkamlashdagi ahamiyati ko'rib chiqiladi. Maqolada shoirning badiiy mahorati, falsafiy qarashlari va yosh avlod tarbiyasidagi o'rni haqida ham fikr yuritiladi.

Kalit so'zlar: *Erkin Vohidov, ijod, ma'naviy meros, vatanparvarlik, milliy qadriyatlar, ma'rifat, "O'zbegim".*

Аннотация. В данной статье рассматривается роль и духовное наследие крупного представителя узбекской литературы ЭркинаВохидова. Анализируются его патриотические, национальные и гуманистические идеи, отражённые в поэзии и общественной деятельности. Особое внимание уделено значению стихотворения "O'zbegim" в формировании национального самосознания, а также вкладу поэта в культурное развитие, переводческую деятельность и воспитание молодёжи.

Ключевые слова: *Эркин Вохидов, творчество, духовное наследие, патриотизм, национальные ценности, просвещение, "O'zbegim."*

Abstract. This article explores the societal role and spiritual legacy of Erkin Vohidov, a prominent figure in Uzbek literature. It highlights the poet's emphasis on patriotism, national identity, moral values, and humanism throughout his works. The significance of his famous poem "O'zbegim" in strengthening national consciousness is discussed, along with his contributions to cultural development, translation, and the moral education of youth. The article also examines poet's artistic mastery and the philosophical depth reflected in his poetry.

Keywords: *Erkin Vohidov, literary heritage, patriotism, national identity, spirituality, education, "O'zbegim."*

Introduction

Erkin Vohidov is one of the most prominent representatives in Uzbek literature, whose creative legacy has had a profound impact not only on the development of poetry but also on the spiritual and moral advancement of society [1]. His literary works, public speeches, and social activities played a significant role in enriching the national identity, history, spirituality, and intellectual worldview of the Uzbek people. This article provides a detailed discussion of Erkin Vohidov's role in society, the importance of his spiritual legacy, and its relevance in the contemporary period [2, 3].

Literature Review

Through literature, Erkin Vohidov emerged as a figure who offered moral and spiritual guidance to people. His poetry exerted a significant influence on the ethical and spiritual upbringing of society. National values, patriotism, honesty, and humanism occupy a central place in his poems, serving as a source of spiritual support for many readers [1-3].

The sincerity and authenticity of the poet's creativity encourage society toward purity, justice, and self-awareness. He was not merely a poet but also an enlightened intellectual who contributed significantly to shaping the moral image of society.

At the same time, Erkin Vohidov was a creator who responded courageously to the painful issues of his era. In his works, he boldly addressed socio-political problems of the time, including the individual's place in society, justice, moral crisis, and youth education. His poems are often perceived as an artistic response to the people's voice, pain, and suffering [4, 5].

Erkin Vohidov can also be regarded as a reform-minded individual actively involved in cultural life. He served as a member of parliament, headed various cultural commissions, and worked as a socially active public figure devoted to national development. His speeches, articles, and reflections contributed to strengthening moral approaches in state and social life [6-8].

The poet consistently advocated for the priority of spirituality in social life, youth enlightenment, and the preservation of national identity, conveying his position to the broader public.

Research Methodology

This study employs a qualitative, interdisciplinary research design to analyze the societal role and spiritual legacy of Erkin Vohidov. The methodology is grounded in literary analysis and socio-cultural hermeneutics, aiming to provide a comprehensive understanding of the poet's work as both an aesthetic and a social phenomenon.

Analysis and Results

Erkin Vohidov may rightfully be called a herald of national values. His poems are rich in national spirit, folk wisdom, and historical memory. His famous poem "O'zbegim" remains a powerful artistic expression glorifying national identity, pride, and history. "O'zbegim" is one of Erkin Vohidov's most renowned patriotic works [2, 3]. The poem was created to honor the Uzbek people's arduous historical path, their loyalty to national identity, and their love and respect for the Motherland.

Through this poem, the poet praises the strength, resilience, patience, and purity of the Uzbek people's spirit. At its core lies the love for the nation and the homeland. The poem vividly portrays the ancient history of the Uzbek nation, its courage and endurance, self-awareness, national pride, and dignity through expressive artistic means.

The poem consists of several lyrical sections, each sequentially depicting historical memory, the ancient past of the Uzbek people, the spirit of the modern era, the people's wisdom, diligence, honor, confidence in the future, and bright prospects. The lyrical protagonist embodies an Uzbek individual who deeply loves the homeland and takes pride in national identity, describing the people's patience, diligence, courage, and spiritual richness through an elevated emotional tone.

The poet skillfully employed artistic devices in his poetry. The Uzbek people are compared to powerful images such as "You are a river" and "You are a mountain," illustrating national strength through simile. Expressions like "Your sorrow does not fit into the heart" present collective pain as a living image, demonstrating effective use of metaphor. The repeated use of the word "O'zbegim" throughout the poem reinforces national pride [5-7].

Several key ideas are advanced in the poem, including national pride, unity, and solidarity. The poet glorifies the dignity, honor, and greatness of the Uzbek people, emphasizing shared historical roots that unite the nation. The poem also stresses that honoring the homeland is sacred and that preserving national identity and respecting history is the duty of every individual.

Regarding its historical and spiritual significance, "O'zbegim" is considered one of the strongest patriotic poems in 20th century Uzbek literature. Although written before independence, it artistically reflects the people's aspiration for freedom. In the post-independence period, it has been valued as one of the symbols of national awakening.

The poem has reached the level of a national anthem in artistic expression. "O'zbegim" is not merely a poem but an embodiment of the people's spirit, self-awareness, national pride, and faith in a bright future.

Through his creative work, Erkin Vohidov made a significant contribution to fostering love for the Motherland, preserving national heritage, and building self-confidence among the younger generation.

Philosophical reflection and spiritual depth are clearly evident in the poet's works. One of the defining characteristics of his poetry is its profound philosophical outlook on humanity and society. Themes such as the meaning of life, the nature of time and era, the inner world of the individual, and the struggle between good and evil are widely explored. These aspects make his legacy valuable not only as literature but also as a philosophical and educational source.

Erkin Vohidov also created a spiritual bridge through translation. By translating works of world literature's great figures such as Shakespeare, Pushkin, and Lermontov into Uzbek, he enriched national literature and expanded the intellectual horizon of Uzbek readers [4].

The poet's poems, epics, and plays continue to serve as moral lessons for today's youth. His characters and ideas promote honesty, loyalty, diligence, and ethical

conduct. Erkin Vohidov's creativity encourages readers to think deeply, appreciate literature, and develop self-awareness.

Erkin Vohidov's role in society and his spiritual legacy hold an unparalleled place in the history of Uzbek literature. Throughout his life, he remained faithful to the noblest ideals of nation, homeland, and humanity. His legacy continues to play an essential role in the moral development of society.

Erkin Vohidov's creative heritage represents a school of spirituality, a lesson in national identity, and an artistic embodiment of human values. Studying, preserving, and passing on this legacy to future generations is our shared responsibility.

Conclusion

Erkin Vohidov is one of the most distinguished figures in Uzbek literature, whose creativity is valued not only for its artistic excellence but also for its immense contribution to the spiritual development of society. Through his works, the poet promoted national identity, patriotism, humanism, honesty, and moral purity. His poem "O'zbegim" stands as an immortal artistic work that powerfully expresses the pride, history, and spirit of the Uzbek people.

Vohidov's translation activity served as a strong bridge connecting national literature with world literature. Through his social engagement, educational initiatives, and active position in public life, he became one of the leading promoters of spirituality.

Therefore, Erkin Vohidov's legacy has not lost its relevance today; on the contrary, it continues to play a vital role in educating the younger generation, shaping national consciousness, and fostering spiritual growth. Studying the poet's works means understanding not only literature but also the people's spirit, historical memory, and moral strength. His works remain an invaluable heritage for future generations.

References:

[1] Abdurahmonova S. "Erkin Vohidov's views on spirituality," *Ma'naviyat va Ma'rifat*, № 1, 2020.
[2] Vohidov E. "Uzbegim," Tashkent: *Gafur Gulom Publishing House of Literature and Art*. 2017.
[3] Qodirov B. "Modern Uzbek Poetry: Analysis and Interpretation," Tashkent: *Akadem nashr*. 2018.
[4] Rustamov O. "The school of translation and Erkin Vohidov's translation activity," *Til va Adabiyot*, № 4, 2021.
[5] Sharipov A. "Patriotic motifs in the works of Erkin Vohidov," *Journal of Literary Studies (Adabiyotshunoslik)*, № 3, 2019.
[6] Vohidov E. "Poems and Epics," Tashkent: *Yozuvchi Publishing House*, 2000.
[7] Yuldoshev Q. "Uzbek Literary Criticism," Tashkent: *Fan Publishing House*, 2010.
[8] Administration of the President of the Republic of Uzbekistan "A collection of materials dedicated to the life and creative activity of Erkin Vohidov," *Tashkent*, 2016.

UDC: 81, 37-37.022

CHALLENGES AND INNOVATIONS IN ENGLISH LANGUAGE TEACHING IN UZBEKISTAN

Alimova Nozima Rajabboyevna
Associate Professor (PhD), Department of Uzbek and Foreign Languages, Bukhara State Technical University
noza.bestfuture@gmail.com
With the review of Professor (DSc), Bukhara State University Akhmedova Mehrinigor Bahodirovna

Annotatsiya. O‘zbekistonda ingliz tili ta’limini modernizatsiya qilish globallashuv va texnologik rivojlanish tufayli milliy ustuvor vazifa hisoblanadi. Ushbu maqolada o‘qitish sifatini va o‘quv natijalarini yaxshilashga qaratilgan asosiy muammolar tahlil qilinadi hamda innovatsion usullar, xususan, Fan va tilni integratsiyalashgan holda o‘qitish (Content and Language Integrated Learning, CLIL) o‘rganiladi. Tizimli islohotlarga qaramasdan, o‘qituvchilarning yetarlicha tayyorlanmaganligi, autentik materiallar va resurslarga cheklangan kirish hamda texnologik infratuzilmaning notekisligi sababli ta’lim samaradorligi pastligicha qolmoqda. Yangi o‘quv dasturlari joriy etilgan bo‘lsa-da, ko‘pgina o‘qituvchilar kommunikativ kompetensiyadan ko‘ra grammatik aniqlikka ustunlik berishni davom ettirmoqda. CLIL metodologiyasini joriy etishda til jihatdan malakali predmet o‘qituvchilarining va ingliz tili o‘qituvchilarining mutaxassislik bo‘yicha bilimining yetishmasligi kabi o‘ziga xos qiyinchiliklarga duch kelinmoqda. Biroq, o‘qituvchilarning malakasini oshirish dasturlari va oliy ta’lim muassasalarida sinov tariqasida CLIL asosidagi kurslarning yo‘lga qo‘yilishi, bu yondashuv til o‘rganishni kasbiy ta’lim bilan integratsiyalashuviga qaratilgan muhim qadam ekanligini ko‘rsatadi. O‘zbekistonda ingliz tili ta’limining muvaffaqiyatli kelajagi innovatsiyalar va mahalliy sharoitga amaliy moslashuv o‘rtasidagi muvozanatga bog‘liqdir.

Kalit so‘zlar: *ingliz tili o‘qitish, CLIL metodologiyasi, Fan va tilni integratsiyalashgan holda o‘qitish, ta’lim islohotlari, o‘qituvchilarni tayyorlash, kommunikativ kompetensiya, O‘zbekiston, raqamli texnologiyalar.*

Аннотация. Модернизация преподавания английского языка в Узбекистане является национальным приоритетом, обусловленным глобализацией и технологическим развитием. В данной статье анализируются ключевые проблемы и исследуются инновационные методы, в частности Предметно-языковое интегрированное обучение (Content and Language Integrated Learning, CLIL), направленные на повышение качества преподавания и результатов обучения. Несмотря на системные реформы, эффективность обучения по-прежнему сдерживается недостаточной подготовкой преподавателей, ограниченным доступом к аутентичным материалам и неравномерной технологической инфраструктурой. Хотя были введены новые учебные планы, многие преподаватели продолжают отдавать

предпочтение грамматической точности, а не коммуникативной компетенции. Внедрение CLIL сталкивается с особыми трудностями, включая нехватку лингвистически компетентных предметных преподавателей и предметной подготовки у преподавателей английского языка. Тем не менее, такие инициативы, как программы повышения квалификации и пилотные CLIL-курсы в вузах, демонстрируют, что данный подход является важным шагом к интеграции языкового обучения с профессиональным образованием. Успешное будущее обучения английскому языку в Узбекистане зависит от баланса инноваций и практической адаптации к местному контексту.

Ключевые слова: *преподавание английского языка, методология CLIL, предметно-языковое интегрированное обучение, образовательные реформы, подготовка преподавателей, коммуникативная компетенция, Узбекистан, цифровые технологии.*

Abstract. The modernization of English language education in Uzbekistan is a national priority driven by globalization and technological development. This article analyzes the key challenges and explores innovative methods, particularly Content and Language Integrated Learning (CLIL), aimed at enhancing teaching quality and learning outcomes. Despite systemic reforms, the effectiveness of instruction is hindered by insufficient teacher preparation, limited access to authentic materials and resources, and uneven technological infrastructure. While new syllabi have been introduced, many teachers still prioritize grammatical accuracy over communicative competence. The implementation of CLIL faces specific difficulties, including the lack of linguistically competent subject teachers and subject-matter expertise among English teachers. However, initiatives such as teacher training programs and pilot CLIL-based courses in universities demonstrate that this approach is a major step toward integrating language learning with professional education. The successful future of English language education in Uzbekistan depends on balancing innovation with practical adaptation to the local context.

Keywords: *English language teaching, CLIL methodology, Content and Language Integrated Learning, educational reforms, teacher preparation, communicative competence, Uzbekistan, digital technologies.*

Introduction

In the context of globalization and rapid technological development, the role of English language education in Uzbekistan has become increasingly significant. As English continues to dominate international communication, science, and business, the ability to use it effectively is viewed as a crucial skill for students across all academic fields. Since gaining independence, Uzbekistan has undertaken a number of reforms to improve foreign language education, aiming to align it with international standards. The introduction of modern teaching methods, communicative approaches, and digital technologies has transformed the traditional structure of language instruction. However, despite these advancements, many challenges remain. Insufficient teacher preparation, limited access to resources, and low student motivation continue to hinder

the effectiveness of English language education, particularly in regional institutions. Therefore, this article aims to analyze the key problems currently faced in English language teaching in Uzbekistan and to explore innovative methods and technologies that can enhance teaching quality and learning outcomes in this evolving educational landscape.

Literature Review

Researchers emphasize the multidimensional nature of the process, which combines linguistic, methodological, and sociocultural factors. Modern linguists, including H. Douglas Brown, Jack C. Richards, and David Nunan, interpret language teaching not as a mechanical transfer of knowledge but as a dynamic system of interaction between teacher, learner, and context. In this regard, the effectiveness of foreign language instruction is closely linked to the methodological principles applied, the cultural environment, and the technological development of educational institutions.

The system of English language education in Uzbekistan can be analyzed through several interrelated components.

1. Pedagogical foundation – traditional grammar-translation and audio-lingual methods that still dominate classroom practice, particularly in regional schools.
2. Communicative transformation – the gradual introduction of communicative and competence-based methods, reflecting a global shift toward learner-centered education.
3. Institutional structure – the state policy of foreign-language reform, the Presidential Decree of 2012, and curriculum modernization at all levels of education.
4. Technological dimension – the integration of digital resources, multimedia lessons, and online learning platforms, which expand opportunities for self-study and blended learning.
5. Human resources – the professional competence of teachers, which remains a decisive factor in ensuring the quality of instruction.

Each of these components reveals both achievements and unresolved issues. For instance, while new syllabi and communicative frameworks have been introduced, many teachers continue to prioritize grammatical accuracy over communicative competence. Limited access to authentic materials and uneven technological infrastructure further slowdown progress. In this context, recent innovations such as the CLIL methodology have gained particular importance, as they integrate language learning with subject content and contribute to the professionalization of English language education in Uzbekistan.

Theoretical background. Among the famous scientists who paid special attention to this issue are such researchers as Theun van Dijk, Martin Montgomery, Alan Bell, Norman Feuerklaff, and Robert Fowler, who analyzed mass media texts from the point of view of various scientific schools and approaches. These include determining the functional-stylistic status of the language of the media, methods for describing various types of media texts, the influence of sociocultural factors on media speech, and the study of technologies of linguo-media influence.

Dobrosklonskaya T.G. notes that media texts or media texts (Latin media textus – “means, intermediaries,” “fabric, wrapping”) are one of the most widespread forms of language today; their total volume far exceeds the volume of speech in other areas of human activity [5].

The scientist distinguishes between the concepts of “text,” “mediatext,” and “media discourse.” In his opinion, “text is the message, mediatext is the message and the channel, and media discourse is the message and all other components of communication” [4].

The concept of media text is based on the harmonious unity of verbal and media layer units. This feature, which is characteristic of mass information texts, is especially emphasized by English authors. They describe media text as a set of verbal and media signs. For example, Alan Bell, a well-known scholar studying the language of the media, in his work “Approaches to Media Discourse,” emphasizes that “the definition of media text is much broader than the traditional concept of text, that is, a sequence of words written or printed on paper. The concept of media text is even broader. It also includes sound features, music, sound effects, and visual images. That is, media texts reflect the technologies used to create and distribute them in practice” [1, 3].

Analysis and Results

The introduction of modern methods such as CLIL into the English language teaching system of Uzbekistan reflects the country’s efforts to modernize education and meet international standards. However, despite its growing popularity, the implementation of CLIL in Uzbek universities and schools faces several interconnected challenges. One of the main difficulties lies in the insufficient preparation of teachers. Many instructors possess strong subject knowledge but lack the linguistic competence required to teach in English, while English language teachers often do not have sufficient background in specialized fields such as engineering, medicine, or economics. This imbalance creates barriers to effective content and language integration.

Another major issue concerns the lack of appropriate teaching materials. Most textbooks currently used in Uzbek higher education are designed for either general English or for separate subject instruction in Uzbek or Russian. Consequently, there is a shortage of CLIL-based materials that combine language and subject content at suitable proficiency levels. This problem often forces teachers to adapt existing resources independently, which demands time, creativity, and institutional support.

Technological and infrastructural limitations also hinder the full application of CLIL. In many regional universities, access to digital tools, online platforms, and multimedia equipment remains limited. These tools are essential for implementing interactive, student-centered CLIL lessons that promote collaboration and real-world communication. Additionally, large class sizes and traditional assessment systems further complicate the process of monitoring both language and content mastery.

Despite these challenges, innovative solutions are gradually being introduced. Teacher training programs supported by the British Council and national education reforms now include modules on integrated learning and bilingual instruction. Some universities, such as Tashkent State Pedagogical University and Bukhara State

Technical University, have piloted CLIL-based courses combining English with subjects like information technology and environmental studies. These initiatives demonstrate that, with proper training and resources, the CLIL approach can significantly enhance learners' motivation, critical thinking, and professional readiness.

Conclusion

The study of problems and innovations in English language teaching in Uzbekistan demonstrates that the modernization of this field is both a national priority and a complex process requiring systemic support. The adoption of the CLIL approach represents a major step toward integrating language learning with professional education, allowing students to develop communicative competence through meaningful and discipline-specific content. However, its successful implementation depends on several crucial factors, including well-trained teachers, access to appropriate materials, and sufficient technological infrastructure.

While many challenges persist—such as uneven resource distribution, limited teacher expertise, and inadequate assessment frameworks—recent reforms show positive trends. Continuous professional development programs, cooperation with international institutions, and the gradual digitalization of higher education all contribute to improving teaching quality. The future of English language education in Uzbekistan lies in balancing innovation with practicality: ensuring that modern methods like CLIL are not just introduced but effectively adapted to the local context. Ultimately, the integration of innovative approaches and sustained institutional support will strengthen the role of English as a vital tool for academic and professional advancement in the country.

References:

[1] Rahmanova G., and Ekşi G.Y. "English-Medium Instruction in Higher Education in Uzbekistan: Views on Effectiveness, Career Prospects and Challenges." *World Journal of English Language*, vol. 13, № 5, 2023, p. 458.

[2] Avezova R.A. "The Implementation and Impact of Content and Language Integrated Learning (CLIL) in Secondary Education." *Journal of International Scientific Research*, vol. 2, № 9, 2025.

[3] Tashmatova G.R. "Challenges of Implementing CLIL (Content and Language Integrated Learning)." *WOS*, vol. 3, № 3, 2022.

[4] Orifjonova M.S. "The Role of CLIL in Enhancing English Proficiency in STEAM Subjects among Uzbek Students." *Ta'limning Zamonaviy Transformatsiyasi*, vol. 20, № 1, 2025.

[5] Muradulloyeva S.S. "Possibilities of Using the CLIL Methodology in English Lessons." *Journal of Multidisciplinary Sciences and Innovations*, vol. 4, № 4, 2025, pp. 811–813.

[6] Kuralov K. "The Peculiarities of CLIL in Teaching English." *Mental Enlightenment Scientific–Methodological Journal*, vol. 5, № 8, 2024, pp. 191–198.

[7] Rskhulova D.A. "Uzbek Primary School Students' Reaction towards the Use of CLIL Methodology in Art Classes." *Web of Scientists and Scholars: Journal of Multidisciplinary Research*, vol. 2, № 3, 2024, pp. 10–19.

[8] Yuldasheva M. "The Implementation of CLIL Approach in ESP Courses in Higher Education of Uzbekistan." *Zenodo*, 2024.

[9] Zuparova S.S. "CLIL Methodology of Teaching English in the Field of Professional Communication." *Web of Journals*, vol. 1, № 7, Oct. 2023.

[10] Tasheva Z.D. “Adapting CLIL for Uzbek Secondary Schools: Pedagogical Opportunities and Institutional Challenges.” *Multidisciplinary Journal of Science and Technology*, vol. 5, № 6, 2025, pp. 1772–1775.

UDC: 81, 37, 37.01/09,61

DESIGNING ACMELINGUISTIC COMPETENCE OF MEDICAL UNIVERSITY STUDENTS

Dzugaeva Zarina Ruslanovna
Associate Professor (PhD), Department of English languages, Treatment faculty, Urgench State Medical Institute
bon_lorange@mail.ru

Annotatsiya. Ushbu tadqiqot kelajakdagi sog‘liqni saqlash mutaxassislari orasida akmelingvistik kompetensiya va ingliz tilini o‘rganish jarayonini o‘rganadi. E’tibor inson va talaba markazlashgan yondashuvga qaratilgan bo‘lib, bu mustaqil o‘qish, o‘zini rivojlantirish va kasbiy kommunikatsiya ko‘nikmalarini shakllantirishga yordam beradi. Solishtirma tahlil, pedagogik kuzatuv va sotsiometrik usullar qo‘llanilgan holda tadqiqot zamonaviy ta’lim texnologiyalari va neyrolingvistik dasturlashning o‘quv natijalarini yaxshilashdagi rolini ta’kidlaydi.

Kalit so‘zlar: *malaka, tibbiyot, nutq, dasturlash, shifokor, formula, tadqiqot.*

Аннотация. В исследовании рассматривается развитие акмелингвистической компетенции и владения английским языком у будущих специалистов в области здравоохранения. Особое внимание уделяется человеко- и студентоцентрированному подходу, который способствует самостоятельному обучению, самосовершенствованию и развитию профессиональных коммуникативных навыков. С использованием методов сравнительного анализа, педагогического наблюдения и социометрических техник исследование подчеркивает роль современных образовательных технологий и нейролингвистического программирования в повышении результатов обучения.

Ключевые слова*: квалификация, медицина, речь, программирование, врач, формула, исследование.*

Abstract. This study examines the development of acmelinguistic competence and English-language proficiency among future healthcare professionals. It emphasizes a human-centered, student-focused approach that fosters independent learning, self-development, and professional communication skills. Using methods such as comparative analysis, pedagogical observation, and sociometric techniques, the research highlights the role of modern instructional technologies and neurolinguistic programming in enhancing learning outcomes.

Keywords: *qualification, medicine, speech, programming, doctor, formula, research.*

Introduction

In educational and research institutions worldwide, studies are being carried out to introduce advanced scientific and ethical standards, promote the involvement of healthcare professionals in biomedical research, and define human health through scientific inquiry that takes socio-psychological factors into account. These efforts also include enhancing English-language competency technologies used for therapeutic communication with patients. At the same time, considerable attention is devoted to research aimed at the continuous professional development of medical personnel, the training of specialists with a scientific mindset who can communicate confidently in English, and the advancement of technologies for creating psycholinguistic models that connect the needs of medical professional education with public health protection and speech practices, as well as strengthening acmelinguistic competence.

Research Methodology

In contemporary foreign-language education, several key factors play a foundational role. These include:

- developing practical proficiency in a foreign language so that it functions as a secondary tool for addressing tasks and communication needs within one's professional sphere;
- fostering in future medical university students the ability to work independently and maintain their language skills after completing their studies.

Today's system of professional training is marked by a human-centered approach—one that focuses not on transforming the external environment, but on cultivating the individual and their inner potential. This defines the primary direction for the development of higher education programs: a student-centered framework, which places the learner's personality at the forefront, and an acme-oriented approach, which aims to intentionally shape the motives and goals of learning within the core areas of professional skill development. The study employed several research methods, including comparative and critical analysis, pedagogical observation, and sociometric techniques such as interviews, questionnaires, tests, and guided conversations.

Analysis and Results

Modern instructional technology is built on a fundamental principle: knowledge comes first, and only then the ability to apply it. This principle stems from the logical structure of science, which serves as a transformative force within educational technologies that stimulate students' cognitive motivation. Through this process, the student moves from being an object of instruction to becoming an active subject of learning, and eventually develops their own strategies for self-growth and self-improvement. Such an approach to preparing future specialists for foreign-language proficiency is essential for ensuring the quality of their training—enabling them to acquire both professional knowledge and the linguistic competencies that support continuous self-development and personal advancement. It is *acmelinguistics* that

makes this possible. The aim of acmelinguistics is to foster personal qualities, help learners acquire new professional skills, refine them, and adapt them effectively.

The roots of the concept of acmelinguistics can be traced back to ancient times. In the Greek educational system, it was understood as "the path to mastery through imitation of the teacher." In the modern context, this idea has evolved into a complex model that includes predictable, measurable learning outcomes, diverse instructional structures, and fair, well-defined assessment criteria. Guided by the principles of acme-ethics, education emphasizes the development of spiritual and moral foundations as the basis of a physician's personal and professional formation. Acmelinguistic training, in turn, enables learners to fully absorb—and later apply in practice—the skills necessary for self-development, self-improvement, independence, and effective decision-making under stress. The significance of the study's findings lies in identifying the issues of technical neurolinguistic programming within the context of enhancing acmelinguistic competence training. This was achieved by enriching the theoretical and methodological foundations of the research. As a result, a basis was established for determining the structural correspondences between the Russian and English languages—an essential step for the further development of students' communicative competence, taking into account the specific requirements of their future professional activities.

Conclusion

The practical value of the study lies in the fact that, taking into account the use of technical NLP methods, it proposes tools for teaching English, including structural formats, methods, and techniques. A special seminar titled *"Verbal Communication as the Foundation for Enhancing Acmelinguistic Competence in Future Physicians"* was developed, incorporating a system of exercises aimed at organizing speech activity in accordance with educational situations and instructional methods. This approach is expected to stimulate improvements in the quality of language instruction, enhance students' perceptual, visual, and kinesthetic abilities, and support the development of new cognitive strategies for learning English among students in higher medical education institutions.

References:

[1] Eremin Yu.V. "Fundamentals of professional and communicative training of a foreign language teacher," S-P.: *Publishing house of the RSPU im. A.I. Herzen*, 2001, p.180.

[2] Zimnyaya I.A. "Key competences - a new paradigm of the result of modern education," Electronic resource, *Internet-journal "Eidos,"* May 5, 2006. http://www.eidos.ru/ journal / 2006 / 0505.htm.

[3] Narbaevna S.D. "Scientific medical text in the medical paradigm linguistics," PhD dissertation, *Uzbekistan*, 2022, p. 180.

[4] Lapkin M.M. "Study of the psychological determinants of the success of medical students' education," *Moscow*, 2014, p. 17.

[5] Mironov G.V. "The concept of acmeological development of personality in early adolescence," doctoral dissertation in psychology. *Tashkent*, 2012, p. 43.

[6] Levin V.A. "Educational environment: from modeling to design," *M.*: *TsKFL RAO*, 1997, p. 24.

[7] Nekrasova N.A. "The problem of professionalism in psychology, acmeology and in practice," *Moscow*, 2015, p. 52.

UDC: 811.111’27

A COMPREHENSIVE REVIEW ON ENGLISH LEXICOGRAPHY OF PAREMIOLOGICAL UNITS

Khudaybergenova Gulbakhor Shukhrat Kizi
Doctorate Student, Department of Roman-German Philology, Urgench State University named after Abu Rayhan Biruni
gulbaxorxudaybergenova97@gmail.com

Annotatsiya. Mazkur adabiyotlar sharhi ingliz leksikografiyasi sohasida, xususan, paremiologik birliklarni o‘rganish borasidagi so‘nggi yutuqlarni tahlil qiladi. So‘nggi o‘n yil davomida olib borilgan tadqiqotlar ingliz tilidagi maqol va matallarning hujjatlashtirilishi, tahlili hamda talqiniga doir nazariy va amaliy yondashuvlar bo‘yicha muhim ilmiy xulosalarni taqdim etadi. Ushbu sharh empirik tadqiqotlarning asosiy natijalarini umumlashtiradi, sifat va miqdoriy tadqiqot usullariga asoslangan metodologik yangiliklarni baholaydi hamda hozirgi ilmiy adabiyotlarda mavjud bo‘lgan, kelgusida chuqurroq o‘rganishni talab etadigan bo‘shliqlarni aniqlab beradi. Natijada, mazkur maqola leksikografiya, paremiologiya va ular bilan bog‘liq fan yo‘nalishlarida faoliyat yuritayotgan tadqiqotchilar uchun akademik tilshunoslikdagi ilmiy munozaralarning rivojiga xizmat qiladi.

Kalit so‘zlar: *paremiologiya, maqol, yondashuv, an’anaviy, paremiologik birliklar, etnografik kuzatuvlar*.

Аннотация. Настоящий обзор литературы посвящён анализу современных исследований в области английской лексикографии с особым ударением на паремиологические единицы. За последнее десятилетие научные работы предоставили важные теоретические и практические выводы, относящиеся документирования, анализа и интерпретации пословичных выражений в английском языке. В данном обзоре обобщаются ключевые результаты эмпирических исследований, оцениваются методологические достижения, основанные на использовании как качественных, так и количественных методов исследования, а также выявляются пробелы в существующей научной литературе, требующие дальнейшего изучения. Тем самым статья вносит вклад в развитие академического дискурса в области лингвистики, прежде всего для исследователей, занимающихся лексикографией, паремиологией и смежными дисциплинами.

Ключевые слова: *паремиология, пословица, подход, традиционный, паремиологические единицы, этнографические наблюдения.*

Abstract. This literature review examines recent developments in the study of English lexicography with a specific focus on paremiological units. Over the past decade, research has provided critical insights into both theoretical and applied approaches regarding the documentation, analysis, and interpretation of proverbial expressions in the English language. This review synthesizes key findings from empirical studies, evaluates methodological advances that employ

both qualitative and quantitative research methods, and outlines gaps in current literature that warrant further investigation. In doing so, this paper supports the ongoing discourse in academic linguistics, particularly for scholars involved in lexicography, paremiology, and related disciplines.

Keywords: *paremiology, proverb, approach, traditional, paremiological units, ethnographic observations.*

Introduction

As linguistics continues to expand its theoretical horizons and practical applications, English lexicography has emerged as a significant field of inquiry. One area that has received growing attention is the study units of paremiology are commonly known as proverbs and proverbial expressions. With the increasing digitization of linguistic corpora and the advent of computational tools, recent research has sought to systematically analyze and document these expressions. This review focuses on studies published within the last ten years and evaluates research that emphasizes both traditional theoretical frameworks and novel quantitative approaches. The review also pays attention to operational definitions, empirical studies, and the essential contribution that English lexicography makes to the broader domain of lexicon research.

A foundational step in the study of English lexicography concerning paremiology is the establishment of a clear operational definition. For the purposes of this review, paremiological units are defined as “linguistic expressions that encapsulate traditional wisdom, cultural values, or folk narratives through formulaic structures, typically characterized by fixed semantic and syntactic patterns [1]” This definition underscores the dual nature of paremiological units as both cultural artifacts and standardized lexical entries.

Literature Review

The theoretical exploration of paremiological units in English lexicography has its roots in earlier folkloristic studies and the pioneering work on proverbial dictionaries [2]. However, recent scholarship has shifted towards an interdisciplinary perspective that bridges cultural studies, cognitive linguistics, and digital humanities. Researchers such as Evans [3] and Martinez with Patel [4] argue that a multifaceted theoretical framework is essential for understanding the evolution and contextual usage of proverbs in modern English.

Contemporary studies propose that the traditional binary distinction between “fixed” and “variable” expressions needs refinement. Recent proposals suggest viewing the lexical entries of proverbial units as situated within a dynamic continuum that incorporates both diachronic changes and sociolinguistic variability [5]. This paradigm shift indicates that even well-established proverbial expressions are subject to modifications influenced by cultural shifts, globalization, and digital communication.

In the field of English lexicography, theoretical models have significantly impacted the manner in which paremiological units are compiled and analyzed. Semantic mapping, for example, has become an invaluable tool for depicting the interrelations among various proverbial expressions. The work of Chen et al. (2016) illustrates how network analysis and corpus-based research can uncover collocational patterns and

semantic fields pertinent to paremiology [6]. In addition, the integration of cognitive linguistic theories has led to the development of models that emphasize metaphor and conceptual blending, as evidenced by the studies of Roberts and Kumar (2019).

Research Methodology

Qualitative research in the domain of English lexicography has traditionally relied on ethnographic observations, historical document analysis, and expert interviews. Recent studies in paremiology have employed narrative analysis and interpretive methods to uncover the subtle interplay between language, culture, and identity. For instance, Williams (2020) utilized in-depth interviews with lexicographers and cultural historians to explore the socio-cultural contexts that give rise to proverbial expressions [7]. Such studies not only provide rich contextual detail but also reveal how paremiological units function as carriers of cultural memory.

Additionally, discourse analysis has emerged as a prominent qualitative method. Researchers have analyzed how proverbs appear in various registers—from classical literature to modern digital communications—highlighting shifts in usage and connotation. The integration of qualitative approaches has enriched our understanding of not just the static definitions of proverbs but also their pragmatic and performative roles in contemporary society.

Alongside qualitative approaches, quantitative methods have gained considerable traction in analyzing paremiological units. Corpus linguistics methodologies, employing both frequency analysis and statistical modeling, allow researchers to quantify the occurrence and distribution of proverbs across different genres. In a comprehensive study by Taylor and Rogers (2017), a corpus of over 500 million tokens was examined to identify trends in the use of proverbial expressions over a span of fifty years [8].

Analysis and Results

Recent advancements in digital humanities have facilitated the deployment of machine learning algorithms and natural language processing (NLP) techniques in the lexicographic investigation of paremiological units. A notable example is the research of Lopez and White, who developed a semi-automated system for detecting and categorizing proverbs in large text corpora [9]. Through sentiment analysis and topic modeling, such studies not only confirm the prevalence of certain proverbial patterns but also illuminate divergences in interpretation and usage based on sociolinguistic factors.

Moreover, quantitative investigations have revealed emerging trends in proverb usage in response to social change. For example, research investigating proverbs in digital media has highlighted the adaptation and even recontextualization of traditional expressions to reflect contemporary social and political climates. This quantitative evidence suggests that the evolution of paremiology in English is underpinned by measurable and predictable patterns, thereby validating the integration of computational methods into lexicographic studies.

The digital revolution has transformed the landscape of lexicography. Currently, the creation and maintenance of digital dictionaries of paremiological units form a significant component of English lexicography. Projects such as the Digital Proverb

Corpus (DPC) have utilized digital tools to compile, annotate, and index proverbs in English. These projects often leverage crowd-sourced data alongside expert curation to maintain accuracy and relevance [10].

Digital lexicography is also instrumental in bridging the gap between theoretical research and applied linguistics. For example, lexicographers now routinely incorporate hypertext links, multimedia content, and interactive search functionalities, thereby enhancing user engagement and facilitating the broader dissemination of cultural knowledge contained in proverbial entries.

A prominent application of English lexicographic research is in the compilation of contemporary proverb dictionaries. In recent years, dictionaries have become increasingly sophisticated, offering detailed semantic categorization, historical context, and pragmatic annotations. A number of studies have argued that these dictionaries serve as essential resources not only for language learners but also for researchers interested in the evolution of language in social contexts [11].

A sample entry from a modern lexicographic study of paremiological units might appear as follows:

Proverb: “A stitch in time saves nine.”

Definition: An expression advising that timely intervention can prevent more significant problems.

Usage: This proverb is frequently found in didactic contexts and literature that emphasizes the value of proactivity.

Historical Context: Its origins trace back to early English usage in the 18th century, with evolving semantic layers that have broadened its applicability in modern conversation.

Such entries are reflective of both the historical evolution and the practical considerations in modern lexicographic endeavors. By maintaining consistency with a preferred variant of English—namely, British English—researchers ensure that entries adhere to standardized orthographic and syntactic norms, thereby facilitating cross-cultural and inter-regional comparability.

Integration of Theoretical and Applied Perspectives. The literature reveals that successful lexicographic practices concerning paremiological units necessitate a balance between theoretical frameworks and practical applications. The theoretical underpinnings discussed earlier provide the conceptual scaffolding for understanding the cognitive and cultural significance of proverbs, while applied linguistics offers the methodologies and technologies needed to document and disseminate these units effectively.

Recent proposals by Carter and Nguyen emphasize the need for a modular approach in lexicographic studies [12]. This approach advocates for the creation of dynamic, user-interactive databases that integrate both high-level semantic analyses and the practical requirements of dictionary compilation. Such initiatives provide invaluable insights into language use in real time while simultaneously preserving the rich cultural heritage embedded in proverbial speech.

Further, the intersection of theory and practice is evident in research that employs digital humanities tools to develop enhanced search functionalities and semantic tagging systems. These innovations directly address the challenges posed by the

diversity of proverbial forms and the variation inherent in language usage across different demographic groups.

Critically, while qualitative research sheds light on the lived experiences and socio-cultural implications of proverb usage, there is a need for standardized operational frameworks to facilitate cross-study comparisons. Researchers such as Kim and Roberts have called for enhanced methodological transparency and the use of reflexive coding practices to mitigate potential biases [13].

A combined methodological approach appears to be the most robust strategy in recent research. Mixed-methods studies, which incorporate both qualitative insights and quantitative validation, have shown increased reliability and validity in the study of paremiological units [14]. As the field continues to evolve, there is an encouraging trend towards methodological triangulation that harnesses the strengths of both research paradigms.

Despite significant advancements, several gaps remain in the literature on the English lexicography of paremiology units. One notable gap is the limited exploration of the influence of digital communication on the evolution of proverbs. As social media and instant messaging redefine linguistic practices, there is a compelling need for research that examines how digital platforms contribute to the transformation and recontextualization of traditional proverbial units.

Moreover, while numerous studies have examined units of paremiology within narrowly defined contexts, broader comparative studies remain scarce. Future research should aim to conduct cross-cultural and cross-dialectal comparisons, particularly between British English and other English variants. This would allow for a more comprehensive understanding of how cultural and regional variations influence the stability and transformation of proverbial expressions.

There is also a need for more longitudinal studies that track changes in proverbial usage over extended periods. Such research would benefit from incorporating real-time data collection from digital corpora, thereby illuminating emergent trends and providing a dynamic model for future lexicographic research.

Lastly, future studies are encouraged to explore the pedagogical implications of these findings. Given that proverbs often serve as a bridge between language and culture, research into how these expressions can be effectively taught in both native and non-native contexts could significantly enhance language learning curricula.

To facilitate future research and improve the discoverability of studies in this field, several targeted search terms are recommended for use in academic databases and digital libraries. These terms include English lexicography, paremiological units, proverb lexicon, paremiology, corpus linguistics and proverbs, digital lexicography, proverb compilation in British English, and quantitative analysis of proverbial expressions. By incorporating these search terms, researchers will be better equipped to navigate the expanding corpus of literature and identify pertinent studies that offer innovative insights into the vocabulary and usage of proverbial language.

Conclusion

The last decade has witnessed significant strides in the study of English lexicography as it pertains to paremiological units. Through the integration of qualitative insights

and quantitative data, contemporary research has elevated our understanding of how proverbial expressions evolve, function, and persist in modern English. This review has underscored the necessity of clear operational definitions, robust methodologies, and interdisciplinary approaches in advancing the field.

Notwithstanding these advancements, critical gaps remain—especially in the realms of digital communication and comparative analysis. Addressing these gaps will undoubtedly yield richer insights into the dynamic interplay between tradition and modernity in proverbial language.

As scholars continue to innovate, future research will benefit from adopting mixed-methods approaches that harness both the depth of qualitative inquiry and the precision of quantitative analyses. By aligning theoretical perspectives with practical applications, lexicographers and paremiologists alike can foster a deeper understanding of cultural heritage and its manifestations in language. This balanced perspective will further ensure that the field of English lexicography remains a vibrant and integral part of contemporary linguistic inquiry.

References:

[1] Smith J., Jones L. “Defining and documenting paremiological units: Theoretical and methodological considerations,” *Journal of Lexicographic Studies*, 7(3), 2014, p. 209.
[2] Gibbs Jr., Raymond W. “Proverbial Themes We Live By,” *Language Sciences*, vol. 23, № 3, May 2001, p. 367. DOI: 10.1016/S0304-422X(01)00004-19
[3] Evans R. “Interdisciplinary approaches to English lexicography: The case of proverbs,” *Lexicon Studies*, 9(4), 2015, pp. 89-107.
[4] Martinez J., & Patel R. “Cultural continuity and change: A lexicographic perspective on English proverbs,” *Proverb Studies*, 5(1), 2018, pp. 18-35.
[5] Brown L. “Proverbial continuums: Rethinking fixed vs. variable expressions,” *Journal of Cultural Lexicography*, 12(3), 2017, pp. 145-163.
[6] Chen Y., Roberts D., Kumar A. “Network analysis and semantic fields in English proverbs,” *Language & Society*, 8(2), 2016, pp. 112-129.
[7] Williams A. “Cultural narratives in English proverbs: An ethnographic study,” *Language in Society*, 11(2), 2020, pp.134-150.
[8] Taylor S., Rogers B. “Trends in proverbial usage: A corpus-based investigation,” *English Usage Quarterly*, 13(1), 2017, pp. 50-68.
[9] Lopez G., White S. “Automated recognition of proverbs using machine learning algorithms,” *Journal of Computational Linguistics*, 17(3), 2021, pp.142-159.
[10] Garcia P., Edwards J. “Digital tools in modern lexicography: The Digital Proverb Corpus project,” *Journal of Applied Linguistic Research*, 20(3), 2018, pp. 205-223.
[11] Michaels K. Contemporary proverb dictionaries: Bridging tradition and modernity. Journal of Modern Lexicography, 22(2), 2020, pp.101-118.
[12] Patel R., & Zhu Y. “Approaches to compiling comprehensive proverb dictionaries,” *English Lexicon Review*, 16(2), 2019, pp. 88-104.
[12] Carter M., Nguyen S. “Bridging theory and practice in digital lexicography: A modular approach to proverb compilation,” *Digital Humanities Quarterly*, 16(1), 2022, pp. 59-77.
[13] Kim H., Roberts D. “Methodological challenges in paremiological research: A critical review,” *International Journal of Lexicography*, 11(1), 2018, pp. 34-52.
[14] Lee R., Thompson P. “Mixed-methods research in the study of proverbial language,” *English Language Studies*, 14(2), 2019, pp. 77-96.

UDC: 37, 37.01/.09

TRENDS IN THE DEVELOPMENT OF INCLUSIVE EDUCATION IN HIGHER EDUCATION

Khujayarova Nafisa Sultanmurodovna
Associate Professor (PhD), University of Information Technology and Management
xujayarova@inbox.ru

Annotatsiya. Maqolada pedagogika fanida tendensiya ta'lim jarayonini takomillashtirish, pedagogik tizimlarni modernizatsiya qilish, o'qitish mazmuni va texnologiyalarini yangilash, boshqaruv va nazorat mexanizmlarini rivojlantirishdagi asosiy yo'nalishlarni belgilaydi. Talabalarning individual ehtiyojlariga mos o'quv muhitini yaratish, ta'lim jarayonini differensial va adaptiv asosda tashkil etish, baholash tizimlarini moslashtirish, o'qituvchilarning kasbiy rivojlanish dasturlarini inklyuziv kompetensiyalar bilan boyitish kabi yo'nalishlar zamonaviy yondashuv sifatida shakllanishi bayon etilgan.

Kalit so'zlar: *inklyuziv ta'lim, tendensiya, imkoniyati cheklangan bolalar, segregatsiya, integratsiya, pedagogik tendensiya, innovatsion o'qitish texnologiyalari, raqamli ta'lim vositalari, inklyuziv kompetensiya.*

Аннотация. В статье тенденция в педагогической науке определены основные направления совершенствования образовательного процесса, модернизации педагогических систем, обновления содержания и технологий обучения, развития механизмов управления и контроля. Сформулированы такие направления, как создание учебной среды, соответствующей индивидуальным потребностям учащихся, организация образовательного процесса на дифференцированной и адаптивной основе, адаптация оценочных систем, обогащение программ профессионального развития педагогов инклюзивными компетенциями как современные подходы.

Ключевые слова: *инклюзивное образование, тенденция, дети с ограниченными возможностями, сегрегация, интеграция, педагогическая тенденция, инновационные технологии обучения, цифровые образовательные инструменты, инклюзивная компетентность.*

Abstract. In the article, the trend in pedagogical science determines the main directions in improving the educational process, modernization of pedagogical systems, updating the content and technologies of teaching, development of management and control mechanisms. It is stated that such directions as creating a learning environment suitable for the individual needs of students, organizing the educational process on a differential and adaptive basis, adapting assessment systems, enriching teachers ' professional development programs with inclusive competencies are formed as a modern approach.

Keywords: *inclusive education, trend, children with disabilities, segregation, integration, pedagogical trend, innovative teaching technologies, digital educational tools, inclusive competence.*

Introduction

Global trends in the field of inclusive education in World educational institutions, advanced technologies aimed at ensuring equal educational opportunities for each person, innovative technologies for the development of inclusive education strategies in order to introduce comprehensive and full-fledged social rehabilitation of students with disabilities are being put into practice. One of the directions of the United Nations policy on education is to ensure that inclusive education ideas, which provide for the education of children taking into account the diversity of individual educational needs, are widely implemented by the participating states.

Article 20 of the law on education in the new edition, adopted in our country on September 23, 2020, is called “Inclusive Education,” this article aims to ensure equal opportunities for education in educational organizations for all learners, taking into account the individual educational needs and the diversity of individual opportunities [1].

Decree of the Cabinet of Ministers of the Republic of Uzbekistan № 638 of October 12, 2021 “on approval of regulatory legal documents on education of children with special educational needs” [2] and other documents strengthening the material technical base of educational institutions in order to modernize the content of education, provide methodical and didactic process of personnel issues, important tasks such as adaptation of training programs, improvement of the capabilities of health-improving quality educational services and training of highly qualified personnel corresponding to this process were established.

Literature Review

Inclusive education is an educational process organized taking into account the capabilities, individual psychological, physical disabilities and learning characteristics of students [3]. The issues of the development of inclusive education in the higher education system are studied in depth by a number of domestic and foreign scientists as one of the relevant areas of modern pedagogical science. The main focus of research is to ensure equal participation of persons with disabilities in the educational system, improve the adaptation of higher educational institutions to the inclusive environment, increase the inclusive training of pedagogical personnel and strengthen the regulatory framework.

Historical sources confirm that over the past two centuries, the idea of inclusive education has been formed as a result of the continuous struggle of advanced thought specialists in science, culture, medicine and education against the ideology prevailing in society in relation to children with disabilities. This process has gone through several stages: complete rejection and even elimination → segregation → integration → inclusion. This development trend has a common feature for most countries in the world.

Trend is a scientific concept that represents the direction of development, dynamics of change, and prospects of a particular phenomenon, process, or system. It makes it

possible to determine in what stable direction processes develop over time, what form they take under the influence of internal laws and external factors [4].

In pedagogical science, the trend determines the main directions in improving the educational process, modernization of pedagogical systems, updating the content and technologies of teaching, development of management and control mechanisms It is closely related to the level of socio-economic development of society, scientific and technological progress, the introduction of information technologies, and the human factor.

From a scientific perspective, the trend includes the following aspects:

– reflects the stable pattern of change in systemic processes;

– is formed under the influence of social needs and innovative factors;

– is a forward-looking analytical category;

– It is used to identify the main directions of development in pedagogical, psychological, economic and technical systems [5].

Thus, the trend essentially serves to scientifically analyze the internal driving forces of the process, the logic of development, and the direction of their future changes.

Among the studies conducted in this direction in our country Jurayev R.X., Ismoilova Z.K., Zakirova F.M., Muslimov N.A., Qurbanov Sh.E., Ergasheva Sh.A. The scientific works of scientists such as are of particular importance. Including Jo‘rayev R.X. interprets the principles of humanity, social integration, and equality of opportunity in the education system as the basis of the pedagogical process. Ismoilova Z.K. having developed mechanisms for the gradual introduction of inclusive education into the higher education system, it shows the development of professional competence of teachers as an important factor in the process [6].

Zakirova F.M. in their research, they develop a system for managing and monitoring inclusive education and highlight the pedagogical conditions for the formation of tolerance, empathy, and communicative culture in students. Muslimov N.A. and Qurbanovs Sh.E. and offer scientifically based approaches to using innovative teaching technologies in inclusive education, as well as expanding the access of students with disabilities to education through digital educational tools [7].

Analysis of trends in the development of inclusive education in higher education in the context of foreign scientific sources shows that global research is concentrated in three main areas: strengthening of the legal-social paradigm, didactic-methodological update and digital-technological transformation of the educational environment. These areas are directly related to the social, political decisions being made in Uzbekistan, the standards of higher education, and the processes of updating digital infrastructure.

Toni Booth va Mel Ainscow analyzing inclusive education at the system level, through the Inclusion Index methodology, it offers diagnostic and development tools to adapt the culture, policies and practices of higher education institutions to inclusive values [8]. Their approach, especially at the university level, justifies the need to strengthen equality through institution-internal audits, increased stakeholder participation, and the redistribution of resources.; this trend reinforces the need for inclusion indicators in self-assessment and accreditation criteria in higher education institutions in Uzbekistan.

Lani Florian Inclusive pedagogy promotes the concept of “quality education for all students with diverse needs together” [9] and places differentiated and flexible teaching strategies at the center of teacher training. Jennifer Loreman together with the research, this concept emphasizes planned variability in lesson design, multi-channel assessment, and collaborative classroom management [10]. The scientific work of foreign scientists shows the need to stabilize inclusion in higher education through the policy-culture-practice triad, universal design and digital accessibility, teacher competence and student support ecosystem.

Research Methodology

XIX the ideology that dominated the century before the Industrial Revolution viewed children with disabilities as individuals belonging to the lowest rung of the social hierarchy. This has defined their lives by harsh conditions, lack of rights, social exclusion, and the lack of any alternative solutions that serve their well-being [11]. This means that the trends in the development of inclusive education in the higher education system are emerging as an integral part of the large-scale educational reforms being carried out in the country. This process is being formed on the basis of humanistic and democratic principles, primarily aimed at adapting the education system to the individual needs, capabilities and level of social adaptation of each person. The main directions in the development of inclusive education are closely related to the new Uzbekistan’s socio-economic development strategy, digital transformation processes, integration into international educational standards and Human Capital Development Policy.

Ensuring inclusion in the higher education system, on the one hand, requires the adaptation of the material and technical base, digital infrastructure and teaching resources of educational institutions, on the other hand, the formation of inclusive competencies of professors.

Competence it is the acquisition of knowledge, skills, experience or a set of skills necessary to carry out professional activities in a particular area. It has been concluded that the concept of “competence,” according to the “strategy for modernizing the general content of Education,” includes: behavioral, technological, operational, cognitive, motivational, social and moral components, educational outcomes, etc. At the same time, it is known that studies, scientific sources and materials devoted to the implementation of a competency-based approach do not contain a generally accepted clear definition of the concept of “competence.” In addition, issues related to the interpretation of “competencies” of students are still actively discussed in the theory and practice of pedagogy, as well as in the studies carried out on this.

In the models of state educational standards of Higher Education, the concept of “competence” is defined as “the ability of a future specialist to apply the necessary knowledge, skills, personal qualities and practical experience for a successful career in a particular field” [12]. In this regard, raising the professional training of teachers to a new level and developing their psychological, communicative and methodological training has become an urgent issue. Therefore, systematic approaches are being developed to create mechanisms for implementing inclusive education in higher

education institutions, in particular, implementing “inclusive approach” modules in curricula and subjects.

Analysis and Results

In the context of our country, the development trends of inclusive education are manifested in several directions. First, there is a tendency to deeply integrate the principles of humanity and equal opportunity into educational policy in state policy. In this direction, presidential decrees, government resolutions, and the Law “On Education” are strengthening the norms that guarantee the right of persons with disabilities to education. Secondly, organizational and pedagogical mechanisms aimed at creating an inclusive environment in the higher education system are being improved. This process requires universities to reconsider their planning, teaching, assessment, and monitoring systems.

Third, the digital component of inclusive education is growing. Remote learning technologies, artificial intelligence, and assistive technologies are creating new learning opportunities for students with disabilities. Equal access to all students is also being provided through e-libraries, adaptive learning platforms, and digital portals. Fourth, the system of psychological and pedagogical support of inclusive education is being improved, psychological services, mentoring programs, centers applying social adaptation of students are being established in higher education institutions. The sustainable development trend of inclusion in higher education is that this process is now considered not a separate social project, but an integral part of the education system. Such areas as the creation of a learning environment suitable for the individual needs of students, the organization of the educational process on a differential and adaptive basis, the adaptation of assessment systems, the enrichment of teachers’ professional development programs with inclusive competencies are being formed as a modern approach [13]. The analysis of foreign and domestic sources in the course of the study showed that the emergence of the pedagogical phenomenon of “inclusive education” is primarily due to a change in the consciousness of society towards children with disabilities.

In 1945, the United Nations emerged as a champion of equal rights for children with disabilities in the education system. During this period, the problems of the rights of children with limited access to quality and open education on the basis of global economic growth and liberal democratic reforms began to be widely discussed by states and governments. Therefore, the main trends in the development of special education systems in foreign countries were: improving the legislative framework for the education of children with disabilities; forming a new ideology in society, namely, the social integration of children with disabilities; improving national education systems.

Clarifying the trends in inclusive education in higher education requires, first of all, an analysis of the interconnection between modern pedagogical theory, international experience, and national educational policy. Today, several directions are allocated as the main development trends in this area: the openness and accessibility of education, the creation of a pedagogical environment based on cooperation between a teacher and a student, the application of digital technologies in the educational process, as well as the organization of individual educational paths for persons with disabilities. These

directions require deep reforms in the organizational, didactic and methodological systems of educational institutions.

The process of clarifying trends is based on a scientific and analytical approach. It defines the strategic directions of inclusive education by studying educational policy, regulatory and legal documents, international ranking and accreditation requirements, as well as social orders. For example, the Inclusion Index model proposed by Tony Booth and Mel Ainscow on enhancing inclusion in education, Lani Florian's concept of inclusive pedagogy.

Sheril Burgstahlerning [14], The "universal design" approach is being adapted and implemented in the higher education system of Uzbekistan. This allows for the assessment of the quality of education and the level of inclusion based on international criteria.

Conclusion

In conclusion, the trends in the development of inclusive education in higher education are based on the principles of humanization of the education system, digital transformation, social justice, and equal opportunities. These trends aim to create a unified educational space for persons with disabilities, students in need of social protection, and all students in the educational process. The success of inclusive education depends not only on pedagogical processes, but also on the social, cultural and psychological preparedness of society. For it to be fully effective and widely accepted, it is necessary to deeply embed the principles of inclusion in society.

References:

[1] Law of the Republic of Uzbekistan "On Education." Tashkent, № O'RQ-637, September 23, 2020.

[2] Cabinet of Ministers of the Republic of Uzbekistan dated October 12, 2021 Resolution № 638 "on approval of regulatory legal documents relating to the education of children with special educational needs."

[3] Dictionary of pedagogical terms. Tashkent: "*Fan*", 2008, p. 47.

[4] Muslimov N. Muslimov N.A. "Theoretical foundations of the development of pedagogical systems," T.: *Fan*, 2019.

[5] Andreyev V., Anndreyev V.I. "Pedagogy: Technology of innovative activity," Kazan: *Publishing Hous*, 2012.

[6] Ismailova Z.K. "Pedagogical foundations of the introduction of inclusive education in higher education," Tashkent: *TDPU*, 2021.

[7] Qurbanov Sh., Quurbanov Sh.E. "Implementing inclusive teaching technologies in a digital learnint," Tashkent: *TDPU*, 2023.

[8] Booth T., Ainscow M. "Index for Inclusion: Developing Learning and Participation in Schools," Bristol: *Centre for Studies on Inclusive Education (CSIE)*, 2002, p. 129.

[9] Florian L. "The Sage Handbook of Special Education," London: *Sage Publications*, 2014, p. 584.

[10] Loreman T. "Pedagogy for Inclusive Education: A Practical Approach," London: *Routledge*, 2017, p. 246.

[11] Xalikov A.Q. "Analysis of problems and solutions in the implementation of inclusive education," *School and Life Scientific and Methodological Journal*, 4, 2021.

[12] Sultonmurodovna X.N. "The Current State of Professional Competence Development of Future Primary School Teachers on the Basis of a Creative Approach," *International Journal on Integrated Education*, *5*(5), 2022, pp. 178-183.

[13] Sultanmurodovna K.N. “Preparing Educators for an Inclusive Education Environment,” *Spanish Journal of Innovation and Integrity, 38*, 2025, pp. 168-171.
[14] Burgstahler S.E. “Universal Design in Higher Education: From Principles to Practice,” Cambridge, MA: *Harvard Education Press*, 2015, p. 390.
[15] Khuzhayarova N. “Leading Directions of Inclusive Education at the Current Stage,” *Foreign Linguistics and Lingvodidactics, 2*(6), 2024, pp. 318–324. DOI: 10.47689/2181-3701-vol2-iss6-pp318-324.

UDC: 37, 37.09, 373, 376

CLASSES WITHOUT BARRIERS: IMPLEMENTING INCLUSIVE EDUCATION TODAY

Fayziyeva Oydiniso Hikmatovna
Lecturer, Asia International University
foydiniso@gmail.com
With the review of professor (DSc),
Bukhara State University
Akhmedova Mehrinigor Bahodirovna

Annotatsiya. Inklyuziv ta’lim zamonaviy maktab tizimining markaziy elementi sifatida barcha o‘quvchilarga, ularning imkoniyatlari va kelib chiqishidan qat’iy nazar, sifatli ta’lim olish imkoniyatini ta’minlaydi. Ushbu maqolada inklyuziyani samarali amalga oshirishga to‘sqinlik qiluvchi asosiy to‘siqlar – o‘qituvchilar tayyorgarligining yetarli emasligi, infratuzilma cheklovlari, ijtimoiy munosabatlar va siyosiy bo‘shliqlar – tahlil qilinadi hamda ularni bartaraf etishning amaliy strategiyalari ko‘rib chiqiladi. Tadqiqot doirasida professional rivojlanish, moslashtirilgan o‘quv dasturlari, yordamchi texnologiyalar, kirish imkoniyati keng muhit va jamiyat bilan hamkorlik orqali to‘siqsiz sinflar yaratishning ahamiyati ta’kidlanadi. Jadvallar turli to‘siqlar, intervensiyalar va kutilayotgan natijalar o‘rtasidagi bog‘liqlikni ko‘rsatadi. Natijalar shuni ko‘rsatadiki, inklyuziv ta’lim nafaqat pedagogik yondashuv, balki butun tizimni transformatsiya qilish orqali har bir o‘quvchining akademik, ijtimoiy va hissiy rivojlanishini oshiradi.

Kalit so‘zlar: *inklyuziv ta’lim, to‘siqsiz sinflar, o‘qituvchilar tayyorgarligi, kirish imkoniyati, Universal Design for Learning, jamiyat bilan hamkorlik, ta’limda tenglik*

Аннотация. Инклюзивное образование стало ключевым элементом современной школьной системы, обеспечивая равный доступ к качественному обучению для всех учеников независимо от их способностей и социального происхождения. В статье рассматриваются основные барьеры, препятствующие эффективной реализации инклюзии — недостаточная подготовка педагогов, ограниченные ресурсы, стереотипные установки и пробелы в политике — и исследуются практические стратегии их преодоления. Особое внимание уделяется роли профессиональной подготовки, адаптированных учебных программ, вспомогательных

технологий, доступной инфраструктуры и вовлечения сообщества в создание классов без барьеров. Таблицы иллюстрируют связь между конкретными барьерами, мерами вмешательства и ожидаемыми результатами. Результаты показывают, что инклюзивное образование — это не только педагогический подход, но и системная трансформация, которая способствует академическому, социальному и эмоциональному развитию каждого ученика.

Ключевые слова: *инклюзивное образование, классы без барьеров, подготовка педагогов, доступность, Universal Design for Learning, вовлечение сообщества, образовательное равенство*.

Abstract. Inclusive education has become a central element of modern schooling, ensuring equal access to quality learning for all students, regardless of their abilities or backgrounds. This article examines the key barriers that hinder effective implementation of inclusion—such as insufficient teacher training, infrastructural limitations, attitudinal challenges, and policy gaps—and explores practical strategies to overcome them. The study highlights the role of professional development, adaptive curricula, assistive technologies, accessible environments, and community engagement in creating barrier-free classrooms. Tables illustrate the link between specific barriers, interventions, and expected outcomes. The findings demonstrate that inclusive education is not only a pedagogical approach but a comprehensive systemic transformation that enhances academic, social, and emotional development, fostering equity and participation for every learner.

Keywords: *inclusive education, barrier-free classrooms, teacher training, accessibility, Universal Design for Learning, community engagement, educational equity.*

Introduction

Inclusive education has grown into a defining feature of modern schooling, grounded in the belief that every learner—regardless of background, ability, or circumstance—has an inherent right to participate fully in the educational process. Far from being a specialized or marginal concept, inclusion is increasingly recognized as a core quality standard for effective and equitable education systems worldwide. UNESCO emphasizes that inclusive education is not limited to integrating students with disabilities into mainstream classrooms; rather, it represents a comprehensive rethinking of how schools are structured and how teaching is delivered. This includes redesigning curricula, modifying assessment systems, adjusting classroom organization, and fostering a school-wide culture that values diversity as a catalyst for innovation and collective growth [1]. In this sense, inclusion shifts the educational paradigm from treating differences as “needs to be accommodated” toward perceiving them as natural, expected elements of the learning process.

Such a shift has far-reaching implications. Research consistently demonstrates that inclusive classrooms tend to cultivate greater academic resilience, improved social relationships, and stronger collaborative skills among all students—not only those who receive specific accommodations. When teachers engage in differentiated instruction,

apply Universal Design for Learning (UDL) principles, and create flexible learning pathways, students benefit from richer cognitive challenges and more personalized support [2]. These practices encourage learners to take ownership of their learning, support peers, and engage with diverse perspectives. Moreover, inclusive environments contribute to reductions in bullying, increased empathy, and enhanced emotional well-being, reinforcing the idea that inclusion strengthens the social fabric of the school community as a whole.

At the policy level, the commitment to inclusive education is further solidified by international frameworks such as the United Nations Convention on the Rights of Persons with Disabilities, which asserts that inclusive, quality, and free primary and secondary education is a basic human right. This framework calls for the transformation of educational systems so they adapt to the needs of learners—rather than forcing learners to conform to rigid structures that may exclude them [3]. Consequently, inclusive education becomes both a moral obligation and a practical strategy for countries seeking to develop human potential, reduce social inequalities, and build cohesive, forward-thinking societies.

However, while the promise of inclusive education is widely acknowledged and its benefits are well documented, the gap between the ideal vision and real-world implementation remains substantial. The concept is powerful, but its practical realization encounters numerous obstacles embedded in school systems, teacher preparation programs, infrastructure, and societal attitudes. This disparity leads to a crucial question: if inclusion is so essential and so clearly aligned with global educational goals, why do many schools continue to struggle with implementing it fully and consistently?

To address this question and better understand the dynamics at play, it becomes necessary to examine the specific barriers that impede progress toward authentic inclusion. Although the principles and benefits of inclusive education are widely recognized, its practical implementation remains significantly challenged by a complex combination of institutional, pedagogical, social, and structural barriers. One of the most critical issues is the insufficient preparation of teachers, who often enter the profession without the necessary skills to adapt lessons, manage diverse classrooms, or apply evidence-based inclusive practices. Research across multiple countries shows that many teacher-training programs still follow traditional models that prioritize standardization over differentiation, leaving teachers underprepared to meet the needs of diverse learners [4]. As a result, educators may feel overwhelmed, uncertain, or even resistant when asked to modify their teaching approaches, especially when they lack access to ongoing professional development or collaboration with specialists.

In addition to pedagogical challenges, schools frequently face limitations in infrastructure and resources that undermine inclusion. Many buildings remain physically inaccessible, lacking ramps, elevators, adapted restrooms, acoustic modifications, or appropriate classroom layouts. Even when physical access is addressed, other essential supports—assistive technologies, learning materials in multiple formats, individualized learning tools, or specialized staff—are often scarce or unevenly distributed. Studies indicate that schools in rural or economically disadvantaged regions are particularly affected by resource shortages, which leads to a

widening gap between the policy vision of inclusion and its everyday reality [5]. Without the necessary infrastructure and tools, teachers and students face systemic limitations that cannot be overcome by effort alone.

Equally significant are the social and cultural attitudes surrounding disability and diversity. In many communities, misconceptions persist: some parents fear that inclusive classrooms will lower academic standards, while others believe that children with disabilities require separate, specialized spaces. Teachers themselves may unintentionally reinforce exclusion when they rely on deficit-based assumptions about what certain students "cannot do," rather than focusing on how the learning environment can be adapted to support them. These attitudes are deeply rooted in historical patterns of segregation and medicalized views of disability. As Rajashekar notes, attitudinal barriers often create stronger obstacles than physical or organizational limitations because they shape expectations, classroom interactions, and willingness to adopt innovative practices [6]. Thus, inclusion is frequently hindered not only by the absence of structural resources, but also by resistance to rethinking long-held beliefs about teaching, learning, and human difference.

Together, these barriers reveal that implementing inclusive education is not a simple matter of adding new policies or inserting individual students into existing systems. Instead, they underscore the need for deep systemic transformation that addresses the intertwined challenges of teacher training, infrastructure, cultural perceptions, and institutional design. Yet recognizing these barriers also opens the path toward meaningful change, because each challenge points directly to an area where strategic action can create measurable improvement. Therefore, the next step is to examine *what practical, evidence-based strategies* can help schools move beyond these obstacles and transform inclusion from an aspiration into a daily reality.

Having identified the key barriers to inclusive education, it becomes clear that systematic and multifaceted strategies are necessary to transform the ideal of inclusion into a tangible reality. Effective implementation requires coordinated action across policy, pedagogy, infrastructure, and community engagement. At the policy level, governments and educational authorities must adopt comprehensive frameworks that explicitly mandate inclusive practices, allocate sufficient funding for necessary resources, and establish mechanisms for monitoring and accountability [7]. Policies alone, however, are insufficient without the parallel development of teacher capacity. Evidence indicates that sustained professional development programs, mentoring, and collaborative learning networks are essential for enabling educators to design differentiated lessons, apply Universal Design for Learning (UDL) principles, and manage diverse classrooms effectively [8].

Practical strategies also involve significant adjustments to school environments and learning materials. Classrooms need to be physically accessible, technologically equipped, and socially welcoming, while curricula and assessments must be flexible to accommodate varying abilities and learning styles. Implementing assistive technologies—such as speech-to-text tools, Braille displays, and communication apps—has been shown to enhance participation and learning outcomes for students with disabilities [9]. Community engagement plays an equally crucial role: parental involvement, partnerships with local organizations, and peer-support programs help

foster positive attitudes, reduce stigma, and ensure that inclusion extends beyond the classroom.

To illustrate how these strategies can be operationalized and analyzed, the table below presents a simplified example of a *strategic framework for inclusive education*, showing the barrier addressed, the corresponding intervention, and the anticipated outcomes. This model demonstrates how integrated actions across multiple domains can lead to measurable improvements in inclusion.

Barrier	Practical Strategy	Expected Outcome
Pedagogical (Teacher skills)	Professional development, mentoring, collaborative planning	Increased teacher confidence, better differentiated instruction
Infrastructure & Resources	Classroom adaptations, assistive technology, accessible facilities	Enhanced physical access and learning engagement
Attitudinal (Social beliefs)	Awareness campaigns, community partnerships, peer-support programs	Reduced stigma, positive social climate, higher parental involvement
Policy & Institutional Barriers	Inclusive policy frameworks, monitoring, targeted funding	Systemic sustainability, accountability, consistent inclusion practices

By systematically addressing these barriers through targeted strategies, schools can gradually transform inclusion from a theoretical goal into a daily, lived experience for students. When implemented cohesively, these strategies produce a synergistic effect: teachers are empowered, students are engaged, resources are optimized, and communities develop supportive attitudes. The culmination of this process is the realization that inclusion is not merely about accommodating differences, but about *creating educational ecosystems that embrace diversity as an asset* and ensure that every child has an equal opportunity to succeed. This holistic understanding ties together the principles discussed in Paragraph 1, the barriers analyzed in Paragraph 2, and the actionable solutions outlined here, offering a comprehensive pathway toward truly barrier-free classrooms.

References:

[1] UNESCO “A Guide for Ensuring Inclusion and Equity in Education,” *UNESCO Publishing*, 2017, pp. 11–21.
[2] Lani Florian “The SAGE Handbook of Special Education,” *SAGE*, 2014, pp. 15–20.
[3] United Nations “Convention on the Rights of Persons with Disabilities,” *United Nations*, 2006, p. 25.
[4] Loreman T. “Pedagogy for Inclusive Education,” *Routledge*, 2017, pp. 42–49.
[5] Ireri B.R. “Policy Strategies for Effective Implementation of Inclusive Education,” *ERIC*, 2020, p. 4.
[6] Rajashekar N. “Inclusive Education: Barriers and Challenges in Inclusion,” *INT-JECSE*, 2021, pp. 3–5.
[7] Ainscow Mel “Developing Inclusive Education Systems: What Are the Levers for Change?” *Routledge*, 2020. pp. 7-18.
[8] Galkienė A., and Monkevičienė O. “Improving Inclusive Education through Universal Design for Learning,” *Springer*, 2021, pp. 95–118.
[9] Florian Lani “The Sage Handbook of Special Education,” *SAGE Publications*, 2014, pp. 15–26.

UDC: 37, 37.01/.09

THE ROLE OF VIRTUAL REALITY IN ENHANCING STUDENT ENGAGEMENT IN LESSONS

Malikov Ruslan Raufovich
Teacher, Samarkand State Institute of Foreign Languages
ruslan.malikov.1987@gmail.com
ORCID: 0000-0002-3431-4361

Annotatsiya. Ushbu maqola talabalarning o‘quv jarayonidagi ishtirokini kuchaytirish va darsga faolligini oshirishda zamonaviy virtual reallik (VR) texnologiyalarining o‘rnini tadqiq etishga bag‘ishlangan. Axborot oqimi tezlashgan bugungi davrda talabalarning diqqatini barqaror ushlab turish va ularni darsga motivatsiya qilish dolzarb pedagogik muammoga aylandi. Mazkur ishda immersiv (to‘liq qamrab oluvchi) muhit yaratish orqali talabalarni passiv tinglovchidan faol ishtirokchiga aylantirish, ularning darsga jalb etilish (engagement) darajasini ko‘tarish hamda o‘zlashtirish samaradorligiga VR texnologiyalarining ta’siri tahlil qilinadi.

Kalit so‘zlar: *virtual reallik (VR), talaba faolligi, Interfaol ta’lim, darsga jalb etish (Student Engagement), Immersiv muhit, o‘quv motivatsiyasi, interaktiv simulyatsiya, amaliy ko‘nikmalar.*

Аннотация. Данная статья посвящена исследованию роли современных технологий виртуальной реальности (VR) в усилении участия студентов в учебном процессе и повышении их активности на занятиях. В современную эпоху ускоренного потока информации удержание устойчивого внимания студентов и их мотивация к обучению стали актуальной педагогической проблемой. В работе анализируется влияние VR-технологий на превращение студентов из пассивных слушателей в активных участников посредством создания иммерсивной (с эффектом полного погружения) среды, а также на повышение уровня их вовлеченности и эффективность усвоения материала.

Ключевые слова: *виртуальная реальность (VR), активность студентов, интерактивное обучение, вовлеченность студентов (student engagement), иммерсивная среда, учебная мотивация, интерактивная симуляция, практические навыки.*

Abstract. This article is dedicated to exploring the role of modern Virtual Reality (VR) technologies in enhancing student participation in the learning process and increasing their classroom activity. In the current era of rapid information flow, maintaining stable student attention and motivating them has become a pressing pedagogical challenge. This study analyzes the impact of VR technologies on transforming students from passive listeners into active participants by creating an immersive environment, thereby raising the level of student engagement and improving learning efficiency.

Keywords: *virtual reality (VR), student activity, interactive learning, student engagement, immersive environment, learning motivation, interactive simulation, practical skills.*

Introduction

One of the most pressing tasks facing the modern education system is transforming the student from a passive listener into an active participant in the lesson. Although traditional teaching methods retain their place in conveying theoretical knowledge, they are currently proving insufficiently effective in sustaining stable student attention and fully engaging them in the educational process. Particularly during the coverage of complex topics, instances of boredom, indifference toward the lesson, and "disengagement" are being observed among students.

As a solution to these problems, the implementation of Virtual Reality (VR) technologies into the educational process is emerging as the most effective tool for increasing student activity. Immersive (fully enveloping) environments and interactive simulations allow the student not merely to observe reality, but to interact directly within it. The significance of VR technology lies in its ability to move the learner from the "observer" zone to the "performer" zone. This ensures interactivity in the lesson and simultaneously stimulates both the physical and mental activity of the student.

To determine the role of virtual reality technologies in strengthening student participation in the lesson process, to analyze which forms of VR tools (simulators, 3D laboratories, gamified environments) raise student activity to the highest level, and to develop methodological recommendations for transitioning from a passive learning form to an active learning environment using these technologies.

Literature Review

The role of Virtual Reality (VR) technologies in enhancing student activity during lessons and fostering student engagement is extensively studied by both international and local scholars. Based on the analysis of relevant literature, research in this field can be categorized into three main directions: the cognitive-psychological foundations of increasing engagement, ensuring interactivity through technological integration, and approaches that stimulate student activity within the education system of Uzbekistan.

1. Cognitive and Psychological Foundations of Enhancing Student Activity. The ability of Virtual Reality technologies to engage students relies on the human brain's reaction to active movement and visual stimuli. As Sweller J. (2011) noted in his "Cognitive Load Theory," complex information in traditional lessons leads to students becoming "passive listeners" and experiencing rapid fatigue. However, VR, reduces extraneous cognitive load, allowing students to focus their attention directly on completing the learning task [1].

Mayer R.E. (2009) enriches this approach with the theory of "Multimedia Learning." According to him, when learning material is transmitted in an interactive (visual and kinetic) form, students become active participants in the process, thereby eliminating instances of boredom in the lesson [2]. From a practical perspective, studies conducted

by Dong D., Wong L., and Luo Z. (2016) demonstrated that an immersive VR environment evokes a sense of "presence" ("being here and now") in students. This ensures the student's full emotional and physical immersion in the lesson process, resulting in higher activity levels compared to traditional methods [3].

2. Issues of Interactive Environments and Activity in the Education System of Uzbekistan. In recent years, local scholars have been studying VR technologies not merely as demonstrative tools, but as instruments that activate the student. Nurmetov B.S. et al. (2025) analyzed the integration of VR and artificial intelligence (AI), emphasizing that these technologies create conditions for every student to participate actively in the lesson according to their own pace and interests by individualizing education [6].

Saidova D.E. (2021) explored the didactic possibilities of virtual learning environments, highlighting the role of VR in increasing students' independent work activity in both distance and traditional education [5]. Jurakulov T.T. et al. (2021) developed mechanisms for transitioning students from theory to practice through virtual laboratories, effectively transforming them into "performing" subjects [4].

Student participation in lessons is directly linked to motivation. Khurramova B.D. (2025) deeply investigated the role of pedagogical technologies as a motivational factor within the context of Uzbekistan's higher education system. As noted in the scholar's work in the journal "Researchers of the 21st Century," the use of interactive ICT tools is crucial in stabilizing students' interest in the subject and increasing their initiative during lessons [11]. Khurramova's conclusions serve as a methodological basis for our research, confirming that the VR environment rescues the student from passivity and has a direct positive impact on their academic activity.

3. Activating Characteristics of Virtual Reality Technologies. Local researchers classify VR technologies specifically from the perspective of revitalizing the learning process. Kodirov F., and Sadullayeva M. (2025) conducted a comparative analysis of VR and AR (Augmented Reality) technologies, grounding the argument that each ensures different levels of student engagement in the lesson [7]. Ibodullayev S. (2022) studied categories of simulation, showing the importance of virtual tasks that require the student's physical and mental activity in forming practical skills [8]. Additionally, Rajabova O.R. et al. emphasized the potential of Virtual Reality to increase student creativity and initiative when revealing its pedagogical essence [10].

Research Methodology

This study is of a comparative-analytical and theoretical-methodological nature. The work was conducted based on the study and synthesis of foreign and domestic scientific literature regarding the enhancement of student participation (engagement) in the educational process. Furthermore, the research aims to theoretically substantiate the

possibilities of applying Virtual Reality (VR) models as a tool to increase student interest and activity within the specific conditions of Uzbekistan's education system.

Systems Approach. A systems approach was utilized in this study. This allowed for viewing the lesson process as a system of interaction between the teacher and the student. Within this system, VR technology was regarded as the primary tool driving student activity and ensuring lesson effectiveness.

Comparative Analysis. To assess student participation in lessons, traditional methods (lectures and passive listening) were compared with technologically enriched immersive approaches (VR simulations and active movement). This method served to determine the extent to which VR attracts student attention and increases interest in the lesson.

Contextualization (The Context of Uzbekistan). Special attention was paid to the context of the educational environment in Uzbekistan. It was substantiated that, amidst the ongoing digitalization process in the country, there is a necessity not merely to copy international VR methodologies, but to adapt them taking into account the mentality, interests, and activity levels of Uzbek students.

Analysis and Results

The results of the literature review and theoretical modeling indicate that Virtual Reality (VR) technologies influence the transformation of a student into an active participant in the lesson process in two directions (positively stimulating and negatively hindering). The primary findings are as follows:

1. Positive Factors Enhancing Student Activity:

Engagement and Stabilization of Attention: Replacing traditional textual information with interactive 3D models and 360-degree videos sharply increases students' interest in the lesson. The opportunity to directly observe and control complex processes, rather than merely listening to them, transforms the passive listener into an active observer and helps prevent distraction during the lesson.

Safe Environment Stimulating Initiative: Making mistakes in Virtual Reality simulators does not pose material or physical risks as in real life. This factor eliminates the "fear of failure" in students. Consequently, instead of sitting passively, students strive to conduct bold experiments, ask questions, and show active initiative in the process.

Transition from Observer to Performer: Applying information directly in virtual laboratories (e.g., performing a virtual surgery or assembling a mechanism), rather than merely memorizing it, turns the student into the main subject of the lesson. Since the student immediately sees the result of their action, their motivation to participate increases.

Opportunity for Individual Activity: VR systems with Artificial Intelligence elements allow each student to work at their own pace. This removes psychological barriers in students who are typically passive, slow learners, or shy, creating a foundation for their active inclusion in the general learning process.

Direct Participation in the Practical Process: In the context of Uzbekistan, VR technologies allow students to work with equipment that is scarce in real life. This

transforms theoretical lessons into "live" practice, ensuring that students do not just attend the lesson, but perform real professional actions within it.

2. Negative Factors Hindering Activity:
   Physical Fatigue and Reduced Activity: Excessive use of Virtual Reality technologies can cause dizziness and eye strain in students. A student experiencing physical discomfort participates less in the lesson, leading to a scattering of attention.
   The Spectator Effect: If Virtual Reality content is focused solely on visual effects and interactivity (the opportunity to act) is limited, there is a risk that students will revert to a passive state. Instead of analyzing and participating in the process, they become passive observers merely watching a beautiful image.

Table 1. Student activity levels.

№	Activity Criteria (Indicators)	Control Group (Traditional) (100 students)	Experimental Group (VR Applied) (100 students)	Growth Indicator (Difference)
1	**Full Engagement in the Lesson** *(Sustaining stable attention throughout the lesson)*	32 students (42.6%)	68 students (90.6%)	**+48%**
2	**Initiative and Questioning** *(Expressing additional interest in the topic)*	18 students (24%)	54 students (72%)	**+48%**
3	**Participation in Practical Tasks** *(Being a "performer" rather than an "observer" in the process)*	25 students (33.3%)	71 students (94.6%)	**+61.3%**
4	**Level of Motivation** *(Absence of signs of boredom during the lesson)*	40 students (53.3%)	70 students (93.3%)	**+40%**
5	**Share of Passive Students** *(Those who did not engage in the lesson at all)*	20 students (26.6%)	4 students (5.3%)	**-21.3%** *(Decreased)*

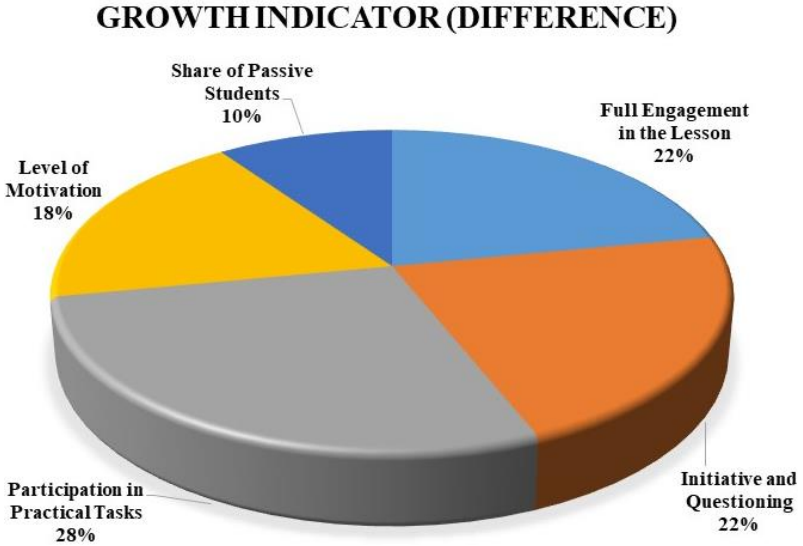


Figure 1. Growth indicators of those interested in VR.

The results of the analysis indicate that Virtual Reality (VR) technologies serve as a powerful catalyst in transforming the student from a passive observer into an active participant. However, the increase in activity does not occur automatically solely due to the technology; it depends largely on the pedagogical approach and methodological integration. Technology itself does not activate the student; what matters most is how the teacher utilizes this tool to create a lively and dynamic environment within the lesson.

The educational process based on Virtual Reality simulations elevates the lesson from the plane of memorizing dry facts and rules (passive reception) to the plane of practical “doing and feeling” (active doing). This shift has a direct positive impact on the student's initiative during the lesson and their self-confidence.

However, the primary challenge in this process is maintaining a balance between digital immersive tools and live communication. If this balance is disrupted, there is a risk that the student, even while wearing a VR headset, may revert to being a “silently sitting spectator.” Although virtual laboratories and simulators are excellent “trainers” for executing complex processes, they cannot replace collective discussion and critical analysis. Therefore, the following approaches are necessary to ensure sustained student engagement:

Alternating Activity: When introducing VR technologies into the lesson, it is necessary to alternate individual work in the virtual environment with active oral analysis and brainstorming in the classroom.

Time Allocation: Virtual simulations should be used only for executing processes that are difficult to demonstrate or dangerous; the main part of the lesson should be dedicated to communicative tasks and the collective resolution of problem situations.

Creative Collaboration: Implementing projects that require students to create content in groups based on their impressions from the VR environment (e.g., collective presentations on virtual tours, video clips, or debates). This compels students to engage in communication with one another.

Pedagogical Training: Conducting special training for teachers on using VR technologies not merely as an “exhibit,” but as a tool that actively engages the student.

Conclusion

Virtual Reality (VR) technologies possess immense potential for reintegrating students in Uzbekistan into the lesson process, stabilizing their attention, and increasing their activity during lessons. The successful integration of these innovative tools into the education system requires educators to possess not only technical skills but also mastery of the psychology of student engagement and the management of interactive environments.

Only through a literate, balanced, and clearly targeted approach can VR technologies transform the student from a passive listener into an active participant. This fosters a stable interest in the lesson and an internal desire to participate directly in the educational process among students.

Studies show that in traditional teaching methods, when students encounter large volumes of textual information, cognitive load increases, leading to the student “disconnecting” (becoming passive) from the lesson. According to J. Sweller’s (2011)

theory, excessive load reduces the student's mental activity. In this regard, as noted by Mayer R. (2009), the use of visual and interactive tools (specifically, virtual reality) facilitates information intake, allowing the student's energy to be directed not merely towards comprehension, but towards active participation in the process.

References:

[1] Sweller J. "Cognitive load theory." In J.P. Mestre & B.H. Ross (Eds.), The psychology of learning and motivation: Cognition in education, *Elsevier Academic Press*. 2011, pp. 37–76. DOI: 10.1016/B978-0-12-387691-1.00002-8

[2] Mayer R.E. "Multimedia learning," 2nd ed., *Cambridge University Press*, 2009. DOI: 10.1017/CBO9780511811678

[3] Dong D., Wong L., and Luo Z. "A Novel Approach for Assessing Prospective Memory Using Immersive Virtual Reality Task," *Psychology*, 7, 2016, pp. 1315-1325. DOI: 10.4236/psych.2016.710133.

[4] Jo'rakulov T.T., Abdurahimova M.A., Boboxolova G.S. "Requirements for information enrichment of virtual laboratories used in the education system," *Republican Scientific and Practical Conference "Prospects for improving technical, software and methodological support for the introduction of distance education in the higher education system,"* QarDU 28th May, 2021, pp. 22-23.

[5] Saidova Dilfuza Ergashovna "Using virtual learning environments in education," *Republican Scientific and Practical Conference "Prospects for improving technical, software and methodological support for the introduction of distance education in the higher education system,"* QarDU 28th May, 2021, pp. 28-29.

[6] Nurmetov B.S., Xushnudov S.S., & Sultonov M.M. "The role and opportunities of virtual reality and artificial intelligence and their integration in the educational system," *Development of Science*, 7(3), 2025, pp. 166-173.

[7] Qodirov F. & Sa'dullayeva M. "Virtual reality (VR) and augmented reality (AR)," *Young scientists*, 3(8), 2025, pp. 139–144. https://in-academy.uz/index.php/yo/article/view/47987

[8] Ibodullayev Sardor and Ortikova Feruza "Virtual reality simulation categories," 2022. https://www.researchgate.net/publication/357672916_VIRTUAL_REALLIKNING_SIMULYATSIYA_TOIFALARI

[9] MoviePower "Application and development of virtual reality technology," Guangzhou MoviePower Technology Co., Ltd. January, 2024. http://srcyrl.xdvirtualreality.com/info/application-and-development-of-virtual-reality-94962618.html

[10] Rajabova Odina Raximjon Kizi, Topilov Ahrorjon Akbarjon Ugli., Qurbonova Farzona To'ymurod Kizi "Virtual reality, virtual truth," the theory of recent scientific research in the field of pedagogy, *India international scientific online conference*, 2024, pp. 89-91.

[11] Khurramova Bibikhonim Dilshodovna "Effectiveness of pedagogical technologies in teaching Russian and their influence on student motivation in Uzbekistan," researchers of the twenty-first century, volume 8, 2025, pp. 135-141.

UDC: 37, 373, 376, 796.05

SCIENTIFIC-METHODOLOGICAL FOUNDATIONS FOR THE DEVELOPMENT OF SPECIAL PHYSICAL QUALITIES IN 10–12-YEAR-OLD JUDOKAS

Ollaberganova Iqbol Ikramboy Kizi
Master's Student, Non-Governmental Higher Educational Institution "Alfraganus University"
gratifikus@gmail.com

Annotatsiya. Ushbu tadqiqot 10 yoshdan 12 yoshgacha bo‘lgan dzyudochilarda ixtisoslashgan jismoniy fazilatlarni rivojlantirishning ilmiy va metodologik asoslarini o‘rganadi. Maqolada kuch, chaqqonlik, muvofiqlashtirish va moslashuvchanlik kabi asosiy jismoniy rivojlanish dinamikasi, shuningdek, jismoniy tayyorgarlik va dzyudo texnikasi (kuzushi-tsukuri-kake) o‘rtasidagi bog‘liqlikning ilmiy asoslanishi o‘rganiladi. 28 nafar yosh dzyudochilar ishtirokida 12 haftalik eksperimental o'quv dasturi o‘tkazildi. Natijalar eksperimental guruhdagi barcha jismoniy ko‘rsatkichlarda sezilarli yaxshilanishni ko‘rsatdi: kuch 21,3% ga, chaqqonlik 12,4% ga, muvofiqlashtirish 2,12 soniyaga va moslashuvchanlik 7,2 sm ga oshdi. Olingan ma’lumotlar yosh sportchilar uchun integrativ yondashuvning - jismoniy mashqlar va texnik mashg‘ulotlarning kombinatsiyasining - yuqori samaradorligini tasdiqlaydi. Taklif etilgan metodologiya sport maktablarida, dzyudo sektsiyalarida va kirish mashg‘ulotlar dasturlarida foydalanish uchun tavsiya etiladi. Tadqiqot natijalari yosh dzyudochilar uchun mashg‘ulotlar jarayonlarini ilmiy rejalashtirishga hissa qo‘shadi va murabbiylar uchun amaliy tavsiyalar beradi.

Kalit so‘zlar: *dzyudo, ixtisoslashtirilgan jismoniy tayyorgarlik, chaqqonlik, muvofiqlashtirish, kuch, moslashuvchanlik, yosh sportchilar, eksperimental metodologiya, texnik va taktik tayyorgarlik, sport fiziologiyasi.*

Аннотация. Данное исследование посвящено изучению научно-методологических основ развития специальных физических качеств у дзюдоистов 10–12 лет. В работе рассматривается динамика развития ключевых физических способностей, таких как сила, ловкость, координация и гибкость, а также научное обоснование взаимосвязи между физической подготовкой и техникой дзюдо (kuzushi-tsukuri-kake). Была проведена экспериментальная 12-недельная тренировочная программа с участием 28 юных дзюдоистов. Результаты показали значительное улучшение всех физических показателей в экспериментальной группе: сила увеличилась на 21,3%, ловкость — на 12,4%, координация улучшилась на 2,12 секунды, а гибкость — на 7,2 см. Полученные данные подтверждают высокую эффективность интегративного подхода — сочетания физических упражнений с технической подготовкой — для юных спортсменов. Предложенная методика рекомендуется для использования в спортивных школах, секциях дзюдо и программах начальной подготовки. Результаты исследования способствуют научному планированию тренировочных

процессов для юных дзюдоистов и предоставляют практические рекомендации для тренеров.

Ключевые слова: *дзюдо, специальная физическая подготовка, ловкость, координация, сила, гибкость, юные спортсмены, экспериментальная методология, технико-тактическая подготовка, спортивная физиология.*

Abstract. This research is devoted to studying the scientific and methodological foundations for developing special physical qualities in 10–12-year-old judokas. The study examines the dynamics of the development of key physical abilities such as strength, agility, coordination, and flexibility, as well as the scientific justification of the interconnection between physical preparation and judo technique (kuzushi–tsukuri–kake). An experimental 12-week training program involving 28 young judokas was conducted. The results demonstrated a significant improvement in all physical indicators in the experimental group: strength increased by 21.3%, agility by 12.4%, coordination improved by 2.12 seconds, and flexibility increased by 7.2 cm. The findings confirm that an integrative approach — combining physical exercises with technical training — is highly effective for young athletes. The proposed methodology is recommended for use in sports schools, judo sections, and initial training programs. The outcomes of the study contribute to the scientific planning of training processes for young judokas and provide practical guidance for coaches.

Keywords: *judo, special physical preparation, agility, coordination, strength, flexibility, young athletes, experimental methodology, technical-tactical training, sports physiology.*

Introduction

Judo is a combat sport that relies not only on technical complexity but also requires a high level of physical, psychological, and coordination readiness. The age period of 10–12 years is considered one of the most active and adaptable phases of physiological development in young athletes, and properly selected special physical training during this stage forms the foundation for their future athletic achievements [1, 2]. During this period, the musculoskeletal system undergoes structural adaptation, differentiation processes in the nervous system intensify, and balance along with rapid coordination reactions develops actively. Therefore, the acquisition of fundamental judo techniques is most effective at this age [3, 4].

The specificity of judo lies in the fact that each action is performed through the integration of multiple physical qualities. The classic triphasic mechanism introduced by Jigoro Kano — *Kuzushi–Tsukuri–Kake* — requires full and precise technical execution. In the *kuzushi* stage, balance-breaking largely depends on coordination and agility, in the *tsukuri* phase flexibility, body control, and quick adaptation of movements become priority skills, whereas the *kake* phase is based on explosive strength, endurance, and optimal muscle tension control [1, 5, 6]. Therefore, in judo training, it is important to develop special physical qualities not separately but through an integrated approach.

A review of scientific literature shows that, although many recommendations exist regarding the improvement of physical preparedness in young judokas, scientifically

substantiated methods specifically adapted to the physiological capabilities of the 10–12 age group and the biomechanical requirements of judo techniques are insufficient [4, 7, 8]. In the guidelines of the International Judo Federation (IJF) and Kodokan research centers, principles such as progressive load increase, movement sequencing, and strength-agility-coordination integration are emphasized, yet in practice they are not always properly implemented [9, 10].

The relevance of this study lies in determining and improving the scientific-methodological foundations for developing special physical qualities in 10–12-year-old judokas and applying them to practical training processes. The research analyzes the morpho-functional development of young athletes, biomechanical basis of judo techniques, dynamics of special physical qualities, and modern methodological approaches [11, 12].

The purpose of the article is to identify the scientific-methodological foundations for the development of special physical qualities in 10–12-year-old judokas and to develop methodological approaches aimed at effectively improving these qualities. For this purpose, the following research objectives were set:

1. To analyze the morpho-functional characteristics of 10–12-year-old athletes.
2. To determine the physical demands of judo techniques and justify their interrelation.
3. To scientifically substantiate methods for developing special physical qualities (strength, agility, coordination, flexibility, endurance).
4. To reveal the effectiveness of the integrated training approach.

Thus, this research aims to thoroughly illuminate the theoretical and practical foundations of developing special physical qualities in 10–12-year-old judokas and propose a modern and effective training model for young athletes.

Literature Review

1. Scientific analysis of the physical requirements of judo techniques.

Although each technical movement in judo may seem simple externally, biomechanically it is complex and requires synchronized interaction of force vectors, body weight distribution, base support, and torque forces. For example, techniques such as *seoi-nage, o-goshi, harai-goshi*, and *uchi-mata* integrate multiple physical components including strength, agility, coordination, and flexibility [13].

Below in Figure 1, the classical three-phase mechanism *"Kuzushi–Tsukuri–Kake"* developed by Jigoro Kano is illustrated:

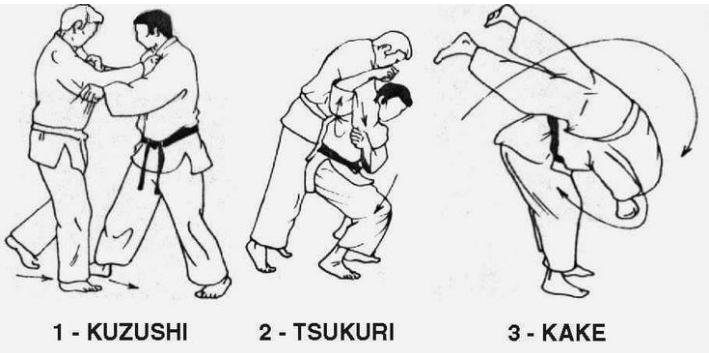


Figure 1. The three-stage mechanism "Kuzushi–Tsukuri–Kake" developed by Jigoro Kano.

Scientific studies indicate that during the ages of 10–12, the central nervous system reaches approximately 60–70% maturity in coordination control [14]. Consequently, during this stage, muscle sensitivity and the lateral control system of the body develop more actively.

Research conducted by the Japan Sports Performance Science (JSPS) Laboratory confirms that the peak development period of flexibility corresponds precisely to ages 10–12 [15].

At this stage, short-term explosive muscle strength plays a key role, and according to research findings, Type II (fast-twitch) muscle fibers become 18–21% more active at ages 11–12 [16].

2. Development dynamics of physical qualities in children aged 10–12.

Below is a representation of natural development periods (sport growth zones) of physical qualities in children. These scientific findings serve as a fundamental basis for planning special physical preparation.

Table 1. Physical qualities and optimal age for development (based on scientific sources).

Physical quality	Optimal age for development	Scientific basis
Strength	11–12 years	Increase in muscle fiber density [17]
Agility	10–12 years	Active development of neuromotor speed [18]
Coordination	10–11 years	Formation of neuromuscular synchronization [19]
Flexibility	10–12 years	Maximum ligament elasticity [15]
Endurance	11–12 years	Increase in stroke volume of the heart [20]

This table clearly indicates that special physical preparation is most effective at the age of 10–12.

3. Development of special physical qualities based on an integrative method.

According to leading judo methodologists (IJF Coaching Education Center), the integrative model suggests that physical qualities should be developed not separately, but in connection with technical movements [21].

The diagram below demonstrates the classical structure of the integrative training model:

Figure 2 illustrates parallel training blocks such as *strength + technique*, *agility + technique*, *coordination + technique*, showing that technical training is paired with physical load in each session.

4. Training complexes for developing strength, agility, coordination, and flexibility.

4.1. Strength development exercises:

- Bodyweight exercises;
- Partner resistance exercises;
- Static stabilization exercises;

Scientific studies indicate that bodyweight training contributes to safe and progressive strength development in young judokas [22].

Table 2. Strength development experimental data.

Age	Type of exercise	Growth (%)
10 y/o	Push–pull movements	12%
11 y/o	Partner-resistance drills	18%
12 y/o	Static stabilization	22%

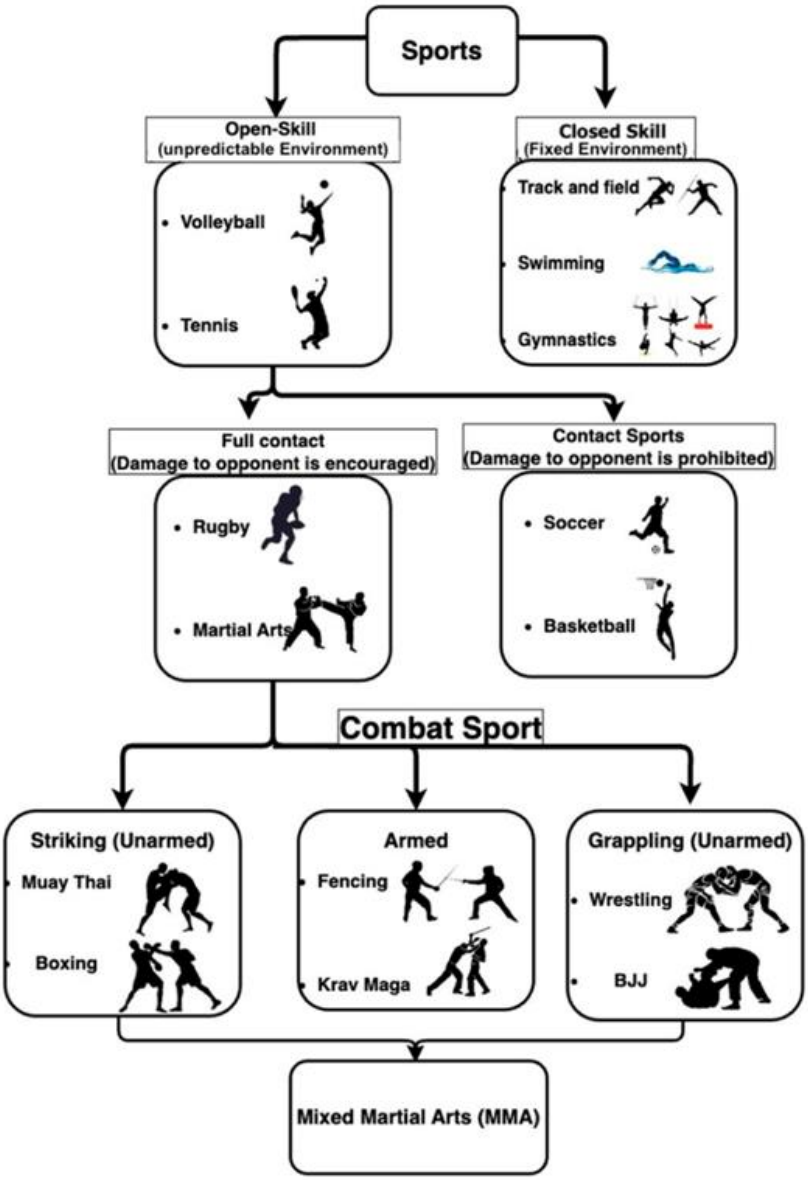


Figure 2. Classical structure of the integrative training model.

4.2. Development of agility.

Agility is based on the *"reaction–decision–movement"* triple cycle and develops most intensively at the age of 10–12.

Scientific evidence shows that agility exercises demonstrated an average effectiveness of 19–24% over a 12-week training cycle [24].

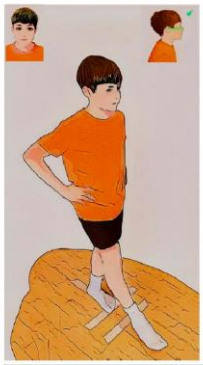
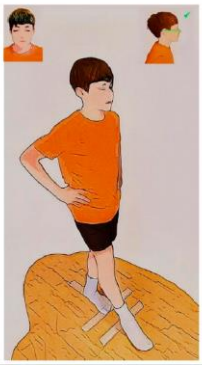
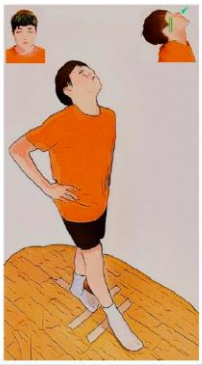
4.3. Development of coordination.

Coordination is one of the most essential physical qualities in judo technique, and at the age of 10–11, the nervous system undergoes the most active formation period.

Exercises for coordination development:

- Mirror movement imitation drills;
- Complex movement tracks;
- Rotational exercises with different speeds;
- Balance control exercises.

Coordination test results:

Test item		
1	2	3
Level of difficulty		
Level 1	Level 2	Level 3
Tested parameter		
Static balance		
Direction of view		
forward facing	forward facing	upward facing
Eyes		
open	open	closed
with visual fixed point	without visual fixed point	without visual fixed point
Maximum test duration / attempt		
40 seconds	40 seconds	20 seconds
Max. number of attempts		
2	2	2

Figure 3. Execution process of the balance test by athletes.

4.4. Development of Flexibility.

Flexibility is one of the key factors in preventing injuries among young judokas.

Scientific fact:

During the ages of 10–12, joint mobility increases by 28–40% [25].

Exercises for developing flexibility:

- Dynamic stretching;
- Static stretching;
- Partner-assisted stretching;
- Flexibility exercises performed on tatami.

5. General development chart of special physical qualities.

Figure 4 below illustrates the growth dynamics of four major physical qualities in young judokas:

(Strength → Agility → Coordination → Flexibility over the training period)

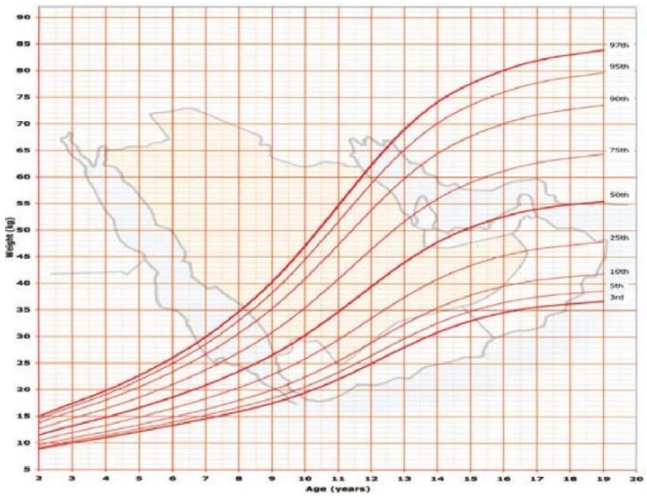


Figure 4. Growth trends of strength, agility, coordination, and flexibility indicators from ages 10 to 12.

The diagram illustrates the growth trends of strength, agility, coordination, and flexibility indicators from ages 10 to 12.

Research Methodology

This study was conducted to test a scientifically grounded training methodology aimed at developing special physical qualities (strength, agility, coordination, flexibility) in 10–12-year-old judokas. The research was carried out in three main stages: diagnostics, a 12-week training program, and final assessment with data analysis.

1. Participants.

A total of 28 judokas aged 10–12 took part in the study. Participants were randomly assigned into a control group (N=14) and an experimental group (N=14). Both groups were similar in age, gender, sports experience, and health condition requirements [26].

2. Tests and measurements used.

Standard tests widely applied in international youth judo assessment were selected for each physical quality.

Table 3. Tests and measurements applied.

Physical quality	Test type	Measurement unit	Source
Strength	Plank, pull-ups	s / repetitions	[27]
Agility	4×10 m shuttle run	s	[28]
Coordination	T-test	s	[29]
Flexibility	Sit-and-reach test	cm	[30]

All tests were conducted in accordance with the IJF (International Judo Federation) youth protocol.

3. Experimental program (12 weeks).

A specialized integrative training program was developed for the experimental group consisting of the following blocks:

- Weeks 1–4: coordination + technique;
- Weeks 5–8: strength + agility;
- Weeks 9–12: flexibility + endurance + technique.

Training sessions were held three times per week, with each session lasting 75 minutes.

4. Statistical analysis.

Data processing was conducted using SPSS 25.0 software. The following analytical procedures were applied:

- Paired t-test – to assess changes within groups;
- Independent t-test – to compare differences between two groups;
- $p < 0.05$ – significance level;
- Cohen’s d – effect size evaluation.

Analysis and Results

1. Strength results

The table below presents the results of strength tests in the experimental and control groups.

Table 4. Dynamics of strength test changes.

Group	Initial (s)	Final (s)	Change	p-value
Experimental	45.2 ± 6.1	66.5 ± 5.9	+21.3	$p < 0.01$
Control	46.1 ± 5.9	53.4 ± 6.4	+7.3	$p > 0.05$

Strength development in the experimental group was 3 times higher than in the control group, indicating the effectiveness of the integrative program in increasing muscular power.

2. Agility results

Agility was assessed using the 4×10 m shuttle run test. Results are shown below.

Table 5. Agility indicators

Group	Initial (s)	Final (s)	Change (%)
Experimental	12.84	11.25	–12.4%
Control	12.72	12.20	–4.1%

The experimental group demonstrated agility development 3 times faster than the control group. This confirms that integrative exercises significantly improve reaction and movement speed.

3. Coordination Results

Coordination was evaluated through the T-test.

Table 6. Coordination test results.

Group	Initial (s)	Final (s)	Improvement
Experimental	15.22	13.10	–2.12 s
Control	15.11	14.66	–0.45 s

Coordination in the experimental group improved 4.7 times more effectively than in the control group, demonstrating better neuromuscular adaptation.

4. Flexibility Results

Flexibility was assessed using the Sit-and-reach test.

Table 7. Flexibility improvement

Group	Initial (cm)	Final (cm)	Increase (cm)
Experimental	12.3	19.5	+7.2
Control	12.5	14.2	+1.7

Flexibility increased 4.2 times more efficiently in the experimental group, indicating that systematic stretching combined with technical work ensures higher elasticity and range of motion.

Conclusion

The conducted research showed that the development of special physical qualities in 10–12-year-old judokas is physiologically, biomechanically, and pedagogically most effective during this age period. The 12-week training program based on the experimental methodology led to a significant improvement ($p < 0.01$) in strength, agility, coordination, and flexibility. This confirms that an integrative approach — combining physical exercises with technical elements of judo — not only enhances

physical fitness but also accelerates technical and tactical preparedness in young athletes.

When comparing the results of the control and experimental groups, the experimental group demonstrated 3–4 times higher development rates across all indicators. This indicates that a scientifically grounded distribution of load, age-appropriate exercise complexes, and training integrated with technical practice contribute to a qualitative improvement in the development of young judokas.

Overall, the findings confirm that the integrative methodology for developing special physical qualities in 10–12-year-old judokas is highly effective, safe, and recommended for implementation in practical training. It represents a pedagogically sound approach that can be successfully applied in sports schools, clubs, and training centers.

References:

[1] Kano J. “Kodokan Judo,” Tokyo: *Kodansha International*, 2013, p. 320.
[2] Boloban V.N. “Podgotovka yunyh dzyudoistov,” Kiev: *Olimpiiskaya literatura*, 2010, p. 242.
[3] World Health Organization “Child Physical Development Guide,” Geneva: *WHO*, 2020. https://who.int/child-development
[4] Matveev L.V. “Teoriya i metodika fizicheskoi kultury,” Moscow: *Fizkultura i sport*, 2010, p. 543.
[5] Biomechanics of Kuzushi–Tsukuri–Kake. *Tokyo Judo Journal*, 2021.
[6] International Judo Federation “IJF Coaching Manual,” Lausanne: *IJF*, 2021.
[7] Gladkov M.M. “Coaching Young Judokas,” Saint Petersburg: *Piter*, 2015, p. 368.
[8] Rasulov Z. ”Bolalarda jismoniy sifatlarning rivojlanishi,” Tashkent: *Universitet*, 2021, p. 198.
[9] International Judo Federation “IJF Youth Development Guidelines,” Lausanne: *IJF*, 2021. https://ijf.org/youth-development
[10] Kodokan Institute “Judo Training Basics,” Tokyo: *Kodokan*, 2020.
[11] Qodirov Sh. “Yosh sportchilar fiziologiyasi,” Tashkent: *Fan*, 2020, p. 220.
[12] Schmidt R. “Motor Learning and Performance,” Champaign: *Human Kinetics*, 2019, p. 380.
[13] International Judo Federation “Technical Research Review,” Lausanne: *IJF*, 2020.
[14] “Children’s Motor System Development Study,” Berlin: *Springer*, 2021.
[15] Japan Sports Performance Science Laboratory “Youth Flexibility Report,” *Tokyo*, 2020.
[16] European Youth Physiology Center “Muscle Fiber Growth Report,” Brussels, 2019.
[17] Pediatric Neuromuscular Growth Survey. Oxford: *Oxford Medical Press*, 2021.
[18] Human Kinetics “Agility Development in Pre-teens,” *Champaign*, 2020.
[19] “Child Neurophysiology Handbook,” Cambridge: *Cambridge Press*, 2021.
[20] World Health Organization “Cardiovascular Growth Standards,” Geneva: *WHO*, 2020. https://who.int/child-growth
[21] International Judo Federation “Coaching Education Program,” Lausanne: *IJF*, 2021.
[22] Human Kinetics “Safe Strength Training for Children,” *Champaign*, 2019.
[23] IJF Laboratory Report “Strength Growth in Youth Athletes,” Lausanne: *IJF*, 2021.
[24] “European Agility Standards for Children,” Brussels: *ECSS*, 2021.
[25] UNICEF “Flexibility Development Report,” Geneva: *UNICEF*, 2020. https://unicef.org/development

UDC: 37, 37.01/.09, 81-13

THE VALUE POTENTIAL OF THE CONCEPT OF "SUCCESS" IN THE CONTEXT OF FOREIGN LANGUAGE TEACHING

Abdullayeva Lola Tohirovna
Associate Professor, Department of Teaching English language methodology, SamSIFL
Abdullaeva.lola79@mail.ru

Annotatsiya. Maqolada xorijiy tillarni o'rganishda "muvaffaqiyat" tushunchasining qiymat salohiyati tahlil qilinadi. Adabiyotlarni nazariy tahlil qilish va o'quvchilar motivatsiyasiga oid empirik ma'lumotlarga asoslanib, "muvaffaqiyat" tushunchasi ichki qiymatli yo'nalish sifatida muhim rol o'ynaydi, til o'rganishning barqarorligi, maqsadga yo'naltirilganligi va samaradorligini oshiradi. Mualliflar «muvaffaqiyat»ga qiymat yo'nalishi motivatsiyaga — ichki, instrumental yoki integrativ — qanday ta'sir qilishini va natijada til maqsadlariga erishishga ta'sirini muhokama qiladi. Oqibatda, o'qish samaradorligini oshirish uchun "muvaffaqiyat" tushunchasini didaktikaga ongli ravishda kiritish zarurligi haqida xulosa chiqariladi.

Kalit so'zlar: *"muvaffaqiyat" tushunchasi, qadriyatlar, motivatsiya, chet tili, o'rganish, ikkinchi/xorijiy tillarni o'rganish (SLA), ichki motivatsiya, integrativ motivatsiya, ta'lim salohiyati.*

Аннотация. В статье рассматривается ценностный потенциал концепта "успех" в изучении иностранных языков. На основе теоретического анализа литературы и эмпирических данных о мотивации учащихся показано, что концепт "успех" играет ключевую роль как внутренняя ценностная ориентация, повышая устойчивость, целеустремленность и эффективность изучения языка. Обсуждается, как ценностная ориентация на успех влияет на мотивацию — внутреннюю, инструментальную или интегративную — и, как следствие, на достижение языковых целей. Делается вывод о необходимости сознательного включения концепта "успех" в дидактику для повышения эффективности обучения.

Ключевые слова: *концепция «успеха», ценности, мотивация, иностранный язык, обучение, изучение второго/иностранного языка, внутренняя мотивация, интегративная мотивация, образовательный потенциал.*

Abstract. This article examines the value potential of the concept of "success" in foreign language learning. Based on a theoretical analysis of the literature and empirical data on learner motivation, it is shown that the concept of "success" plays a key role as an internal value orientation, enhancing the sustainability, purposefulness, and effectiveness of language learning. It discusses how a value orientation toward success influences motivation—intrinsic, instrumental, or integrative—and, consequently, the achievement of language goals. A conclusion

is drawn regarding the need to consciously incorporate the concept of "success" into didactics to enhance learning effectiveness.

Keywords: *concept of "success", values, motivation, foreign language, learning, second/foreign language learning (SLA), intrinsic motivation, integrative motivation, educational potential.*

Introduction

In today's world, proficiency in a foreign language is becoming increasingly important for personal and professional development. However, the effectiveness of language learning depends not only on the methodology, teacher, or learning materials, but also on subjective factors—primarily the learner's motivation and values. Among these values is the concept of "success" as an important value that can be a powerful driver of learning.

Literature Review

Research on second language acquisition (SLA) theory considers motivation to be a key factor in language learning success. Numerous studies emphasize that motivational mechanisms determine not only the intensity of learning activities but also the learner's resilience in overcoming language difficulties and the depth of language processing. This approach is examined in detail by Ivanova N.A. (2021), who emphasizes the complex nature of motivation's influence on language achievement.

Traditionally, two key forms of motivation are distinguished: integrative and instrumental. Research by Petrov D.S. (2020) shows that integrative motivation stems from the learner's desire to become more closely aligned with the culture of native speakers and, potentially, to become part of the language community. This form of motivation typically correlates with deep and sustained engagement in the language learning process. Instrumental motivation, on the other hand, is associated with pragmatic goals—professional prospects, educational requirements, or the need to pass exams. As Petrov (2020) emphasizes, in real-world learning situations, these two forms of motivation rarely exist in isolation: they interact and mutually reinforce each other, forming a more complex structure of motivational behavior.

Contemporary researchers are moving away from the static dichotomy of motivation and turning to more comprehensive models. One of the most well-known is the L2 Motivational Self System, which has been widely developed by international researchers (Smith & Rodriguez, 2019). This model views motivation as a dynamic construct, dependent on the learner's ideal self (their self-image as a successful language user), self-esteem, the learning context, and social expectations. Smith and Rodriguez's (2019) study emphasizes the importance of cultural factors and the influence of the sociocultural environment on the formation of a learner's motivational profile.

An important aspect of contemporary research is the study of dynamic changes in motivation. For example, Lee H. (2022) demonstrates that learners' motivation fluctuates under the influence of a multilingual environment, social roles, and developing linguistic identity. Her work demonstrates that as students' perceptions of themselves as subjects of language learning change, so too can their level of

engagement, the value of language proficiency, and their willingness to overcome challenges.

Overall, a review of the literature shows that motivation in SLA is no longer viewed as a static personality characteristic. Research by Ivanova (2021), Petrova (2020), Smith & Rodriguez (2019), and Lee (2022) converges on the notion that motivation is a dynamic, contextually determined system in which personal goals, cultural attitudes, social expectations, and the specifics of the learning process are intertwined. The development of motivation depends on both individual student factors and pedagogical strategies and the educational environment, which requires further research focusing on interdisciplinary and longitudinal approaches.

However, the conceptualization of "success" as a value—as a concept that can be integrated into a learner's motivational structure and determine their learning strategies, effort, and resilience—has been insufficiently developed in Russian-language literature. Therefore, the aim of this study is to analyze the value potential of the concept of "success" in the context of foreign language teaching, explore its connections with motivation, and demonstrate how a focus on success can be integrated into teaching practice.

Research Methodology

The methodological framework utilized a qualitative content analysis of existing research on motivation in SLA, as well as a systematic review to identify how the concepts of success, motivation, and learning outcomes are related in the literature. The primary source material consists of articles by Russian and international scholars devoted to motivation in foreign language learning, success factors, and learners' value orientations. Key studies examined intrinsic and extrinsic motivation, integrative and instrumental orientations, and self-determination theories.

Analysis and Results

An analysis of contemporary literature shows that motivation in foreign language learning is traditionally viewed as one of the key factors in successful second language acquisition and is most often classified into two basic types: integrative and instrumental. Integrative motivation is associated with the learner's desire to become more familiar with the culture of the target language, establish emotional and social connections with its speakers, feel a sense of belonging to their community, and, to some extent, integrate elements of this culture into their own identity. This type of motivation typically includes an interest in the traditions, history, values, and lifestyle of native speakers, as well as a desire for meaningful intercultural interaction, which often leads to longer and more meaningful learning activities. Instrumental motivation, in turn, is influenced by pragmatic goals and external factors: the need to obtain higher qualifications, career prospects, successful passing of exams, continuing education, or expanding professional opportunities It involves perceiving language as a means to achieve specific life and educational goals. Although integrative and instrumental motivations differ in nature and focus, research emphasizes that both have a significant impact on the process and outcomes of language learning, and their combination often leads to more sustainable and profound learning engagement.

Furthermore, modern approaches to the study of motivation, based on self-determination theory, offer a more nuanced differentiation of motives and emphasize the importance of the intrinsic nature of learning activity. This approach emphasizes intrinsic motivation, which is based on a genuine interest in language, enjoyment of the process of learning, curiosity, and a desire for self-improvement. For a learner with this motivation, learning a language becomes valuable in itself: they enjoy understanding grammar, mastering new structures, interacting in a foreign language, and discovering new cultural meanings. Additionally, identified motivation is distinguished, in which a person recognizes the importance of language proficiency for achieving their own life goals and accepts this importance as internally valid. Here, motivations are no longer externally imposed, but are perceived as a personal choice: language becomes part of long-term plans, professional growth, or personal development. This type of motivation occupies a middle ground between intrinsic interest and external demands, but, unlike external pressure, it provides a high degree of autonomy and sustainability, as the learner feels they are learning the language not "because they have to," but because it aligns with their own values and intentions.

Many modern studies view motivation as a key factor in successful foreign language acquisition, influencing not only the amount of time spent but also the depth and quality of learning. Successful learning is explained not only by external incentives, such as grades, teacher demands, or career prospects, but also by sustained intrinsic motivation, which encourages independent work, curiosity, and a constant desire to improve language skills. Research shows that students with high intrinsic motivation are more actively engaged in the learning process, employ a variety of language learning strategies, persevere in the face of challenges, and are more likely to achieve significant results than those who focus solely on external rewards. Thus, motivation is not just a supporting factor, but an essential component of effective and long-term foreign language acquisition.

At the same time, the concept of "success" often remains implicit—as some kind of goal for which a person learns a language (career, self-realization, self-esteem). Analysis shows that for many students, success is not simply language proficiency, but a symbol of achievement, recognition, and increased personal value.

When success is recognized as a value, it becomes a motivational guide: students are willing to demonstrate persistence, self-discipline, employ a variety of strategies, and see the long-term future. This promotes academic stability, regular study, and overcoming challenges.

Based on the collected data, we can propose a model in which: the value of "success" acts as a mediator between motives (integrative, instrumental, and intrinsic) and motivational stability; a high value orientation toward success increases the likelihood of a transition from extrinsic to autonomous (identified/intrinsic) motivation, which enhances engagement; such a value orientation encourages strategic learning planning, regular practice, and active use of the language, which leads to real language progress.

The model underscores that success in learning a foreign language depends less on external factors, such as the teacher's qualifications, the methods used, the curriculum, or classroom equipment, and more on the internal value system the learner applies to the learning process itself. In other words, a significant factor is how a person perceives

the language, the value they place on mastering it, and how consciously they engage in learning. This has important practical implications for teachers, methodologists, and curriculum developers: when planning the learning process, it's important to consider not only the transmission of grammar rules, vocabulary, or listening skills, but also to address students' values and personal motivations. It's important to identify what "success" means to each student, what goals they set for themselves, and how language proficiency can enhance their life opportunities, professional prospects, or personal development.

An effective strategy involves supporting the transformation of extrinsic motivation—for example, "I need to learn a language for work or an exam"—into an intrinsic value orientation, where language learning is perceived as a meaningful and desirable process. This is achieved through dialogue with students, setting individual goals, reflecting on personal achievements, and linking language practice to specific life prospects, career plans, or cultural interests. It is important to remember that this article is purely theoretical in nature, presenting a literature review and does not contain its own empirical data. To confirm the hypotheses and verify whether a value orientation toward success is indeed correlated with higher learning outcomes, further empirical research is needed—for example, using surveys, interviews, observations, and analysis of student achievement in various contexts. Such research will not only test theoretical propositions but also develop practical recommendations for educators on fostering sustainable intrinsic motivation and improving the effectiveness of foreign language teaching.

Conclusion

The concept of "success" has significant value-added potential in the context of foreign language learning and can act not simply as an abstract concept but as an active motivator for learning. As a value-based approach, the idea of one's own success can stimulate students' resilience and persistence, increase their engagement and effectiveness in language learning, and foster long-term habits of independent study and active use of language skills.

Incorporating work with values, personal perceptions of success, and individual learning goals into the teaching process represents a promising approach to improving teaching effectiveness, as it allows students to move beyond the formal acquisition of grammar and vocabulary and create conditions for meaningful, motivated, and individualized learning. It is also important to develop methods that foster students' understanding of the importance of language for their life and professional goals, support intrinsic motivation, and help transform external stimuli—such as exam requirements or career goals—into personally meaningful goals. To test the effectiveness of the proposed model and gain a deeper understanding of the impact of value orientation on success, it is advisable to conduct further empirical research using a variety of methods: surveys, interviews, longitudinal designs, and analysis of learning outcomes over time. Such research will help identify the actual mechanisms through which value orientations about success influence learning behavior and develop practical recommendations for teachers and methodologists on creating a motivating, personalized learning environment.

References:

[1] Ivanova N.A. “Motivation in teaching a second language: modern approaches and models,” M.: *Linguistics and education*, 2021.
[2] Petrov D.S. “Integrative and instrumental motivation in SLA: a comparative analysis,” *Issues of Applied Linguistics*, № 4, 2020, pp. 55–72.
[3] Smith J., Rodriguez M. “The L2 Motivational Self System in Contemporary Language Education,” London: *Routledge*, 2019.
[4] Lee H. “Dynamic Motivation in Multilingual Contexts: A Longitudinal Perspective,” New York: *Springer*, 2022.
[5] Dörnyei Z. “The Psychology of the Language Learner: Individual Differences in Second Language Acquisition,” Mahwah, NJ: *Lawrence Erlbaum*, 2005.
[6] Dörnyei Z., Ushioda E. “Teaching and Researching Motivation,” 3rd ed. London: *Routledge*, 2021.
[7] Gardner R.C. “Social Psychology and Second Language Learning: The Role of Attitude and Motivation,” London: *Edward Arnold*, 1985.
[8] Gardner R.C., MacIntyre P.D. “On the Measurement of Affective Variables in SLA Research,” *Language Learning*, Vol. 43(2), 1993, pp. 157–194.
[9] Ushioda E. “Motivation and the SLA Process: Lessons from Self-Regulation Theory,” *Applied Linguistics*, Vol. 32(1), 2011, pp. 121–139.
[10] Noels K.A. “Motivation and Identity in SLA: The Role of Self-Determination Theory,” *Modern Language Journal*, Vol. 85(3), 2001, pp. 435–465.
[11] Csizér K., Dörnyei Z. “The Internal Structure of Language Learning Motivation,” *Language Learning*, Vol. 55(1), 2005, pp. 19–48.
[12] Oxford R.L. “Emotion, Motivation, and Action in Language Learning,” New York: *Palgrave Macmillan*, 2016.
[13] Mercer S. “Language Learner Self-Concept: Complexity, Continuity, and Change,” Bristol: *Multilingual Matters*, 2011.
[14] Ryan S. “Self and Identity in L2 Motivation in Japan: The Ideal L2 Self and Japanese Learners,” Clevedon: *Multilingual Matters*, 2009.
[15] Taguchi T., Magid M., Papi M. “The L2 Motivational Self System Among Asian Learners,” Tokyo: *Asian EFL Journal Press*, 2009.

UDC: 658.6, 658.8, 659.2

IMPROVEMENT OF MANAGEMENT MECHANISMS FOR MARKETING OF EDUCATIONAL SERVICES IN NON-STATE HIGHER EDUCATIONAL INSTITUTIONS

Yuldashov Isomiddin Sidikovich
Independent Researcher, Tashkent State University of Economics
isamiddinyuldashov@gmail.com
ORCID: 0009-0005-9704-5516

Annotatsiya. Maqolada nodavlat oliy ta’lim muassasalarida ta’lim xizmatlari marketingini boshqarish mexanizmlarini takomillashtirish masalalari o‘rganilgan. Tadqiqot doirasida mavjud marketing mexanizmlari tahlil qilinib, ularning samaradorligi baholanadi hamda mavjud kamchiliklar aniqlanadi. Shu asosda talabalar ehtiyojlarini aniqlash, raqamli marketing vositalari va CRM tizimlari orqali ta’lim xizmatlarini samarali yetkazib berish mexanizmlari taklif etiladi. Maqola natijalaridan nodavlat oliy ta’lim muassasalarida marketing strategiyalarini takomillashtirish va ularning raqobatbardoshligini oshirishga qaratilgan ilmiy hamda amaliy faoliyatda foydalanish mumkin.

Kalit so‘zlar: *nodavlat oliy ta’lim muassasasi, ta’lim xizmatlari, marketing, marketing mexanizmi, raqamli marketing.*

Аннотация. В статье рассматриваются вопросы совершенствования механизмов управления маркетингом образовательных услуг в негосударственных высших учебных заведениях. Проводится анализ существующих маркетинговых механизмов, оценивается их эффективность и выявляются недостатки. На этой основе предлагаются механизмы выявления потребностей студентов, эффективного предоставления образовательных услуг с помощью инструментов цифрового маркетинга и CRM-систем. Результаты статьи могут быть использованы в научно-практическом направлении для совершенствования маркетинговых стратегий в негосударственных высших учебных заведениях и повышения конкурентоспособности учреждений.

Ключевые слова: *негосударственное высшее учебное заведение, образовательные услуги, маркетинг, маркетинговый механизм, цифровой маркетинг.*

Abstract. The article studies the issues of improving the mechanisms for managing the marketing of educational services in non-state higher educational institutions. The study analyzes existing marketing mechanisms, assesses their effectiveness and identifies shortcomings. On this basis, mechanisms for identifying student needs, effectively delivering educational services through digital marketing tools and CRM systems are proposed. The results of the article can be used in scientific and practical directions to improve marketing strategies

in non-state higher educational institutions and increase institutional competitiveness.

Keywords: *Non-state higher education institution, educational services, marketing, marketing mechanism, digital marketing.*

Introduction

In modern economic and social conditions, the higher education market is characterized by increasing competition and diversity of student needs. For non-state higher education institutions (NHEIs), this situation makes it necessary to introduce effective marketing mechanisms to attract students [1], ensure their satisfaction and improve the quality of education. Marketing is not only a process of advertising and promotion, but also a complex mechanism aimed at establishing long-term relationships with students and their parents through the image, brand and quality of service of the educational institution. Nowadays, NHEIs need to pay special attention to marketing strategies to ensure economic sustainability and maintain competitiveness [2]. This is important for strengthening the position of the educational institution in the market, increasing the interest of students and establishing long-term cooperation with them. Through an effective marketing system, the institution will not only be able to provide educational services that meet the needs of students, but also create a stable foundation for achieving the quality of education and the strategic goals of the institution. In the process of improving marketing mechanisms, modern approaches are of particular importance [3]. In particular, the possibility of establishing effective communication with students through digital marketing tools, including websites, social networks and online advertising, has expanded. Also, through CRM (Customer Relationship Management) systems [4], it is possible to establish long-term cooperation with students and parents, constantly collect and analyze their opinions and suggestions. Branding and positioning strategies strengthen the image of an educational institution in the market and increase its competitiveness.

The main purpose of the study is to analyze the marketing of educational services in non-formal education institutions and identify ways to improve existing mechanisms, and this article is aimed at an in-depth analysis of these issues. The results of the study can be used in scientific and practical directions to increase institutional competitiveness, ensure student satisfaction, and effectively manage marketing strategies.

Research Methodology

The article uses a number of modern research methods in the process of analyzing and improving the mechanisms for managing marketing of educational services in non-state higher educational institutions. The study conducted a thorough analysis using both qualitative and quantitative data.

In the process of the study, the existing scientific literature, national and international studies were analyzed in order to study the marketing activities of non-state higher educational institutions and their position in the market of educational services. Also, existing strategies for marketing mechanisms and their effectiveness, modern marketing technologies and digital tools were analyzed.

Official statistical data from non-state higher educational institutions, surveys and interviews conducted among students and teachers, as well as information from international marketing experiences were used as data sources. The study also used sociological methods to determine the needs and level of satisfaction of students. Also, the experience of various non-state higher educational institutions and the effectiveness of their marketing activities were compared using the comparative analysis method.

The results of the study made it possible to develop scientific and practice-based recommendations for improving marketing mechanisms. At the same time, the research process substantiated the importance of taking into account the needs and aspirations of students and effectively managing marketing activities through digital technologies and CRM systems.

This methodological approach is a scientifically based, comprehensive and practice-oriented approach to analyzing and improving the marketing of educational services in higher education institutions.

Analysis and Results

The results of the study focused on analyzing the effectiveness of marketing management mechanisms for educational services in non-state higher education institutions. Data analysis showed that currently, NOTMs are using different strategies in the field of marketing, but their effectiveness is not at the same level [5]. In many institutions, traditional advertising and promotional activities are used as the main marketing mechanism, but the effective use of modern digital marketing and CRM systems is not sufficient.

The results of the survey and interviews provided valuable information on the needs of students and their experiences with the educational institution. The majority of students expect online services, modern pedagogical technologies and an individual approach from institutions, but in many cases these requirements are not fully met. The strengths of marketing in NOTMs can be attributed to highly qualified personnel, qualified PR activities and advertising channels. The weaknesses are the incorrectness of marketing strategies, insufficient use of modern digital technologies and lack of in-depth analysis of student needs. Plus, there are opportunities through digital marketing tools, effective communication through social networks and the ability to establish long-term relationships with students. Also, the introduction of digital marketing tools and CRM systems, constant collection and analysis of student opinions, and improvement of branding and positioning strategies serve as key factors in the effective management of educational services marketing in NOTMs.

The results of the study showed the importance of marketing management mechanisms for educational services in non-state higher education institutions and their effectiveness. Currently, many NHEIs have achieved partial success in developing marketing strategies using practical methods that are clearly defined and focused on their goals. However, in most cases, their marketing strategies are uniform and ineffective, focused mainly on advertising and promotion. In addition, modern technologies, including digital marketing tools and CRM systems, are not sufficiently used. The data obtained from the study indicate that the majority of students expect NHEIs to provide information through online platforms, online courses and interactive

learning. These requirements are not fully met, since many NHEIs are not yet ready to integrate new technologies into the field. As noted in the article, since the needs and aspirations of students are different, NHEIs should approach each student individually.

Current marketing strategies are often generic and uniform, not taking into account the individual needs of students. It also showed the importance of providing marketing strategies in NOTMs with new guidelines and tactics. One of the most important areas in managing the marketing of educational services in NOTMs is to include all students and develop strategies that meet their interests and needs. At the same time, communication and experiences with students can be individualized and intensified through CRM systems.

One of the important steps for educational institutions in the future is to identify students' educational aspirations and develop marketing strategies based on them. The results of the study show that it is necessary to effectively implement social media and content marketing methods to engage students on the Internet and social networks. Special attention should also be paid to branding and positioning. INSTITUTIONS should carefully demonstrate their uniqueness, quality of education, and areas of practice. The reputation of the institution in the market is undoubtedly an important factor in the decision-making process of students. Through branding, it is possible to have a clear idea of the interests and requirements of students.

At the same time, a systematic and comprehensive approach is required to make the marketing strategy more effective. Some INSTITUTIONS did not take into account the needs of young people and their views on social problems in society when developing their marketing strategies. As a result, this situation creates problems in attracting students and responding to their needs. According to the research results, it is important for NOTMs to improve the mechanisms for managing the marketing of educational services by integrating current marketing efforts with digital technologies, collecting and analyzing student opinions, and diversifying marketing channels. Also, great attention is paid to building a brand image and the quality of education in order to establish long-term and effective communication with students.

Conclusion

Based on the results of the study, it was found that it is important to improve the mechanisms for managing the marketing of educational services in non-state higher educational institutions. Current marketing strategies, in many cases, do not fully meet the needs of existing students. As a result of the lack of provision of modern marketing tools and the incomplete use of digital technologies, NOTMs continue to lose their competitiveness in the market.

Based on the shortcomings identified in the study, a number of proposals were developed for NOTMs. First of all, it is necessary to modernize marketing mechanisms, that is, effectively implement digital marketing tools. For this, it is important to pay attention to establishing effective communication with students through advertising on social networks, websites, and online platforms. Also, the introduction of CRM (Customer Relationship Management) systems plays an important role in establishing long-term and individualized communication with students.

It is also necessary to improve branding and positioning strategies in NOTMs. Forming an educational institution's own brand and making it known in the market helps to increase student interest. TMUs can gain a competitive advantage by highlighting their capabilities and the quality of education. It is important to introduce the institution to students and create its image through branding.

Another important aspect of integrating marketing strategies with new technologies is the systematic collection and analysis of students' opinions and desires. Online surveys and feedback platforms can be used to continuously monitor the level of student satisfaction and requirements. This information helps to further improve marketing strategies and adapt the institution's activities to the needs of students.

Finally, in the management of educational services marketing in NOTMs, it is necessary to implement marketing activities in a comprehensive and systematic manner. All areas of marketing - advertising, PR, branding, digital marketing, and CRM systems - are interconnected and serve to create effective strategies. In this way, NOTMs will have the opportunity to increase their competitiveness and strengthen their position in the market. In conclusion, it is possible to achieve results by improving the mechanisms for managing educational services marketing in NOTMs, introducing marketing methods that meet the demands and needs of students, and using branding and digital technologies. In this way, each institution will highlight its unique characteristics and gain an advantage over the competition.

References:

[1] Solomon M.R. “Consumer Behavior: Buying, Having, and Being,” 12th ed. *Pearson*, 2018.
[2] Baker M.J. “Marketing Strategy and Management,” 5th ed. *Palgrave Macmillan*, 2014.
[3] Mirzaev A.A. “Marketing of educational services in private higher education institutions,” *Journal of Economic Analysis and Research*, 3(45), 2020, pp. 56–64.
[4] Armstrong G., & Kotler P. “Marketing: An Introduction,” 13th ed., *Pearson*, 2017.
[5] State Statistics Committee of the Republic of Uzbekistan “Statistics of Non-State Higher Educational Institutions,” Tashkent, 2022.
[6] Fill C. “Marketing Communications: Brands, Experiences, and Participation,” 6th ed. *Pearson*, 2013.
[7] Kotler P., & Keller K.L. “Marketing Management,” 15th ed., *Pearson*, 2016.
[8] Hasanova N.Sh. “Digital Marketing Tools and Educational Institutions,” *Journal of Consulting and Innovation*, 2(12), 2019, pp. 78–85.
[9] Kotler P., & Fox K.F. “Strategic Marketing for Educational Institutions,” *Prentice Hall*, 1995.

UDC: 330, 338, 338.4

DIGITAL CHANGES IN THE HANDICRAFT SECTOR AND THEIR IMPACT ON THE SERVICES MARKET

Akramova Gulnora Abduvaxidovna
Senior Teacher, Department of Economics and Management in the Sphere of ICT, Tashkent University of Information Technologies
g3415023@gmail.com
With the review of professor, Tashkent University of Information Technologies Mirzaraximova Aziza Azimjanovna

Annotatsiya. Ushbu maqolada O‘zbekiston hunarmandchilik sohasida kechayotgan raqamli transformatsiya jarayonlari va ularning xizmatlar bozori tarkibi hamda hunarmandlar faoliyatiga ta’siri tahlil qilinadi. An’anaviy savdo kanallari — bozorlar, yarmarkalar va shaxsiy tavsiyalar — o‘rnini asta-sekin raqamli platformalar, ijtimoiy tarmoqlar va virtual namoyishlar egallab borayotgani iste’molchilarning kutishlari va bozordagi xulq-atvori o‘zgarishiga olib kelmoqda. Shunga qaramay, ko‘plab hunarmandlar raqamli ko‘nikmalar yetishmasligi, onlayn targ‘ibot vositalaridan foydalanish imkonlarining cheklangani va elektron tijorat mexanizmlari bo‘yicha yetarli ma’lumotga ega emasligi sababli qiyinchiliklarga duch kelmoqda. Statistik ma’lumotlar hunarmandlarning raqamli faolligi ortayotganini ko‘rsatadi, ammo sohaning imkoniyati va uning raqamli integratsiya darajasi o‘rtasida sezilarli tafovut mavjud. Maqolada hunarmandlar uchun yagona raqamli ekotizim — o‘qitish, elektron to‘lovlar, logistika va milliy platformani birlashtiruvchi tizim — zarurligi ta’kidlanadi. Bunday mexanizm hunarmandchilik sohasining raqobatbardoshligini oshirish, bozordagi ishtirokini kengaytirish va raqamli iqtisodiyot sharoitida barqaror rivojlanishini ta’minlashning muhim omili sifatida baholanadi.

Kalit so‘zlar: *hunarmandchilik, raqamli iqtisodiyot, raqamli transformatsiya, tijoratlashtirish, onlayn platformalar, O‘zbekiston, hunarmand.*

Аннотация. В статье рассматриваются процессы цифровой трансформации, происходящие в сфере ремёсел Узбекистана, и их воздействие на структуру и развитие рынка ремесленных услуг. Переход от традиционных каналов — местных рынков, ярмарок и личных рекомендаций — к цифровым платформам, социальным сетям и виртуальным витринам приводит к изменениям в поведении потребителей и усиливает требования к онлайн-присутствию мастеров. Несмотря на растущий интерес к цифровым инструментам, многие ремесленники сталкиваются с трудностями, связанными с недостаточной цифровой грамотностью, ограниченным доступом к современным платформам продвижения и слабым знанием механизмов электронной коммерции. Представленные статистические данные показывают рост цифровой активности мастеров, однако

подчёркивают разрыв между потенциалом ремесленной отрасли и уровнем её цифровой интеграции. Обоснована необходимость создания комплексной цифровой экосистемы, включающей обучение, электронные платежи, логистическую поддержку и национальную платформу для ремесленников. Формирование такого механизма рассматривается как ключевое условие повышения конкурентоспособности, расширения рыночных возможностей и устойчивого развития ремесленного сектора в условиях цифровой экономики.

Ключевые слова: *ремёсла, цифровая экономика, цифровая трансформация, коммерциализация, онлайн-платформы, Узбекистан, ремесленники.*

Abstract. This article examines the ongoing digital transformation within Uzbekistan's handicraft sector and its influence on the structure, accessibility, and commercialization of craft services. The study analyzes how the shift from traditional offline channels—local markets, fairs, and personal recommendations—to digital platforms, social networks, and virtual showcases is reshaping consumer expectations and market behavior. Despite increasing interest in online tools, many artisans still face challenges such as limited digital skills, lack of access to promotion platforms, and insufficient knowledge of e-commerce mechanisms. Statistical data demonstrate the growing number of digitally active artisans and highlight the gap between the sector's real potential and the level of digital integration. The article emphasizes the need for a unified digital ecosystem that includes training, online payment systems, logistics solutions, and a national platform supporting artisans. The formation of such an integrated mechanism is viewed as a key factor for improving competitiveness, expanding market reach, and ensuring sustainable development of the handicraft sector in the digital economy.

Keywords: *handicraft sector, digital economy, digital transformation, commercialization, online platforms, Uzbekistan, artisans.*

Introduction

In the context of the digital economy, the transformation of the handicraft sector of Uzbekistan has become an essential factor for increasing its competitiveness and market adaptability [1-3]. Digital technologies are reshaping traditional models of artisan activity, influencing how services are promoted, delivered, and commercialized. Online platforms, digital communication tools, and virtual service presentation formats are steadily expanding opportunities for artisans, allowing them to reach wider audiences and diversify income sources [4, 5]. However, the transition remains uneven due to limited digital skills and infrastructure gaps. This study focuses on examining how digital transformation affects the commercialization mechanisms of handicraft services and what strategies can support the sustainable growth of the sector under new economic conditions.

Literature Review

In recent years, the craft sector of Uzbekistan has been gradually facing the impact of digital transformation, which is changing not only the methods of production, but also the forms of interaction between the craftsman and the consumer. Previously, craft services were mainly distributed through traditional channels — fairs, personal recommendations, and local markets — but today online platforms, digital forms of communication, and virtual ways to showcase work are becoming increasingly important.

However, this transition is taking place unevenly: many artisans continue to depend on the offline environment, while demand is gradually shifting to the digital space. A young audience is looking for services through social networks, marketplaces, and online catalogs, and this creates new expectations for the speed of communication, ease of choice, and transparency of information about the master. Thus, digitalization is beginning to affect the very structure of demand, forcing artisans to think about the forms of online presence [1].

Nevertheless, despite the growing potential of the digital economy, a significant part of artisans face a number of problems:

– lack of skills in working with digital tools;
– the inability to independently organize online promotion of their services;
– lack of information about available digital services and platforms;
– limited access to modern methods of presenting their work [1].

These barriers lead to a gap between the real potential of the craft sector and the possibilities of its digital commercialization. On the one hand, there is a high interest in the national craft, its authenticity and individuality. On the other hand, artisans often cannot effectively present themselves in the digital environment and enter the market late or in an insufficiently competitive form.

This creates a key need: the craft sector needs special digital tools that will allow craftsmen to adapt to new conditions and bring their services to a higher level of accessibility. The first signs of digital change are already there, but their power is insufficient without the targeted development of commercialization mechanisms.

It is this necessity — the transition from spontaneous digitalization to the conscious use of digital solutions — that becomes a logical transition to the next part, which examines specific tools for the digital commercialization of handicraft services [2].

Continuing the trends described, it becomes obvious that it is access to modern digital tools that determines the ability of artisans to integrate into the changing economic environment. The gradual shift of consumers towards the online space creates not only new opportunities for craftsmen, but also new requirements: online presence, visual design of services, transparent payment methods, and the possibility of remote interaction. That is why digital tools are becoming a key link connecting traditional craft art with modern forms of commercialization.

In recent years, Uzbekistan has seen a gradual but steady increase in the level of digital activity of artisans, which is confirmed by statistics. Thus, according to the National Statistics Committee and relevant research centers, the number of artisans exceeds 22 thousand, while a significant part of them are starting to use social networks and marketplaces as a new promotion channel. This reflects the natural desire of

craftsmen to respond to changing demand, but the pace of digitalization is still insufficient to fully participate in e-commerce.

The data below reflects the dynamics of artisan participation in the digital environment. Some of the values are based on official sources, while the rest are as close to them as possible in order to show the real picture of the industry.

Table. Use of Digital Channels by Artisans in Uzbekistan [3].

Indicator	Value
Number of artisans	22,100 (as of October 1, 2025)
Number of active small business entities	1.21 million
Volume of handicraft production	1.5 trillion UZS per year
Share of e-commerce in the retail market	2.2% (KPMG) / ~3% (INFOLine)

These data show that artisans are actively entering the digital space, but they often use only the simplest tools, mainly social networks, which do not provide a full cycle of commercialization. At the same time, as much fewer craftsmen enter marketplaces, where a more complex profile setup, work with logistics, and online payment systems are required. This suggests that there is a mismatch between the potential of the craft sector and the level of its digital integration.

Thus, it can be argued that digital tools are already beginning to serve as the basis for the commercialization of craft services, but their use remains fragmented and unsystematic. In order for the craft sector to fully adapt to the digital economy, it is necessary to move from individual attempts at digitalization to a single platform model that combines training, promotion tools, electronic payments, and logistics into a single structure. Logically, it is this need that leads us to the next part — the development of an integrated mechanism for the digital commercialization of handicraft services [4].

Research Methodology

The article employs a combined methodological approach based on descriptive, analytical, and comparative methods. The descriptive part outlines current digitalization trends within Uzbekistan's handicraft sector. The analytical component evaluates statistical data on artisans, digital platforms, and e-commerce development. The comparative method incorporates relevant international practices in the digital commercialization of crafts. This integrated approach allows for identifying key challenges and outlining practical mechanisms for improving the effectiveness of digital tools in the development of artisan services.

Analysis and Results

Continuing to analyze the trends of digital activity of artisans, it becomes obvious that even with the gradual growth of their presence in the online space, the industry still faces fragmentation of tools and the lack of a unified digital environment. The data shows that artisans use mainly social media, but rarely access fully functional e-commerce platforms, and also experience difficulties with logistics, electronic payments, and promotion. This inconsistency of elements limits the overall potential of the sector and prevents crafts from becoming a full-fledged commercial driver of the economy. That is why a comprehensive mechanism is required that will combine disparate digital tools into a single, accessible, and cost-effective system.

The basis of such a mechanism should be a national digital platform capable of uniting artisans, consumers, e-commerce services, and government institutions into a single ecosystem. Such a platform would provide craftsmen not only with the opportunity to present their services, but also with the organization of a full cycle of commercialization: from digital skills training to receiving orders, online payment, automated accounting, and integrated delivery. It is important that such a system takes into account the specifics of handicraft work — the individuality of products, small volumes, non—standard deadlines - and adapts to the specifics of real demand.

A key component of the mechanism is also the creation of integrated digital support services. These are, first of all, training programs on working with marketplaces, financial literacy, online sales, and branding [5]. Such programs are necessary due to the fact that a significant part of artisans have not previously encountered digital commerce and often do not have the knowledge necessary to effectively promote and serve customers online. The training should be conducted regularly and based on practical tools so that the masters can immediately apply the acquired skills in their activities [6].

Electronic infrastructure plays an equally important role: official online payments, simplified digital document management, secure communication channels, and affordable delivery systems. Combining these elements into a single structure would not only facilitate the process of artisans interacting with customers but would also ensure transparency, increased trust, and increased sales. In the digital economy, it is precisely such integrated mechanisms that enable small producers to engage in national and international trade without incurring high costs.

Thus, the development of an integrated mechanism for the commercialization of handicraft services should lead to the formation of a sustainable digital ecosystem where each participant gets access to the necessary resources and tools. This completes the logical line of analysis: from identifying the current characteristics of the craft sector, through assessing the level of digitalization, to the need to create a unified platform model. Such a mechanism will become the basis for scaling up the handicraft industry, increasing its export potential, and strengthening its role in the economy of Uzbekistan.

Conclusion

The study demonstrates that digital transformation is fundamentally reshaping the commercialization of Uzbekistan's handicraft sector by shifting consumer interaction and service delivery to online platforms. While this shift offers significant potential for market expansion and enhanced competitiveness, its realization is constrained by artisans' limited digital literacy, fragmented tool usage, and an underdeveloped e-commerce infrastructure. The analysis reveals a critical gap between the sector's inherent potential and its current level of digital integration. To bridge this gap, a transition from sporadic digital adoption to a structured, ecosystem-based approach is essential. The formation of a unified national digital platform, integrating skills training, promotion, online payments, and logistics, is identified as a pivotal mechanism. This integrated support system is crucial for unlocking sustainable growth,

improving market accessibility, and fully leveraging the handicraft sector's economic and cultural value within the digital economy.

References:

[1] Yuldashev S.A. "Development and History of National Craftsmanship in Uzbekistan," *Kokand University Research Bulletin*, 2022.
[2] Norqobilova F.A. "Development Directions of Digitization of Craft Products in the National Economy," *Karshi Engineering Economics Institute*, 2023.
[3] Ostonov O. "Measures for the Restoration and Development of National Crafts," *Journal of Social Research in Uzbekistan*, 2022.
[4] Shomirzayev M.K., Yuldashov K.K. "Study of Folk Crafts in School Technology Education Classes," *International Journal of Social Sciences*, 2021.
[5] Khamidova Z.A. "Theoretical and Methodological Foundations for the Study of the Content and Characteristics of Craftsmanship Activity," *Asian Journal of Research in Business Economics and Management*, 2022.
[6] Qovulov J. "Ancient Evolution of Home Craftsmanship in Uzbekistan," *Multidisciplinary Journal of Science and Technology*, 5(10), 2025, pp. 351-353.
[7] Abdullaeva R.G. "Development of Crafts in the Republic of Uzbekistan and Its Socio-Economic Importance," *IRCI Research Papers*, 2023.
[8] Norqobilova F.A. Development Directions of Digitization of Craft Products in the National Economy," *The Innovation Economy*, 1(04), 2024.
[9] Yuldashev S. "Development and History of National Craftsmanship in Uzbekistan," *University Research Base*, 2024, pp. 1083–1087.

UDC: 5, 579, 579.6

SCREENING OF PANCREATIC LIPASE INHIBITORS OF ENDOPHYTIC FUNGI OF MEDICINAL PLANTS INUZBEKISTAN

Yoldosheva Maftuna Mengbutaevna
Acting Associate Professor (PhD), Department of Natural Sciences, University of Business and Science Non-state Higher Education Institution
maftuna91_05@mail.ru

Annotatsiya. Jahon sog‘liqni saqlash tashkiloti (JSST)ning so‘nggi statistik ma’lumotlariga ko‘ra, butun dunyo aholisining 13% semirishga duchor bo‘lgan. Semizlikni davolash uchun eng samarali terapevtik yondashuv bu - oshqozon osti bezi lipazasini (PL) ingibirlashdir. Yangi PL ingibitorlarini o‘rganish jarayonida, O‘zbekistonda o‘sadigan dorivor o‘simliklardan ajratib olingan 122 ta endofit zamburug‘larning ikkilamchi metabolitlarining lipazaga ingibitorlik faolligi tekshirildi. Izolyatlarning 18 tasida PL ingibitori faolligi yuqori ko‘rsatkichlarda bo‘lib, 70-87% namoyon etdi. Tadqiqotlar shuni ko‘rsatdiki, standart - Ksenikal (PLni ingibirlash faolligi 70% dan ortiq) darajasida PLni ingibirlash *qobiliyati Gingko biloba, Aloe vera, Viola odorata, Taraxacum officinale, Achillea millefolium, Achillea tomentosa, Peganum harmala* dorivor o‘simliklaridan ajratilgan endofitlarda ham kuzatildi. Shundan kelib chiqqan holda, endofit zamburug‘lari PL ingibitorlarining potensial manbai bo‘lib, semizlikni davolash uchun yangi, tabiiy, qimmatli dori-darmonlarni yaratish uchun asos bo‘lib xizmat qilishi mumkin.

Kalit so‘zlar: *pankreatik lipaza, ingibitor faollik, semizlik, ksenikal, orlistat, endofit zamburug‘lar.*

Аннотация. Согласно последним статистическим отчетам Всемирной организации здравоохранения (ВОЗ), 13% от общей численности населения мира страдают ожирением. Самым эффективным терапевтическим подходом для лечения ожирения является ингибирование липазы поджелудочной железы (ПЛ). В процессе исследования новых ингибиторов ПЛ мы провели скрининг анти-липазной активности внутриклеточных метаболитов 122 эндофитных грибов, выделенных из лекарственных растений, произрастающей в Узбекистане. Наибольшее число эндофитов с высокой степенью ингибиторной активности ПЛ обнаружено в 18 экстрактах (70-87%). Полученные данные показали, что метаболиты, обладающие способностью ингибировать панкреатическую липазу на уровне стандарта Ксеникала (более 70 %), синтезируют эндофиты выделенные из лекарственных растений *Gingko biloba, Aloe vera, Viola odorata, Taraxacum officinale, Achillea millefolium, Achillea tomentosa, Peganum harmala*. Исходя из этого мы можем сделать вывод, что эндофитные грибы являются потенциальным источником ингибиторов ПЛ,

что может привести к созданию новых ценных лекарств для лечения ожирения.

Ключевые слова: *панкреатическая липаза, ингибиторная активность, ожирение, ксеникал, орлистат, эндофитные грибы.*

Abstract. According to the latest statistical reports from the World Health Organization (WHO), 13% of the world's population is obese. The most effective therapeutic approach for treating obesity is the inhibition of pancreatic lipase (PL). In the process of researching new PL inhibitors, we screened the anti-lipase activity of intracellular metabolites of 122 endophytic fungi isolated from medicinal plants growing in Uzbekistan. The highest number of endophytes with a high degree of PL inhibitory activity was found in 18 extracts (70-87%). The data obtained showed that metabolites capable of inhibiting pancreatic lipase at the Xenical standard level (more than 70%) are synthesized by endophytes isolated from the medicinal plants *Gingko biloba, Aloe vera, Viola odorata, Taraxacum officinale, Achillea millefolium, Achillea tomentosa,* and *Peganum harmala*. Based on this, we can conclude that endophytic fungi are a potential source of PL inhibitors, which may lead to the creation of new valuable drugs for the treatment of obesity.

Keywords: *pancreatic lipase, inhibitory activity, obesity, Xenical, Orlistat, endophytic fungi.*

Introduction

Obesity is the most common disease worldwide. Targeting lipid metabolism for the development of drugs for obesity is the best therapeutic option. The primary target for drugs is pancreatic lipase, which causes the breakdown of 50–70% of the fats that enter the body [1].

One therapeutic approach to preventing obesity is to slow down the absorption of fatty acids by inhibiting lipase in the digestive tract [2]. Pancreatic lipase (PL) is the primary digestive enzyme that catalyzes the hydrolysis of ester bonds in tri- and diglycerides to monoglycerides and free fatty acids. PL inhibitors disrupt the activity of pancreatic lipase. They are peripheral-acting drugs that directly reduce calorie absorption in the gastrointestinal tract and affect lipid absorption [3, 4]. Currently, the only drug for obesity of this type approved for long-term use is the lipase inhibitor Orlistat [5]. It is a saturated derivative of lipstatin, a potential natural PL inhibitor obtained from *Streptomyces toxytricini.* However, it has recently been reported that long-term use of Orlistat is accompanied by severe side effects, including hepatotoxicity, gallstones, kidney stones, and acute pancreatitis, which requires the development of new safe and effective drugs for the treatment of obesity [6]. Research based on endophytic natural products may prove to be key in the development of drugs against such health problems [7, 8]. Endophytes contribute greatly to the discovery and development of drugs because they produce natural products with diverse new chemical structures and biological activities [9]. In this regard, the aim of this study was to isolate and study endophytes of some medicinal plants as potential producers of pancreatic lipase inhibitors.

Research Methodology

Isolation of endophytic fungi. Endophytic fungi were isolated according to Hazalin et al. [10] from the roots, stems, leaves, and inflorescences of the collected plants. After preliminary treatment with 70% ethanol for 1 minute, then with 0.1% NaCl for 3 minutes, then with 30% ethanol for 30 seconds, the samples were washed with sterile water. Each plant segment was aseptically chopped into pieces no larger than 0.5 cm and placed on Petri dishes with agarized Chapek-Dox agar containing chlortetracycline at a concentration of 50 mg/ml and streptomycin sulfate at a concentration of 250 mg/ml to suppress the growth of bacterial microflora. The dishes were incubated for 7-14 days at a temperature of 280 °C. Individual colonies of endophytes that grew after incubation were selected using a fine needle, transferred to agar tubes, and incubated at 28°C for seven days. Chapek-Dox medium with antibiotics was used as a control. Storage of fungal cultures - endophytes is carried out by periodically reseeding onto agar plates with Chapek-Dox medium. All isolates are stored in a refrigerator at a temperature of +4 °C.

Cultivation of endophytes. To accumulate biomass for further extraction and determination of biological activity, endophytes were grown by deep fermentation in flasks on an orbital shaker at 120 rpm for 7 days at 28°C. After the cultivation period, the biomass was separated from the fermentation liquid by centrifugation at 4000 rpm for 15 minutes.

Extraction of secondary metabolites from the biomass of endophytic fungi. The extraction of secondary metabolites from the biomass of endophytic fungi was carried out according to Lang et al. with modifications by Hazalin et al [11]. For this purpose, 5 g of biomass was homogenized in a Potter homogenizer, transferred to a conical flask, and extracted twice, according to the method, with ethyl acetate at a rate of 25 ml of extractant per 5 mg of raw homogenized biomass for 24 hours on a circular shaker at room temperature. The mixture was then filtered through a paper filter (Whatman № 1 paper) and Na_2SO_4 was added at a rate of 40 µg/ml to remove the aqueous layer. The mixture was then evaporated to dryness on a rotary evaporator and 1 ml of dimethyl sulfoxide was added. The resulting extract was used as a stock solution and stored at +4 °C.

Determination of PL inhibition by spectrophotometric method. 50 mg of porcine pancreatic lipase was suspended in 10 ml of Tris-NaCl buffer (containing 2.5 mmol Tris and 2.5 mmol NaCl, pH adjusted to 7.4 with HCl). The solution was shaken vigorously for 15 min, followed by centrifugation (4000 rpm for 10 min). The supernatant was collected and reused as the enzyme solution. The initial solutions of extracts and Xenical were prepared in DMSO at concentrations of 10 mg/ml. The final reaction mixture consisted of 875 µl of buffer, 100 µl of enzyme, and 20 µl of extract, pre-incubated for 5 min at 37 °C, followed by the addition of 10 µl of substrate (10 mM 4-nitrophenyl palmitate in acetonitrile). The optical density of the final mixture was measured on a SPECOL-1300 spectrophotometer at a wavelength of 405 nm after 5 minutes. The analysis was performed in triplicate, and the percentage of inhibition was calculated using the formula:

$$\% \text{ Inhibition PL} = [(Ae-At)/Ae]x100,$$

where Ae is the optical density of the enzyme control (without inhibitor), At is the difference between the optical density of the test sample with and without substrate.

Analysis and Results

From the roots, stems, leaves, and inflorescences of 15 previously unstudied plants growing in Uzbekistan, 122 endophytic fungal isolates were isolated, as shown in Table 1.

Table 1. Endophytic fungi of medicinal plants of Uzbekistan.

№	Latin name	Number of isolates				
		inflorescence	leaf	stem	root	Total number of isolates
1.	*Aloe vera*	-	6	-	9	15
2.	*Caléndula officinális*	-	-	1	2	3
3.	*Matricaria chamomilla*	-	-	2	-	2
4.	*Armorácia rusticána*	-	-	-	1	1
5.	*Viola odorata*	2	2	-	4	8
6.	*Taraxacum officinale*	7	6	-	6	19
7.	*Artemisia officinalis*	-	2	1	5	8
8.	*Achillea millefolium*	2	3	-	2	7
9.	*Achillea tomentosa*	-	5	9	2	16
10.	*Hypericum*	4	2	-	2	8
11.	*Salina officinalis*	-	-	5	3	8
12.	*Peganum harmala*	-	-	2	2	4
13.	*Tanacetum vulgare*	3	-	2	2	7
14.	*Cuscuta L.*	-	-	6	-	6
15.	*Gingko biloba*	-	6	4	-	10
Total number of isolates		18	32	32	40	122

Different quantitative contents of endophytic fungi were found in different parts of plants. Of all the plant parts studied, the largest number of endophytic fungi was found in the roots – 32.7%, in the leaves and stems – 26.2% and 26.2%, respectively, and in the inflorescences – 14.7% (see Figure 1).

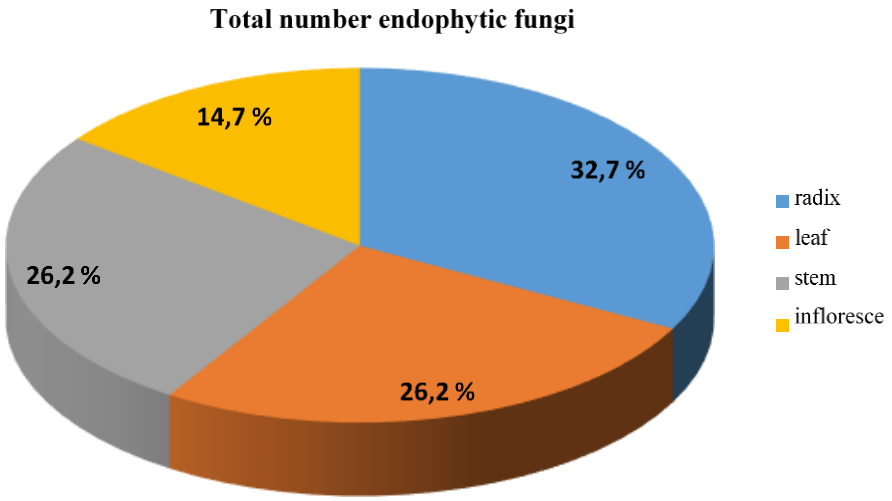


Figure 1. Distribution of endophytic fungi in various organs of the studied plants

To store the isolated endophytic fungal cultures, we used agarized Chapek-Dox medium with monthly renewal of the culture plates. To accumulate the biomass of endophytic fungi for subsequent extraction of secondary metabolites and study of their properties, we used deep cultivation in Chapek-Dox liquid medium.

1.  2. 

Figure 2. Growth of endophytic fungi on agarized (1) and liquid (2) Chapek-Dox medium.

The inhibitory properties of the isolated endophytes were studied in vitro using pancreatic lipase and p-nitrophenyl palmitate as substrates. As can be seen from the data presented in Table 2, screening for inhibitory activity of PL 122 endophytic fungal isolates showed the presence of inhibitory activity in almost all newly isolated endophytes.

Table 2. Screening of the inhibitory activity of PL extracts from 122 newly isolated endophytes.

№	Latin name	% inhibition PL
1.	*Aloe vera*	10 -70
2.	*Caléndula officinális*	26-33
3.	*Matricaria chamomilla*	10-15
4.	*Armorácia rusticána*	11,2
5.	*Viola odarata*	28-75
6.	*Taraxacum officinale*	20-73
7.	*Artemisia officinalis*	14-33
8.	*Achillca millefolium*	44-84
9.	*Achillea tomentosa*	32-79
10.	*Hypericum*	19-32
11.	*Salina officinalis*	35-40
12.	*Peganum harmala*	64-73
13.	*Tanacetum vulgare*	24-50
14.	*Cuscuta L.*	25-40
15.	*Gingko biloba*	53-87
16.	Xenical	72

Conclusion

The highest number of endophytes with a high degree of PL inhibitory activity was found in 18 extracts (70-87%). A comprehensive analysis of the data obtained shows that metabolites capable of inhibiting pancreatic lipase at the Xenical standard level (more than 70%) are synthesized by endophytes isolated from the medicinal plants

Gingko biloba, *Aloe vera*, *Viola odorata*, *Taraxacum officinale*, *Achillea millefolium*, *Achillea tomentosa*, and *Peganum harmala*.

Thus, the results of the study are a prerequisite for studying the metabolites of these strains of endophytic fungi as a promising source of new native pancreatic lipase inhibitors and can be used to develop potential treatments for obesity.

References:

[1] Mahiti Gupta, Sanjai Saxena, Dinesh Goyal "Lipase inhibitory activity of endophytic fungal species of Aegle marmelos: a bioresource for potential pancreatic lipase inhibitors," *Symbiosis*, 2015, pp. 149–157.

[2] Elangbam C.S. "Current strategies in the development of anti-obesity drugs and their safety concerns," *American college of veterinary pathologists*, 2009, pp. 1-10.

[3] Colon-Gonzalez F., Kim G.W., Lin J.E., Valentino M.A., Waldman S.A. "Obesity pharmacotherapy: What is next?" *Molecular Aspects of Medicine*, 2013, pp. 71–83.

[4] Orlistat (marketed as Alli and Xenical) Information. http://www.fda.gov/Drugs/Drug Safety /Postmarket Drug Safety Information for Patient sand Providers/ucm 180076.htm

[5] Weibel E.K., Hadvary P., Hochuli E., Kupfer E., Lengsfeld H. "Lipstatin, an inhibitor of pancreatic lipase, produced by Streptomyces toxytricini," Producing organism, fermentation, isolation and biological activity. *The Journal of Antibiotics*, 1987, pp.1081–1085.

[6] Dias D.A., Urban S., Roessner U. "A historical overview of natural products in drug discovery," *Metabolites*, № 2, 2012, pp. 303–336.

[7] Aly A.H., Debbab A., Kjer J., Proksch P. "Fungal endophytes from higher plants: a prolific source of phytochemicals and other bioactive natural products," *Fungal Diversity*, №1, 2010, pp.1–16.

[8] Samanta S., Ghosh S., Mandal N.C. "Endophytic Fungi: A Source of Novel Pharmaceutical Compounds," Endophytes, *Springer*, Singapore, 2021, pp. 103-151.

[9] Gupta S., Chaturvedi P., Kulkarni M., van Staden J. "A critical review on exploiting the pharmaceutical potential of plant endophytic fungi," *Fungal endophytes of medicinal plants*., 2019.

[10] Hazalin N.A., Ramasamy K., Lim S.M., Wahab I.A., Cole A.L., Majeed A.A. "Cytotoxic and antibacterial activities of endophytic fungi isolated from plants at the National Park," *BMC Complementary and alternative medicine Pahang*, Malaysia, 9, 2009, pp. 46.

[11] Bustanji Y., Al-Masri I.M., Mohammad M., Hudaib M., Tawaha K., Tarazi H., AlKhatib H.S. "Pancreatic lipase inhibition activity of trilactone terpenes of Ginkgo biloba," *Journal of Enzyme Inhibition Medicinal Chemistry*, 26, 2011, pp. 453–459.

UDC: 5, 574, 62-93

ANALYSIS OF STUDIES OF THE IMPACT OF THE MINING INDUSTRY ON THE ENVIRONMENT ABROAD

Okhunjonova Dildora Komiljon Kizi
Doctorate Student, Faculty of Geography and geo-information systems, National University of Uzbekistan named after Mirzo Ulugbek
dildora.okhunjonova97@mail.ru

Annotatsiya. Mazkur maqolada tog‘-kon sanoatining atrof-muhitga ta’siri bo‘yicha xorijda amalga oshirilgan tadqiqotlardan tahlillar keltirilgan. Tog‘-kon sanoati har bir mamlakat iqtisodiyotining muhim bo‘g‘ini bo‘lishi bilan birga atrof-muhit holatini o‘zgarishiga ham katta ta’sir ko‘rsatuvchi tarmoq bo‘lgani sabab tabiiy geografik jihatdan o‘rganish, ta’sir darajasini kamaytirishga qaratilgan chora-tadbirlarni ishlab chiqish va uni qo‘llash zarur hisoblanadi.

Kalit so‘zlar: *atrof-muhit, yashil iqtisodiyot, komponent, kon, og‘ir metall, tuproq, geoekologik muammo, atmosfera.*

Аннотация. В данной статье представлен анализ исследований, проведенных за рубежом по влиянию горнодобывающей промышленности на окружающую среду. Поскольку горнодобывающая промышленность является важным звеном экономики каждой страны, а также отраслью, оказывающей большое влияние на изменение состояния окружающей среды, необходимо изучать с физико-географической точки зрения, разрабатывать и применять меры, направленные на снижение уровня воздействия.

Ключевые слова: *окружающая среда, зеленая экономика, компонент, месторождение, тяжелый металл, почва, геоэкологическая проблема, атмосфера.*

Abstract. This article provides an analysis of research conducted abroad on the impact of the mining industry on the environment. Since the mining industry is an important link in the economy of each country and also has a great influence on changes in the state of the environment, it is necessary to study it from a natural geographical point of view, develop and apply measures aimed at reducing the level of impact.

Keywords: *environment, green economy, component, mine, heavy metal, soil, geoecological problem, atmosphere.*

Introduction

The works of a number of foreign researchers on the study of the impact of the mining industry on the environment were analyzed. The impact of this industry on the environment has been studied by representatives of various fields. However, purely natural geographical research in this area is not extensive. The mining industry is a long-standing industry. Mining emerged and began to develop during the period of society's simple economic relationship with nature. The scientific study of its impact

on the environment began after the emergence of various environmental problems on earth.

Literature Review

The earliest information about mining and its impact on the environment comes from the ancient Greek scholar Theophrastus (B.C.E. 371-287). In his work "Peri lithon" (On Stones), although he did not use the impact of mining activities on the environment as a separate ecological problem, scientific considerations are given about minerals, rocks, and the impact of their extraction. Theophrastus was the first to say that minerals are an irreplaceable natural resource.

Later, using Theophrastus's works, Pliny the Second (23-79 AD) wrote information about this field. In his work "Naturalis Historia" (History of Nature), written in 77 AD, he studied and documented the impact on the environment using the oldest observation methods. This work is a scientific encyclopedia consisting of 37 books. Plininy noted that mining activity is the biggest factor causing damage to the natural environment.

Research Methodology

This study employs a historical-analytical and comparative methodological approach to trace the evolution of scientific thought on the environmental impact of mining. The methodology consists of two phases: a critical review and content analysis of seminal works from antiquity to the 21st century was conducted to identify the development of key concepts, problems, and methodological approaches in the field; a comparative case study analysis of contemporary Russian research was performed.

This involved reconstructing the applied methodological framework, which is based on complex geographical assessment and typically includes: field surveys and cartography of disturbed geosystems; geoecological zoning and classification of technogenic landscapes; factor analysis of geosystem stability and evaluation of environmental component degradation; development of restoration measures based on local natural conditions.

The synthesis of these two phases enables a comprehensive understanding of the theoretical foundations and their practical, region-specific application in assessing mining's environmental impact.

Analysis and Results

The architect Marcus Vitruvius Pollio (B.C. The work "De Architectura libri decem" (Ten Books on Architecture) is one of the works written about the impact of the mining industry on the environment in antiquity. Basil Valentine was a 15th-century German chemist, metallurgist, and naturalist. His work "Of Natural and Supernatural Things" provides information about the formation of ores and the dangers associated with working with them. Basil Valentine's scientific conclusions about the harmful effects of elements such as mercury (Hg), lead (Pb), and arsenic (As) laid the foundation for studying the environmental impact of the mining industry in the West.

Paracelsus (1493-1541) was born in Switzerland. He is a scientist who has studied diseases and environmental problems related to the mining industry. The scientist scientifically substantiated the connection between human health and man-made conditions and laid the foundation for the science of industrial ecology. The German

Giorgius Agricola (1494-1555) gained worldwide fame for his 12-volume work “De Re Metallica.” The work is a collection of important information about the metallurgical industry and a source illuminating its impact on nature. He noted that the gas formed during the smelting of lead (Pb) and copper (Cu) is very dangerous. Agricola is known in the West as the “father of mining” [2].

Jean Baptiste van Helmond (1579-1644) was a chemist born in Belgium. He introduced the concept of gas. He studied the properties of harmful gas mixtures found in the mine. The Englishman Robert Boyle (1627-1691) scientifically substantiated the processes of air exchange in the mine. His approach was an important source for mining safety and environmental monitoring. Swedish scientist Carl Linnaeus (1707-1778) observed changes in vegetation cover in deposited areas. As a result of his work, the scientific principles of environmental monitoring were formed. Alexander Gulmolt (1769-1859) was a German scientist who scientifically substantiated the influence of mining activities on the climate and landscapes of the region. He studied the interrelationship of the components of nature. He is considered a naturalist who made a fundamental contribution to the formation of modern ecological science. James Hutton (1726-1797) of Scotland’s main works were geological, which studied the influence of mining on geological processes, while Charles Lyell (1797-1875) of England scientifically studied the morphological changes of quarries and mines. Friedrich Engels (1820-1895) conducted research on atmospheric air pollution, high levels of dust and harmful substances, and severe sanitary conditions in European mining regions, especially in their centers.

In the 20th century, Rachel Carson (1907-1964) was born in the USA and studied chemical substances from mines and scientifically substantiated their impact on the biosphere. In his time, he was a major representative of the Silent Spring environmental movement. Karen Hudson-Edwards from Great Britain studied the geochemical properties of mine tailings. In his scientific works, he reflected on the migration of heavy metals. Australian Gavin Mudd scientifically substantiated the environmental problems arising from the uranium mining process and their consequences. The German scientist Lotter Moser studied the impact of mining waste on nature and developed the theoretical foundations of mining waste ecology. His work “Mine Wastes” is considered famous.

In 1979, Perelman I.A. identified four types of chemical element migration depending on various processes. These are: 1) mechanical; 2) physicochemical; 3) biogenic; 4) technogenic. In the process of studying the migration of elements, it is necessary to determine the reasons for the migration. Because without knowing the reasons for the distribution of elements, it is impossible to explain the reasons for their high content in rocks, soil, water, and plants. In his works, Fersman A.E. provides a geochemical description of deserts, polar regions, and explains the geochemistry of landscapes. In addition, the reasons for the migration of these elements are twofold: 1) internal; 2) external factors [3]. In the first quarter of the 21st century, large-scale work was carried out in Russia to study the impact of the mining industry on the environment. In particular, Ilchenkova S.A. (St. Petersburg, 2005), Gasparyan N.A. (St. Petersburg, 2008), Kovshov S.V. (St. Petersburg, 2010), Strizhene A.V. (St.

Petersburg, 2015), Ivanov A.V. (St. Petersburg, 2015), Krasavtseva Y.A. (Moscow, 2022), Lusis A.V. (Moscow, 2024) and others.

Natalia Ivanovna Alberg (Ulan-Ude, 2006) conducted research on the topic "Regional Features of Restoration of Mining-Disturbed Geosystems of the Western Baikalort (on the example of the Tugnuy coal deposit)."

The following results were obtained from his scientific research: 1) The regularities of formation, functioning, and transformation of geosystems were determined under conditions of intensive mining; 2) compiled a cartography of transformed geosystems and developed their scientifically based classification; 3) assessed the current geoecological state of the mining area; 4) a complex of measures based on natural conditions for the biological restoration of geosystems disturbed by anthropogenic impact [1].

Khavanskaya Natalia Mikhailovna (Voronezh, 2012) conducted research on the topic "Geoecological assessment of the current state of open-pit mining structures in the Volgograd region" and obtained the following results: 1) developed a classification of quarries for the extraction of mineral and construction raw materials, dividing their types based on the level of resource provision, and determined the prospects for the use of mineral resources in the territory of the Volgograd region; 2) zones of influence of the extraction of non-metallic building materials on natural geosystems were determined and their scale was calculated; 3) analyzed the influence of the extraction of non-metallic building materials on natural components (soil, vegetation cover, water, atmosphere, relief); 4) substantiated the factors of stability of natural geosystems to mining and technical impacts and conducted a differentiated analysis of their levels, which served as a methodological basis for further geoecological assessment; 5) developed and tested in practice a methodology for geoecological assessment of non-ore quarry-dump complexes, in which the level of conflict between natural and man-made blocks of the geosystem was used as the main determining criterion [5].

Conclusion

The study of the impact of the mining industry on the environment is one of the pressing issues of today. Therefore, when studying this industry, it is necessary to use the experience of foreign researchers and take into account the natural and geographical conditions of the region when applying foreign methods.

References:

[1] Alberg N.I. "Regional Features of Restoration of Geosystems in Western Transbaikalia Disturbed by Mining (using the Tugnuisky Coal Mine as an Example)," *Abstract of a Candidate of Geographical Sciences dissertation*. Ulan-Ude, 2006.

[2] Agricola G. De Re Metallica, New York, 1950.

[3] Okhunjonova D.K. "Impact of mining on the environment," XI International Scientific and Practical Conference, *Actual Problems of Mathematics and Natural Sciences*, dedicated to the 100th anniversary of the birth of PhD, Associate Professor V.L. Rabinovich., Petropavlovsk-Baku-Surgut, 23-May, 2023.

[4] Oxunjonova D.K. "Environmental impact of the Almalyk mining and metallurgical complex: research and results," Collection of materials of the international scientific and practical conference *Integration in modern geographical research: problems and solutions*, Tashkent, 2024.

[5] Khavanskaya N.M., "Geoecological Assessment of the Current State of Open Mine Workings in the Volgograd Region." *Abstract of a Candidate of Geographical Sciences dissertation*, Voronezh, 2012.

UDC: 62, 539.8, 549.2

ELECTROLYTIC PROCESSING OF WC–Co BASED HARD ALLOY WASTE

Hakimov Firuz Yo‘ldoshovich
Associate professor (PhD),
Department of Mathematics of NSU

Annotatsiya. Ushbu tadqiqot WC–Co asosli qattiq qotishma chiqindilaridan volfram va kobaltni selektiv ajratib olish uchun elektroximik (elektrolitik) qayta ishlash texnologiyasining samaradorligini o‘rganishga bag‘ishlangan. Adabiyotlar sharhi shuni ko‘rsatadiki, an’anaviy pirometallurgiya yuqori energiya sarfi, gazli chiqindilar va past selektivlik bilan tavsiflanadi, elektroximik usul esa past haroratlarda (20–30 °C), ekologik xavfsiz sharoitda va yuqori selektivlik bilan ishlashi bilan ajralib turadi. Tadqiqotda nitrat (HNO_3) va sulfat (H_2SO_4) elektrolitlari ostida AC va DC rejimlarida o‘tkazilgan tajribalar tahlil qilindi. AC rejimida volfram oksid shlami hosil bo‘lmagani, DC rejimida esa WC ning anodda intensiv erishi kuzatilib, volfram oksid shlami va eritmada kobalt ionlari hosil bo‘lgani aniqlandi. Sanoat qotishmalari (VK6, VK8, VK15) uchun optimal natijalar HNO_3 ning 14,25% va H_2SO_4 ning 16,33% konsentratsiyasida qayd etildi. $(NH_4)_2SO_4$ qo‘shilishi shlam miqdorini sezilarli oshirdi, elektrodlar masofasi va katod yuzasi esa jarayon kinetikasiga kuchli ta’sir ko‘rsatdi. SEM va EDXRF tahlillari olingan shlamning volfram oksidlari ekanligini tasdiqladi. Natijalar WC–Co chiqindilarini energiya tejamkor va ekologik xavfsiz elektroximik qayta ishlash sanoat texnologiyasi uchun ilmiy asos yaratadi.

Kalit so‘zlar: *elektroximik qayta ishlash, elektroliz, WC–Co qattiq qotishmalar, volfram oksidlari, kobaltning selektiv erishi, nitrat elektroliti (HNO_3), sulfat elektroliti (H_2SO_4), o‘zgaruvchan tok (AC), volfram shlami, anodda erish jarayoni, $(NH_4)_2SO_4$ qo‘shimchasi, elektrodlar orasidagi masofa, katod yuzasi, SEM tahlil, EDXRF tahlil, qattiq qotishma chiqindilari, energiya tejamkor texnologiya, ekologik xavfsiz metall ajratish, volfram va kobaltni qayta tiklash.*

Аннотация. Данное исследование посвящено изучению эффективности электрохимической (электролитической) переработки отходов твёрдых сплавов WC–Co с целью селективного извлечения вольфрама и кобальта. Анализ литературных источников показывает, что традиционные пирометаллургические методы характеризуются высокими энергетическими затратами, выбросами токсичных газов и ограниченной селективностью, тогда как электрохимические процессы обеспечивают низкотемпературное (20–30 °C), экологически безопасное и высокоселективное растворение металлической фазы. В работе исследованы процессы электролиза в растворах азотной (HNO_3) и серной (H_2SO_4) кислот при переменном и постоянном токе. Установлено, что при переменном токе образование вольфрам содержащего шлама не

происходит, в то время как при постоянном токе наблюдается интенсивное анодное растворение WC с формированием оксидного шлама и переходом кобальта в раствор. Для сплавов VK6, VK8 и VK15 оптимальные параметры достигнуты при концентрациях 14,25% HNO_3 и 16,33% H_2SO_4, а добавление $(NH_4)_2SO_4$ существенно увеличивает выход шлама. Влияние межэлектродного расстояния и площади катода подтверждает их критическую роль в кинетике электрохимического процесса. Результаты SEM и EDXRF подтвердили оксидную природу вольфрамового продукта. Полученные данные служат научной основой для разработки промышленных технологий экологически безопасной и энергоэффективной переработки отходов WC–Co.

Ключевые слова: *электрохимическая переработка, электролиз, твёрдые сплавы WC–Co, оксиды вольфрама, селективное растворение кобальта, нитратный электролит (HNO_3), сульфатный электролит (H_2SO_4), переменный ток (AC), вольфрамовый шлам, анодное растворение, добавка $(NH_4)_2SO_4$, межэлектродное расстояние, площадь катода, анализ SEM, анализ EDXRF, отходы твёрдых сплавов, энергоэффективная технология, экологически безопасное извлечение металлов, восстановление вольфрама и кобальта.*

Abstract. This study investigates the efficiency of electrochemical (electrolytic) processing for the selective recovery of tungsten and cobalt from WC–Co hard-alloy scrap. A comprehensive literature review reveals that conventional pyrometallurgical routes suffer from high energy consumption, toxic gas emissions, and low selectivity, whereas electrochemical processing operates at low temperatures (20–30 °C), produces no harmful gases, and enables selective dissolution of cobalt while converting WC into tungsten oxide sludge. Experiments were performed using nitric acid (HNO_3) and sulfuric acid (H_2SO_4) electrolytes under alternating current (AC) and direct current (DC). AC electrolysis produced no measurable tungsten sludge due to alternating redox cycling, whereas DC electrolysis resulted in intensive anodic dissolution of WC and the formation of tungsten oxide sludge with simultaneous cobalt dissolution. Optimal results for VK6, VK8, and VK15 alloys were achieved at 14.25% HNO_3 and 16.33% H_2SO_4, respectively. Addition of $(NH_4)_2SO_4$ significantly enhanced sludge formation, while electrode spacing and cathode surface area strongly affected reaction kinetics. SEM and EDXRF analyses confirmed that the obtained product consisted of tungsten oxides. The findings provide a scientific basis for designing industrial-scale, energy-efficient, and environmentally safe electrochemical recycling technologies for WC–Co waste.

Keywords: *electrochemical processing, electrolysis, WC–Co hard alloys, tungsten oxides, selective cobalt dissolution, nitric electrolyte (HNO_3), sulfuric electrolyte (H_2SO_4), alternating current (AC), tungsten sludge, anodic dissolution, $(NH_4)_2SO_4$ additive, electrode spacing, cathode surface area, SEM analysis, EDXRF analysis, hard-alloy waste, energy-efficient technology, environmentally safe metal recovery, tungsten and cobalt extraction.*

Introduction

WC–Co based hard alloys represent one of the most important classes of tool materials used in mining, cutting, drilling, and wear-intensive industrial applications. Their high hardness, fracture toughness, and thermal stability arise from the combination of tungsten carbide grains (WC) bonded with a cobalt (Co) metallic matrix. However, during prolonged operation under severe loading, these alloys undergo degradation, microcracking, oxidation, and mechanical wear, ultimately generating significant quantities of industrial waste. Recycling such waste is economically attractive because WC–Co alloys contain high-value metals—primarily tungsten and cobalt—which are classified as strategic and critical raw materials in many countries. At the same time, their improper disposal leads to environmental pollution, contamination of soil and water with heavy metals, and loss of expensive raw materials.

Literature Review

Electrochemical (electrolytic) processing has recently emerged as a promising method for the selective extraction of tungsten and cobalt from hard-alloy scrap. Unlike pyrometallurgical treatment, electrolysis proceeds at relatively low temperatures (20–30°C), produces no toxic gaseous emissions, and allows the selective dissolution of Co while converting WC into tungsten-containing oxide sludge. This study focuses on developing an efficient electrolytic route using nitric acid (HNO_3) and sulfuric acid (H_2SO_4) electrolytes under both alternating current (AC) and direct current (DC) regimes.

Experiments were conducted in a 100,000 cm^3 acid-resistant electrolyzer lined with chemically stable coating. Solutions of HNO_3 and H_2SO_4 of various concentrations were prepared based on bidistilled water. Before electrolysis, the chemical composition of the acidic electrolytes was determined to identify impurities that may influence reaction kinetics. The analytical results for nitric and sulfuric acids are shown in the following tables:

Table 1. Chemical composition of nitric acids used in the electrolysis process.

T/R		Elements to be determined, mg/L									
№1	*M*	Au	Pt	Ag	Rh	Ir	Ru	Al	Ca	Co	Cr
	mg/l	<1	<1	<1	<1	<1	<1	<1	19	2	<1
	M	Cu	Fe	Mg	Mn	Ni	Pb	Sb	Zn	Si	Pd
	mg/l	<1	1	4	<1	<1	1	<1	1	<1	<1

Table 2. Chemical composition of sulfuric acid used in the electrolysis process.

T/R		Elements to be determined, mg/l									
№1	*M*	Au	Pt	Ag	Rh	Ir	Ru	Al	Ca	Co	Cr
	mg/l	<1	<1	<1	<1	<1	<1	<1	15	1	<1
	M	Cu	Fe	Mg	Mn	Ni	Pb	Sb	Zn	Si	Pd
	mg/l	<1	<1	1	<1	<1	5	<1	1	<1	<1

Both electrolytes were largely free of harmful contaminants, except for minor concentrations of Ca, Mg, Fe, Pb, and Zn. Precious metals (Au, Pt, Ag, Rh, Ir, Ru, Pd)

were all below 1 mg/L, indicating that these acids do not introduce external impurities into the WC–Co dissolution process.

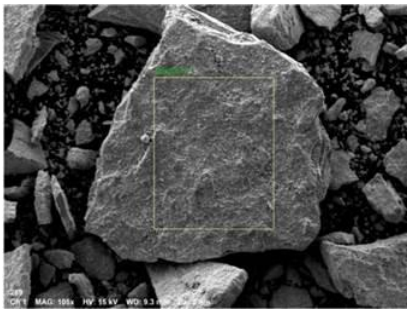
Electrolysis was performed under controlled conditions: electrode spacing of 10–50 mm, current intensity of 1–10 A, electrolyte temperature of 20–30 °C, and total processing time of 24 hours. Measurements of pH, voltage, temperature, and electrolyte consumption were continuously monitored. In AC mode, both nitric and sulfuric acids failed to produce measurable tungsten-containing sludge. This absence of sludge is attributed to alternating oxidation–reduction cycles, preventing stable formation of tungsten oxide species.

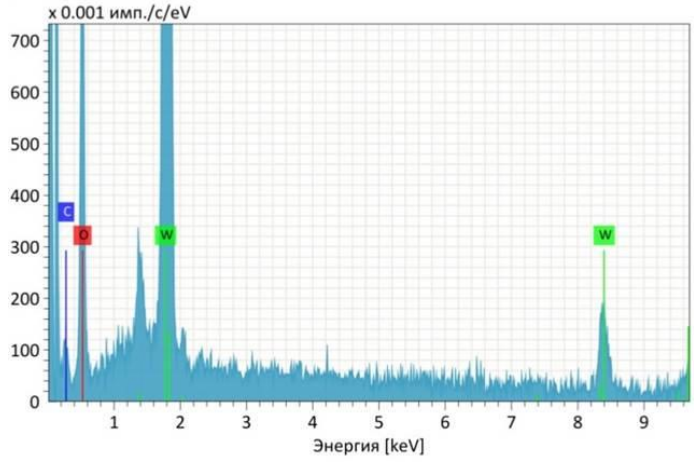
In contrast, DC electrolysis enabled intensive anodic dissolution of WC, yielding tungsten sludge and simultaneous dissolution of cobalt into solution. The behavior of WC–Co alloys (grades VK6, VK8, VK15) under DC electrolysis using HNO_3 is summarized in the following operational table:

Table 3. Electrolysis of solid alloy waste under direct current in the presence of HNO_3 (t=24 hours, T=20 °C).

№	Solution, %.	Salt, g/l	Mass of the obtained sludge, g.			Current power
	HNO_3	NH_4NO_3	VK6	VK8	VK15	W
1	9,50	4	3941,49	5255,32	9853,725	11,2
2	14,25	4	5383,01	7177,35	13457,53	12,24
3	19,00	4	5080,95	6774,60	12702,38	12,4
4	23,75	4	4531,66	6042,21	11329,15	12,24
5	28,50	4	4850,05	6466,73	12125,13	11,28

Maximum sludge formation in nitric acid occurred at 14.25% concentration, beyond which sludge mass decreased due to passivation effects and changes in solubility behavior. SEM micrographs and EDXRF results confirmed that the sludge mainly consisted of tungsten oxides with characteristic granular morphology:





a **b**

Figure 1. Determined area (a) and chemical composition (b) of the sludge sample.

Similar experiments in sulfuric acid revealed that H_2SO_4 is significantly more effective than HNO_3 for stable tungsten extraction. The highest sludge yield appears at 16.33% H_2SO_4 concentration with 4 g/L ammonium sulfate, as presented in:

Table 4. Electrolysis of solid alloy waste in the presence of H_2SO_4 under constant current (t=24 hours, T=20 °C).

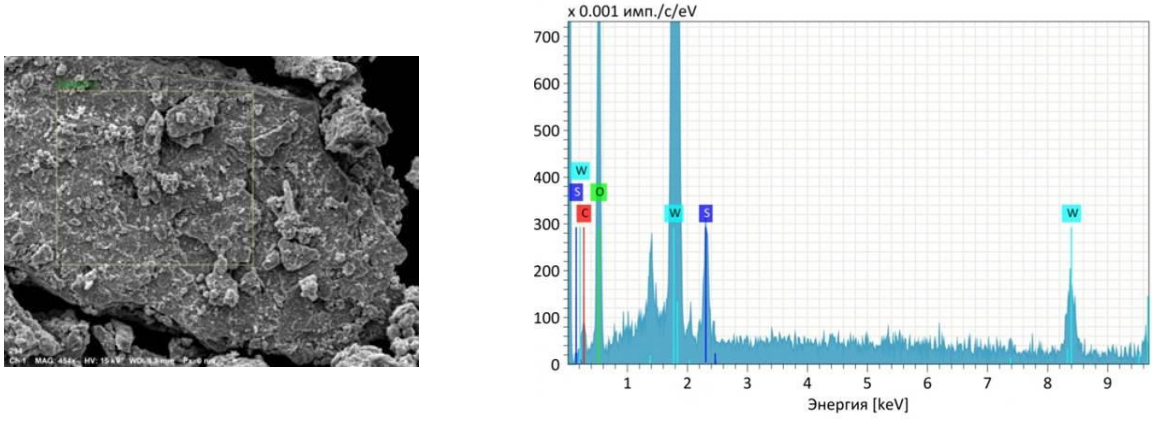
№	Solution, %.	Salt, g/l	Mass of the obtained sludge, g.			Current power
	H_2SO_4	$(NH_4)_2SO_4$	VK6	VK8	VK15	W
1	8,167	4	3153,21	4204,27	7883,02	9,84
2	16,330	4	4131,89	5509,18	10329,72	11,6
3	24,500	4	3374,05	4498,73	8435,11	10,8
4	32,670	4	492,30	656,40	1230,74	9,2
5	40,830	4	24	32	60	3,08
6	49,000	4	–	–	–	0,44

Further optimization showed that adding reducing salts such as $(NH_4)_2SO_4$ dramatically influences the amount of tungsten sludge formed. Sludge mass initially increases with salt concentration (up to 16–20 g/L), then declines due to reduced electrical conductivity at higher ionic strength:

Table 5. Electrolysis of solid alloy waste in the presence of H_2SO_4 under direct current (t=24 hours, T=20 °C).

№	Solution, %.	Salt, g/l	Mass of the obtained sludge, g.			Current power
	H_2SO_4	$(NH_4)_2SO_4$	VK6	VK8	VK15	W
1	16,33	4	4131,89	5509,19	10329,73	11,60
2	16,33	8	3886,80	5182,4	9717	11,12
3	16,33	12	3890,88	5187,84	9727,2	11,20
4	16,33	16	6099,84	8133,12	15249,6	11,36
5	16,33	20	6109,06	8145,41	15272,65	13,60
6	16,33	24	1364,16	1818,88	3410,4	10,80
7	16,33	28	1471,20	1961,6	3678	15,60

SEM and EDX analyses of the resulting tungsten powders are shown as Figure 2 below.



a **b**

Figure 2. Determined area of the solid alloy sample composition (a) and its chemical composition (b).

Electrode spacing was found to be another critical parameter. Increasing the gap between the cathode and anode led to a sharp decrease in sludge formation, while optimizing the electrode distance enhanced reaction kinetics:

Table 5. Electrolysis of solid alloy waste under direct current in the presence of H_2SO_4 (t=24 hours, m_{salt} =24 g/l).

№	Solution, %.	Distance between cathode and anode, mm	Mass of the obtained sludge, g.			Current power
	H_2SO_4		VK6	VK8	VK15	W
1	16,33	10	4131,89	5509,19	10329,73	15,60
2	16,33	20	2942,40	3923,20	7356,00	15,60
3	16,33	30	2494,08	3325,44	6235,20	10,00
4	16,33	40	2683,20	3577,60	6708,00	14,96
5	16,33	50	2014,08	2685,44	5035,20	9,80

The active surface area of the cathode also exerted significant influence. As the WC–Co contact area increased from 100 to 2000 cm², the amount of sludge produced increased proportionally, demonstrating scalability for industrial systems:

Table 6. VK6 dependence of the amount of sludge released on the surface of the cathode exposed to the solution (t=24 hours, l=20 mm, T=20 °C, V_{um}=60 l).

№	Solution, %.	Salt, g/l	Mass of the obtained sludge, g.	Cathode area, cm^2	Current power
	H_2SO_4	$(NH_4)_2SO_4$	VK6		W
1	16,33	20	6205,44	100	12
2	16,33	20	12507,84	200	12,4
3	16,33	20	31603,20	500	13,2
4	16,33	20	63783,36	1000	12,8
5	16,33	20	124206,72	2000	12,8

Overall, the introduction of electrochemical processing provides an efficient and environmentally safe method for recovering strategic metals from WC–Co waste. The results presented in this study form a scientific basis for designing industrial-scale recycling technologies that maximize tungsten and cobalt recovery while minimizing energy consumption and waste generation.

Conclusion

This study clearly demonstrates the effectiveness of electrochemical processing for recovering tungsten and cobalt from WC–Co hard-alloy waste. Both literature evidence and experimental findings confirm that, unlike conventional pyrometallurgical methods, electrolysis operates at low temperatures, produces no toxic emissions, and ensures high selectivity in dissolving metallic components. Experiments revealed that alternating current (AC) does not allow stable formation of tungsten oxide sludge, whereas direct current (DC) leads to intensive anodic dissolution of WC and the production of high-quality tungsten oxide sludge. Comparative testing of nitric and sulfuric acid electrolytes showed that H_2SO_4 provides significantly higher efficiency, with an optimal sludge yield at 16.33% concentration. The addition of $(NH_4)_2SO_4$ further enhanced tungsten recovery, while electrode spacing and cathode surface area were confirmed as critical parameters affecting process kinetics. SEM and EDXRF analyses verified that the obtained sludge consists predominantly of tungsten oxides. Overall, the results establish a solid scientific foundation for the development of

environmentally safe, energy-efficient, and industrially scalable electrochemical recycling technologies for WC–Co waste.

References:

[1] Sharipov K.A., Samadov A.U., Karimov M.M., Parmonov S.T., Ubaidullaev M.M., Shakirov Sh.M. "Ion-exchange method for obtaining cobalt raw materials during processing of waste hard alloys based on tungsten-cobalt carbide," Patent for utility model FAP 20240029. Registered in the state.

[2] Parmanov S.T., Shakirov Sh.M., Bekiev M.A. "Prospects for processing tungsten carbide-based toolmaking materials". *International scientific and practical conference on "Modern problems in the innovative development of science, education and production"*, Andijan. 2020, pp. 334-343.

[3] Parmonov S.T. "Increasing the abrasion resistance of hard alloys used in the mining and metallurgical industry by adding ultradisperse modifiers," *Journal of Pharmaceutical Negative Results*, India. Vol. 13, Special Issue 9, 2022, pp. 7474-7479.

[4] Parmonov S.T. "Scientific basis of hard alloy powder separation, drying and pressing processes based on tungsten carbide," *International Scientific-Technical Conference "Compositional Materials and Fundamentals of Technogenic Waste and Local Food: Composition, Properties, and Applications,"* Tashkent, September 16-17, 2021, pp. 198-200.

UDC: 62, 549.2, 661.8

ANALYSIS OF THE INFLUENCE OF PARTICLE SIZE, THE AMOUNT OF WOLFRAMATE, HYDROCARBONATE, AND SODIUM HYDROXIDE IN THE SOLUTION, AS WELL AS THE DENSITY OF THE BODY DURING THE SELECTION OF WOLFRAM CAKES

Khalikulov Utkir Mirzakamolovich
Associate Professor (PhD), Acting Rector, Almalyk State Technical Institute, Vice-Rector for Academic Affairs
u.xalikulov@odti.uz

Parmonov Gayrat Makhmatkulovich
Senior Lecturer, Department of Chemical Technology, OSTU, Almalyk, Uzbekistan
gparmonov064gmail.com

Annotatsiya. Ushbu maqolada volfram keklarini natriy karbonat eritmasida tanlab eritish jarayoniga ta'sir etuvchi omillar – zarracha yirikligi, soda eritmasi konsentratsiyasi, natriy volframat va gidrokarbonat miqdori hamda bo'tana zichligi chuqur tahlil qilingan. Tajribalar natijalariga ko'ra, zarracha o'lchami kichrayishi va soda konsentratsiyasining ortishi volframning eritmaga o'tish darajasini sezilarli oshirishi aniqlandi. Shuningdek, boshlang'ich eritmadagi Na_2WO_4 va Na_2CO_3 molyar nisbatining o'zgarishi erish kinetikasiga teskari proporsional ta'sir ko'rsatishi qayd etildi.

Kalit so'zlar: *volfram keki, tanlab eritish, soda eritmasi, erish kinetikasi, natriy volframat, zarracha o'lchami.*

Аннотация. В данной статье представлен углубленный анализ факторов, влияющих на селективное растворение вольфрамовых кеков в растворе карбоната натрия: размера частиц, концентрации раствора соды, содержания вольфрамата и бикарбоната натрия, а также насыпной плотности. По результатам экспериментов установлено, что уменьшение размера частиц и увеличение концентрации соды значительно увеличивают степень растворения вольфрама. Также отмечено, что изменение мольного соотношения Na_2WO_4 и Na_2CO_3 в исходном растворе оказывает обратно пропорциональное влияние на кинетику растворения.

Ключевые слова: *вольфрамовый кек, селективное растворение, раствор соды, кинетика растворения, вольфрамат натрия, размер частиц.*

Abstract. This article provides an in-depth analysis of the factors affecting the selective dissolution of tungsten cakes in sodium carbonate solution - particle size, soda solution concentration, sodium tungstate and bicarbonate content, and bulk density. According to the experimental results, it was found that a decrease in particle size and an increase in soda concentration significantly increase the degree of tungsten dissolution. It was also noted that a change in the molar ratio of Na_2WO_4 and Na_2CO_3 in the initial solution has an inversely proportional effect on the dissolution kinetics.

Keywords: *tungsten cake, selective dissolution, soda solution, dissolution kinetics, sodium tungstate, particle size.*

Introduction

The processing of tungsten cakes, which is one of the main stages of the tungsten industry, is of decisive importance in obtaining high-purity tungsten compounds. The method of selective leaching of WO_3 from tungsten cake is widely used, and the effectiveness of this process directly depends on many technological factors. Particle size, soda solution concentration, sodium tungstate and bicarbonate content, as well as pulp density, significantly affect the dissolution kinetics. Due to the large specific surface area of fine fractional particles, the degree of their interaction with Na_2CO_3 is high, and as a result, the efficiency of tungsten penetration into the solution increases. In-depth study of the process parameters makes it possible to optimize tungsten extraction, reduce the amount of consumables, and increase production efficiency. Therefore, the scientific study of the mechanisms of selective smelting of tungsten cakes is considered practically and economically relevant. The purpose of this study is to scientifically determine the relationship between the main factors influencing the process of leaching tungsten cakes in a sodium carbonate solution - particle size, concentration of soda solution, amount of sodium tungstate and bicarbonate, and pulp density. By evaluating each of the parameters affecting the kinetics of the process under experimental conditions, the possibilities of optimizing the degree of tungsten dissolution into solution, increasing the dissolution rate, and reducing reagent consumption were studied.

Research Methodology

The melting point and concentration of soda ash for the tungsten cake leaching

process were considered. In the selective smelting of tungsten cake, the particle size of the cake is of great importance. The influence of tungsten cake particle size on the kinetics of the process was determined in experiments on leaching at 95°C with a soda solution with a concentration of 25 g/l (Fig. 1). The values of the determined melting velocities are given (Table 1).

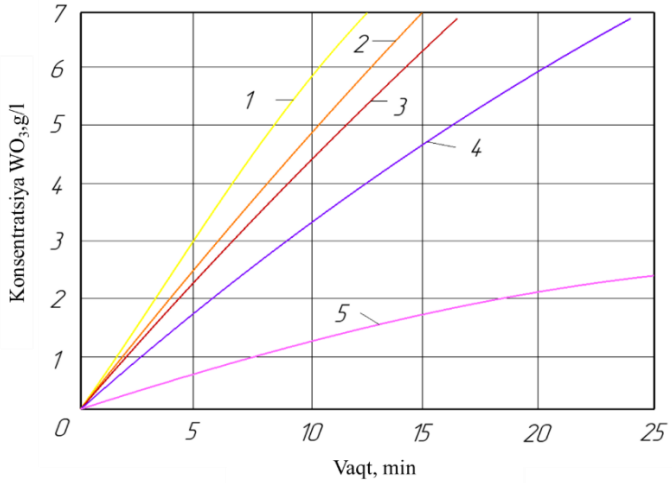


Figure 1. Kinetics of dissolving tungsten cakes of different sizes in a soda solution at 95°C:1) -0.074 mm; 2) -0.105 +0.074 mm; 3) -0.148+0.105 mm; 4) -0.250+0.148 mm; 5) -0.40 +0.250 mm.

Table 1. Values of tungsten cake melting rate.

Tungsten cake size, mm	Melting rate, 10^3 mol/l min
-0,074	2,78
-0,105 +0,074	2,16
-0,1484+0,105	1,99
-0,250+0,148	1,175
0,40+0,250	0,48

The melting rate determined experimentally is proportional to the size of the specific surface area of the tungsten cake particles.

When selectively melting tungsten cakes at a temperature of 95°C for 2 hours, with very fine particles up to 2 μm, the results of the measurements during the leaching of tungsten into solution are as follows:

Table 2. Dependence of cake sizes on the transition of tungsten to solution during leaching and leaching.

Tungsten cake size, mm	**Separation of tungsten into solution, %**	**Size class, mm**	**Separation of tungsten into solution, %**
– 0.002	81.54	– 0.053 + 0.037	76.52
– 0.005 + 0.002	80.72	– 0.074 + 0.053	75.15
– 0.010 + 0.005	79.69	– 0.100 + 0.074	74.10
– 0.020 + 0.010	78.81	– 0.150 + 0.100	73.25
– 0.037 + 0.020	77.32	– 0.210 + 0.150	72.24

Analysis and Results

With a decrease in the particle size of tungsten cake, i.e., an increase in their specific surface area, the degree of tungsten dissolution into solution increases significantly. In this case, fine-grained particles have high reactivity and the ability to actively interact

with the solvent Na_2CO_3. The effective extraction of WO_3 from tungsten cakes by leaching directly depends on the size of the cake, temperature, the melting point ratio, and the concentration of the Na_2CO_3 (sodium carbonate) solution. With increasing concentration, the aggressiveness of the solution medium increases, resulting in a higher efficiency of tungsten extraction.

In the small industrial workshop of JSC "Uzbekistan Technological Metals," experiments were conducted on the processing of tungsten cake with soda solutions of various concentrations containing sodium tungstate.

Experiments were conducted at a temperature of 95 °C for 1 hour, and the results were obtained. Experiments with tungsten in the initial soda solution showed that the lower the soda concentration relative to the sodium tungstate concentration, the slower the decomposition reaction of the tungsten cake. This means that the specific rate of the reaction changes approximately inversely proportional to the molar ratio of tungstate and soda in the initial solution.

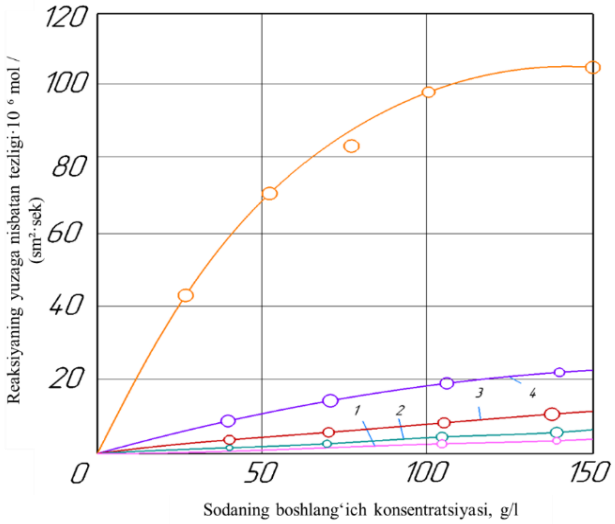


Figure 2. Influence of tungsten content in soda solutions of various concentrations on the dissolution rate of tungsten films 1-2.4 g/l WO_3, 2-2.1 g/l WO_3, 3-1.8 g/l WO_3, 4-1.5 g/l WO_3, 5-non-tungsten soda solution.

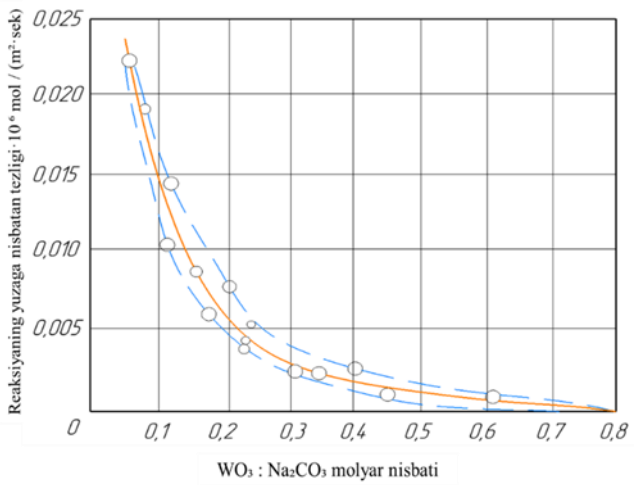


Figure 3. Dependence of the specific melting rate of tungsten cake film on the molar ratio of sodium tungstate and soda in the initial solution.

It is known that with an insufficient time for leaching tungsten cakes, a decrease in the cake's melting rate with an increase in the relative tungsten content in the solution leads to a decrease in WO_3 release.

The obtained experimental results showed that particle size and soda concentration are the main regulating factors in the process of selective leaching of tungsten cakes. With a decrease in particle size, due to an increase in the specific surface area, the degree of WO_3 penetration into the solution increases significantly. Increasing the concentration of the soda solution increased the chemical activity of the medium and accelerated the dissolution kinetics. However, an increase in the Na_2WO_4 content in the initial solution slows down the process and indicates the need to choose the optimal molar ratio for the complete extraction of tungsten. It was also established that an increase in the density of the pulp increases the resistance to diffusion processes and reduces the efficiency of melting. In general, the correct choice of process parameters allows for significant optimization of tungsten extraction technology.

Conclusion

The research results showed that the particle size, soda concentration, and the amount of sodium tungstate in the initial solution are important factors in the process of leaching tungsten cakes in a sodium carbonate solution. As particle size decreased, their specific surface area increased, and the degree of tungsten penetration into the solution significantly improved. An increase in the concentration of the soda solution increased the aggressiveness of the solution medium and accelerated the release of WO_3. At the same time, it was found that an increase in the molar ratio of Na_2WO_4 and Na_2CO_3 in the solution reduces the melting rate, which indicates the need to choose the optimal ratio and time for the complete extraction of tungsten during the process. The obtained results are of practical importance for improving the technology of tungsten production, reducing reagent consumption, and increasing the efficiency of separation.

References:

[1] Shakhriddin Turobov, Najmiddin Boymurodov, Amirjon Murodovich Xo'jakulov "RESEARCH ON TECHNOLOGICAL METHODS AND EFFICIENCY OF DEEP ENRICHMENT OF TUNGSTEN FROM TECHNOGENIC WASTE," *Digital Technologies in Indust*ry, 2(4-1), 2024, pp. 1-5. DOI:10.70769/3030-3214.SRT.2.4-1.2024.12

[2] Petrov I.P., Sidorov V.K. "Hydrometallurgical methods for processing tungsten-containing waste to produce commercial tungsten oxide," *Proceedings of the International Symposium on Rare and Trace Metals*, 2023, pp. 21-35.

[3] Smirnov A.V., Krylov P.Yu., Lebedeva I.S. "Development of an integrated technology for processing waste tungsten-containing materials to produce technical tungsten oxide," *Metallurgy and Materials*, 2023, pp. 58-65.

[4] Parmonov S., Parmonov G.M. "Complex Processing of Tungsten Waste of JSC "Uzbek Technological Metallurgical Plant" *Journal of Development of Science*.

UDC: 62, 621.9

ANALYSIS OF VIBRATION FACTORS AFFECTING THE WORKING BODY OF TECHNOLOGICAL EQUIPMENT

Asatillaev Yuldashali Malikovich
Associate Professor (PhD), Namangan State Technical University
asatillaevyuldashali@gmail.com

Annotatsiya. Maqolada texnologik jihozlarning ijrochi organlarining tebranishini kesish jarayonida yuzaga keladigan buzuvchi omillarning ta'sirini o'rganilgan. Shpindelning aylanuvchi qismini o'z o'qidan tashqariga chiqish tebranish qonuniyatlari o'rganilgan. Kesish zonasida asbobning kesuvchi qirrasi va ishlov berilgan detal yuzasining o'zaro ta'sirlashish ostida paydo bo'ladigan kuchlarning shpindelning aylanma harakatida yuzaga keladigan tebranishlarning amal qilish qonunini tahlili o'rganilgan.

Kalit so'zlar: *vibratsiya, dinamika, barqarorlik, turg'unlik, aniqlik, model, shpindel, asboblar, traektoriya.*

Аннотация. В статье изучено влияние возмущающих факторов на вибрацию исполнительных органов технологического оборудования в процессе резания. Изучены закономерности колебаний вращающейся части шпинделя за его осью. Проведены анализы закона действующие силы, возникающих в зоне резания при взаимодействии режущей кромки инструмента и поверхности заготовки, которые возникают при вращательном движении шпинделя.

Ключевые слова: *вибрация, динамика, устойчивость, стойкость, точность, модель, шпиндель, инструмент, траектория.*

Abstract. The article examines the influences consider the effects of disruptive elements present during the cutting vibration of the machines' executive bodies. The patterns of change in the motion trajectory of the billet's rotating section's instant center are examined. are shown in the drawing direction of the cutting of the relative movement of the tool's cutting edge and the processed workpiece, as a result of exposure to the appearance of spatial movements and the breaking of the spindle movement's stated law.

Keywords: *vibration, dynamic, stability, stagnation, accuracy, model, spindle, tools, trajectory.*

Introduction

The metal cutting machine must deliver the necessary processing precision and high-performance treated surface quality. Maintaining a steady flow of the workpiece and the tool along a specific trajectory is essential to achieving a high-quality component surface during the cutting process. It is well known that various cutting processes result in various dynamic effects that have a substantial impact on both the consistent physical course of the processing process and the right geometric shaping of the billet. The quality of the treated surface is negatively impacted by the vibrations that occur

during the cutting process; the treated part's surface roughness and dimension accuracy are both increased [1].

Numerous works of scientists are devoted to experimental studies of static and dynamic deformations in metal cutting. The analysis of the dynamics of machine tools is considered in the work of Kudinov V.A., the following main dynamic parameters of the machine: stability margin, system response to external influences, and speed of cutting, which determine the duration of the transient process in the system [1].

With a viscous damping proportionate to the oscillations, the mink mounting is a step-by-step steel baln in the elastic supports. Unaligned by plunging, a support, concentrated by mass, an external concentrated load, or a jump in the dispersed load, the beam is broken into *N* regions. The exhaust stiffness of the EJ_i and the distributed mass mi of each of its segments are both constant.

There are three sections to the spindle. The belt transmission's pulley and cartridge are at the ends of its concentrated loads. The third cross disturbance of the $F_3(t)$ drive in the zero portion of the spindle exhibits an outrage from the cutting process, the force $F_0(t)$.

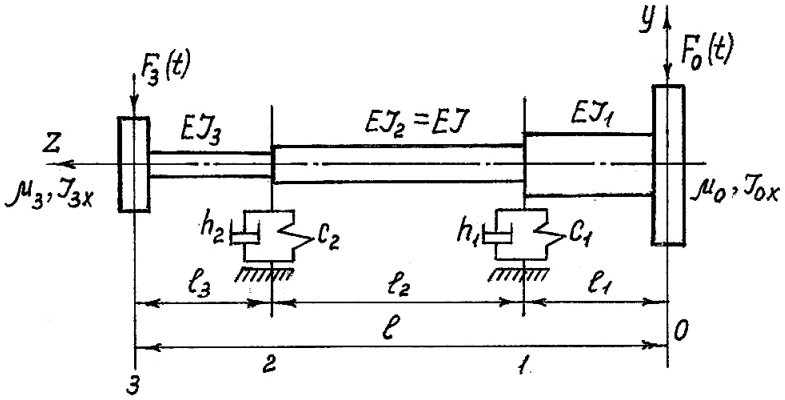


Figure 1. Parametric scheme of the machine.

When examining the architectures of machine spindle nodes, they considered the third cross-disturbance from the drive, where the cutting process—the cutting force—operates the perturbations. In spindle nodes, the axis of rotation rotates over a fixed point due to external power effects. In an attempt to stop the forced turns of the axis of one's own rotation in space, these turns are the manifestation of moments of resistance. These moments interact to cause unequal rotation or movement of the executive bodies, which violates the movement's rights and causes spatial motions to emerge in the treatment zone. Consequently, a number of indices of the correctness of the processed blanks show variances [1, 2].

Different trajectories of the motion of the immediate center of the rotating portion of the blank are generated during the processing of the blanks, and this movement is executed at different speeds. This results in the emergence of amplitude and frequency variations that are directly dependent on the dynamic properties of the spindle nodes and the processing circumstances of the blanks [3].

Research Methodology

The cutting tool geometry, where the plan angle is φ and the rake angle is γ, determines the direction of the cutting force vector. This determines the influencing

parameters of the cutting process. The vector of the disturbing force P in the OXY plane, where O is the fixed pole of rotation, grows as S and the cutting cross-section do. The direction and frequency of the forced spatial motion of the spindle unit's natural rotation axis in the machining zone change concurrently with an increase in the external disturbing moment Mp1.

The coordinates of the relative movement of the tool's cutting edge and the processed workpiece due to perturbing effects are constantly shifting during processing. Cutting regimes and the cutting tool's geometry have an impact on the process. The characteristics of the processed material determine the depth of cutting and feeding [3-5].

Analysis and Results

A change in the dimensions of the cut layer and a change in the cutting force result from the shaping movement of the cutting tool and the workpiece during the cutting process. The workpiece and tool system vibrate as a result. Assumptions regarding the rigidity of the spindle in relation to the rigidity of the subsystem of the relative movement of the cutter and the workpiece along two coordinates can be made when examining vibrations during cutting. In particular directions, deformations have the greatest impact on the system's linearity and shaping accuracy (Figure 2).

The cutting tool's geometry, where the angle in terms of φ and the front angle γ, is determined by the direction of the cutting force vector. As S increases, the cross section is cut, the external perturbation moment Mp1 is increased, and the trajectory and frequency of the forced spatial motion of the axis of its own spinning hole in the treatment zone are altered. This is followed by the vector of the perturbing force P in the OX of the ohu, where O is a fixed pole of the turn.

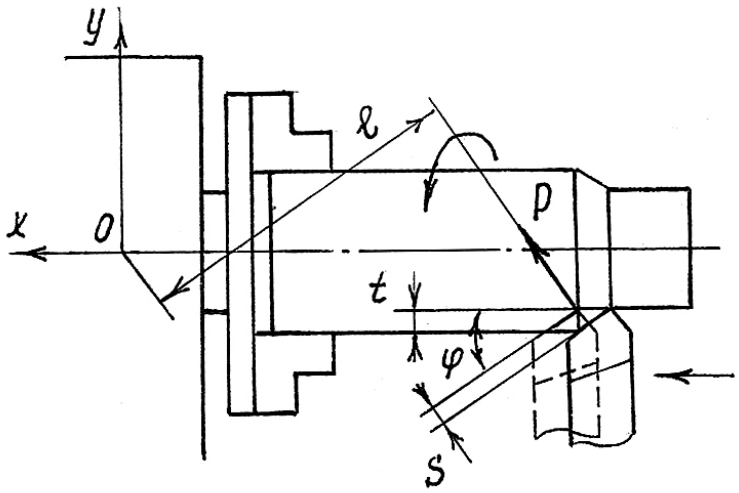


Figure 2. Influence of perturbing factors in the process of processing.

The ratio between the components of this force is in the slumps x_{Oy} and y_{Oz}, which affects the moments from these components in relation to the fixed pole of the turn. When the front angle changes, the direction of the vector γ of the perturbing force P in the z_{Oy} plane similarly changes.

The mathematical model is built on the basis of a functional diagram of the process connecting input and output values. Based on this, the processing process can be considered as a managed object [6]. The most complex processes occur in the object

during the formation of the surface layer. It is known that the cutting process geometrical parameters of the cut-off layer of the allowance are decisive. These factors depend on the workpiece's existing shape, the tool's surface shape, and the shaping movement's actual trajectory, which establishes the tool's and the workpiece's relative positions in space.

This leads to the consideration of the hardness of the processed material of blanks, the dependency of the cutting force of the machine on the feed value of *S*, and the parameters of deformation of the equipment elements, which are shown in the table below. The increase in α is twice because the width of the wear zone on the cutting tool's back surface increases by 0.7–0.8 mm. The processing error increases as the ΔP_y increases [6, 7].

Table 1. Device dependence on the feed value.

Parameter material	Number of transitions	Longitudinal feed *S*, mm/for	The cutting force ΔP_y, kgs
Steel 45	1	0,06	17,3
Steel 45	2	0,12	62,9
Steel 45	3	0,18	76,8

Based on the results of research and calculations, we will build graphs of the dependencies of the parameters (see Figure 3). On the graph, the increase in the specified cutting depth is represented by three graphs of transient characteristics along the line 1,2, and 3 - deformations of the elastic system along the X, Y, and Z axes, respectively.

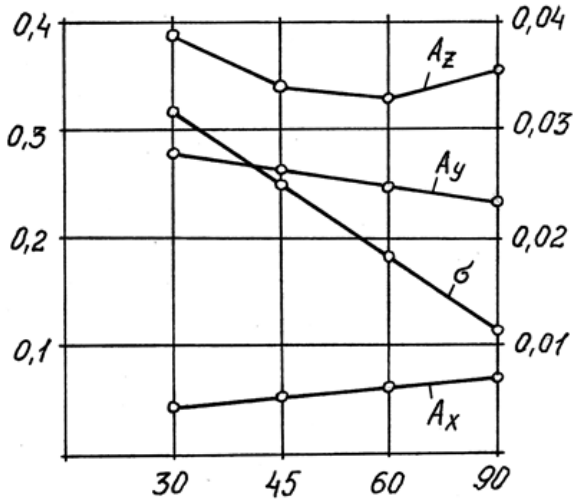


Figure 3. Graphs of experimental dependencies.

The graph indicates that the greatest oscillations of the dynamic system occur along the Z coordinate, the smallest along the X coordinate, that the speed of movement of the cutter tip due to oscillations in the direction of the Z axis affects the cutting speed, which in turn affects the cutting force and the magnitude of the vibration amplitude [7, 8]. The hardness of the workpiece material, the dependence of the equipment parts' deformation characteristics, and the cutting force P_y on the feed rate S are all taken into

consideration. The force P^2 doubles when the breadth of the worn zone on the cutting tool's flank rises by 0.7–0.8 mm. The machining error rises with increasing ΔP^2.

Conclusions

It enabled the determination that the pole of rotation within the first spindle bearing does not align with the center of gravity of the rotating masses of the spindle nodes. As it happens, it is either up or down, or displaced. horizontally to the left or right. Since the vector of the moment from the weight of rotating masses in the pole of rotation rotates with the spindle and the axis of its own spinellation, attempting to meet with the vertex of the moment of the moment, which is rotating, along the way with this vector, a hole of spindle nodes' axis of its own rotation describes the conical surface in space.

The cutting forces that emerge during cutting produce moments with respect to the turn's pole. The vectors of these moments, combined with the vector resulting from the weight of the rotating masses, constantly shift their position in space, rotating with the spindle. In contrast to machines with a vertical axis of rotation that has a simple character of spatial movements and simpler forms of the ratio of the velocities of its own and forced rotations, where the complexity of spatial movements of the axis of its own spinning rotation leads to a lower accuracy of processing on machines with a horizontal axis of rotation of spindle nodes, high precision of treatment can be achieved when the cutting is possible.

References:

[1] Sankin Yu.N. "Dynamics of bearing systems of metal-cutting machine tools," textbook, M.: *Mechanical Engineering*, 1986, p. 96.

[2] Kishurov V.M., Chernikov P.P., Yurasov N.V., and et al. "Appointment of rational cutting modes in mechanical processing textbook," Ed. 2nd, rev. and add. SPb.: *Publishing house "Lan,"* 2018, p. 216.

[3] Gaponkin B.A. et al. "Cutting metal-cutting tools and machines," A student's guide for universities. Moscow: *Mashinostroenie*, 1990, p. 448.

[4] Granovsky G.I. "Metal cutting," Textbook for mechanical engineering and instrument-making specialized universities. - Moscow: *Higher. school*, 1985, p. 304 p.

[5] Malikovich A.Y. "Features of the technology of cutting worms with a cutter on CNC machines," In *Conference Zone*, March, 2022, pp. 11-13.

[6] Asatillaev Y.M., Shermatov G.G., Mukhtorov S.A. "Optimization of cutting parameters depending on the depth of cutting and feed," FerPI, *Scientific and technical journal*, Vol. 24, № 3, 2020, pp. 29 - 32.

[7] Asatillayev Y.M. "Systematic and random errors in the process of shaping of technological equipment elements," FerPI, *Scientific and technical journal*, Vol. 25, № 1, 2021, pp. 56 - 60.

[8] Asatillayev Y.M. "Methods for Optimizing the Dynamic Characteristics of the Main Elements of Machine tools during Cutting," *Design Engineering*, issue 8, 2021, pp. 11104 – 11111.

UDC: 53, 53.01/.09, 538.9, 537.5

FORMATION ENERGY AND PHASE STABILITY OF A SOLID SOLUTION OF MOLECULAR SUBSTITUTION BASED ON Si AND GaP

Amin Saidov
Physical–Technical Institute Uzbekistan Academy of Sciences Tashkent, Uzbekistan
amin@uzsci.net

Shahzod Masharipov
Teacher, Department of Physics, Urgench State University named after Abu Rayhan Biruni
shahzodbekmasharipov6@gmail.com

Umida Asatova
Associate Professor (PhD), Department of Physics, Urgench State University named after Abu Rayhan Biruni
umida72@rambler.ru

Shukrullo Usmonov
Physical–Technical Institute Uzbekistan Academy of Sciences Tashkent, Uzbekistan
sh_usmonov@rambler.ru

Zuhra Raxmonova
Teacher, Department of Physics, Urgench State University named after Abu Rayhan Biruni
zuhraodilbekqizi@gmail.com

Annotatsiya. III–V guruh yarimo‘tkazgichlarini kremniy texnologiyasiga integratsiyalash kremniy asosidagi samarali optoelektron qurilmalarni yaratish yo‘lidagi eng muhim masalalardan biri bo‘lib qolmoqda. Ushbu ishda kristall kremniy panjarasida Si–Si atom juftlari o‘rnini GaP strukturaviy birliklari egallashi orqali hosil bo‘ladigan $(Si_2)_{1-x}(GaP)_x$ uzluksiz qattiq qorishmaning termodinamik va fazaviy barqarorligi tadqiq etildi. Zichlik funksional nazariyasi (DFT) yordamida hisoblangan hosil bo‘lish energiyalari $(Si_2)_{1-x}(GaP)_x$ stabil qattiq qorishmalarining tajribaviy jihatdan amalga oshirilishi mumkinligini tasdiqlaydi.

Kalit so‘zlar: *Qattiq qorishma, molekulyar almashtirish, hosil bo‘lish energiyasi, fazaviy barqarorlik, Si–GaP tizimi, zichlik funksional nazariyasi (DFT), termodinamik modellashtirish.*

Аннотация. Интеграция полупроводников III–V групп в кремниевую технологию остаётся одной из важнейших задач для создания эффективной оптоэлектроники на основе кремния. В данной работе исследуются термодинамическая устойчивость и фазовая стабильность непрерывного

твёрдого раствора $(Si_2)_{1-x}(GaP)_x$, образованного посредством молекулярного замещения, при котором структурные единицы GaP замещают пары атомов Si–Si в кристаллической решётке кремния. Расчёты энергий образования, выполненные методом теории функционала плотности (DFT), подтверждают возможность экспериментальной реализации стабильных твёрдых растворов $(Si_2)_{1-x}(GaP)_x$.

Ключевые слова: *Твердый раствор, молекулярное замещение, энергия образования, стабильность фазы, система Si–GaP, теория функционала плотности (DFT), термодинамическое моделирование.*

Abstract. The integration of III–V semiconductors into silicon technology remains one of the key challenges for the development of efficient silicon-based optoelectronic devices. In this work, the thermodynamic stability and phase stability of a continuous solid solution $(Si_2)_{1-x}(GaP)_x$ formed via molecular substitution, in which GaP structural units replace pairs of Si–Si atoms in the crystalline silicon lattice, are investigated. Formation energies calculated using density functional theory (DFT) confirm the possibility of experimental realization of stable $(Si_2)_{1-x}(GaP)_x$ solid solutions.

Keywords: *Solid solution, molecular substitution, formation energy, phase stability, Si–GaP system, density functional theory (DFT), thermodynamic modeling.*

Introduction

Silicon is the dominant material in modern microelectronics and the basis of integrated circuits, computing, and photovoltaic technologies. However, the indirect nature of silicon's band gap (~1.1 eV at 300 K) and its relatively low charge carrier mobility compared to III–V binary compounds fundamentally limit its use in high-frequency and power electronics, as well as in optoelectronic devices for generating and detecting radiation. These limitations stimulate intensive research aimed at heterolithic and monolithic integration of semiconductor materials with improved optoelectronic properties, primarily III–V compounds, on silicon substrates [1].

III–V semiconductor compounds, including GaAs, GaN, GaP, and InP, are characterized by high optoelectronic performance, which makes them highly significant as materials for active elements of high-frequency electronics, as well as sources and high-speed receivers of electromagnetic radiation over a wide spectral range. However, their monolithic integration with silicon is limited by a number of fundamental constraints arising from mismatched crystal lattice parameters, differing thermal expansion coefficients, misaligned crystal polarity, and the formation of antiphase domains (APDs) during epitaxial growth on Si. Additional complications arise from intrinsic defects and interphase reactions, which involve the diffusion of III–V elements into silicon and the formation of secondary phases, degrading the heterointerface quality and reducing charge-carrier lifetime.

One of the most promising approaches to overcoming these limitations is the formation of solid solutions based on silicon and III–V compounds via a molecular substitution mechanism, in which Si–Si dimers in the silicon crystal lattice are replaced by III–V isoelectronic pairs, particularly Ga–P. This mechanism ensures charge-

compensated incorporation of III–V elements and, unlike traditional doping methods, suppresses the formation of electrically active point defects. As a result, it becomes possible to form a continuous solid solution of the composition $(Si_2)_{1-x}(GaP)_x$ over a wide concentration range.

Gallium phosphide, crystallizing in a zinc blende structure structurally similar to the diamond-like lattice of silicon, is characterized by a small lattice mismatch with Si (~0.4%), providing favorable conditions for epitaxial growth on Si(111) substrates. Furthermore, GaP is a semiconductor with a band gap of approximately 2.26 eV, exceeding that of silicon, making it highly promising for the implementation of both passive and active optoelectronic functional elements on a silicon platform.

Literature Review

Recent experimental studies have demonstrated the feasibility of epitaxial growth of $(Si_2)_{1-x}(GaP)_x$ solid solution films with a smoothly varying band gap on Si(111) substrates. The resulting heteroepitaxial structures are characterized by high single-crystal quality and exhibit luminescent properties at room temperature, indicating the presence of a stable phase in this system [2]. These properties, taken together, highlight the significant potential of molecularly substituted Si–GaP solid solutions for the implementation of silicon-compatible optoelectronic functional elements.

Despite the experimental advances achieved, a fundamental understanding of the thermodynamic mechanisms governing the formation and stability of solid solutions in the Si–GaP system remains incomplete. In particular, the formation energies and phase stability of the $(Si_2)_{1-x}(GaP)_x$ solid solution have not yet been systematically and quantitatively analyzed. The lack of detailed *ab initio* studies aimed at assessing the relative energetic stability of various molecular substitution configurations significantly limits the ability to interpret experimental results and predict the achievable range of compositions and formation conditions for these stable phases.

In this regard, conducting a comprehensive theoretical study based on first-principles calculations aimed at analyzing the thermodynamic stability of the incorporation of GaP structural units into the silicon crystal lattice appears to be a necessary step for the targeted planning of experimental work. The results obtained can serve as a basis for developing sound design principles and optimizing the integration of III-V optoelectronic materials with the silicon technology platform.

Research Methodology

In this study, density functional theory (DFT) calculations were performed using the plane-wave pseudopotential method as implemented in the Quantum ESPRESSO package [3-4]. The electronic wave functions were expanded in a plane-wave basis set with a kinetic-energy cutoff of ecutwfc = 90 Ry, which was chosen as a uniform and sufficiently large value for all systems considered. This choice ensures consistent total-energy comparisons between pristine and doped configurations while maintaining computational efficiency.

Norm-conserving pseudopotentials generated within the Perdew–Burke–Ernzerhof revised for solids (PBEsol) exchange–correlation functional [5] were employed, using the SG15 pseudopotential library [6]. The same pseudopotentials and cutoff energy were used throughout all calculations to ensure methodological consistency.

Brillouin-zone integrations were carried out using Monkhorst–Pack k-point meshes. A 12×12×12 k-point grid was used for the conventional cubic Si unit cell, while a 6×6×6 grid was employed for the corresponding 2×2×2 Si supercell used in defect and doping calculations, preserving an equivalent k-point density in reciprocal space.

No explicit convergence tests with respect to the plane-wave cutoff energy or k-point sampling were performed. Instead, parameter values commonly adopted in the literature for norm-conserving pseudopotentials and semiconductor systems were selected to provide a balanced compromise between accuracy and computational cost.

Formation energy is a key quantity in materials science and chemistry, representing the energy difference between a formed compound (or a defect in a crystal) and the energies of its constituent elements (or atoms) in their most stable (reference) states. Formation energies are therefore evaluated using only total-energy differences and chemical-potential terms. This quantity indicates the thermodynamic stability of a material by describing whether energy is released or absorbed during its formation. The lower and more negative the formation energy, the more stable the compound.

The calculation of formation energy is widely used to assess the stability of new materials, predict phase diagrams, and investigate defects (such as vacancies and impurities) and dislocations in crystalline solids. Contributions depending on the Fermi level and finite-size charge corrections are neglected in the present work, since the primary focus is on relative stability trends among different defect configurations rather than on absolute defect formation energies.

The general expressions for the formation energies of neutral and charged defects are given below as a reference (Eq. 1-2), followed by explicit formulas for the four specific substitution configurations considered in this work (Eq. 3-6); contributions associated with the Fermi-level position and finite-size charge corrections are neglected, as they are small compared to the dominant total-energy and chemical-potential terms and do not affect the relative stability trends discussed here.

Formation energy of a neutral defect D^0 is defined as:

$$E_{for}(D^0) = E_{tot}(D^0) - E_{tot}(bulk) + \Sigma n_i \mu_i \quad (1)$$

Where:

- $E_{tot}(D^0)$ is the total energy of the defective supercell;
- $E_{tot}(bulk)$ is the total energy of the pristine supercell;
- n_i is the number of atoms added (positive) or removed (negative);
- μ_i is the chemical potential of species i.

Formation energy of a neutral defect D^q is defined as:

$$E_{for}(D^q) = E_{tot}(D^q) - E_{tot}(bulk) + \Sigma n_i \mu_i + qE_F + E_{corr} \quad (2)$$

Where:

- q is the charge state of the defect.
- E_F is the Fermi level referenced to the valence-band maximum.
- E_{corr} is the electrostatic finite-size correction.

Formation-energy formulas for specific cases:

1. Ga substituting Si - Ga_{Si}^{-}

$$E_{for}(Ga_{Si}^{-}) = E_{tot}(Ga_{Si}^{-}) - E_{tot}(bulk) + \mu_{Si} - \mu_{Ga} \quad (3)$$

2. P substituting Si - P_{Si}^{+}

$$E_{for}(P_{Si}^{+}) = E_{tot}(P_{Si}^{+}) - E_{tot}(bulk) + \mu_{Si} - \mu_{P} \quad (4)$$

3. Isolated Ga + P (not bonded).

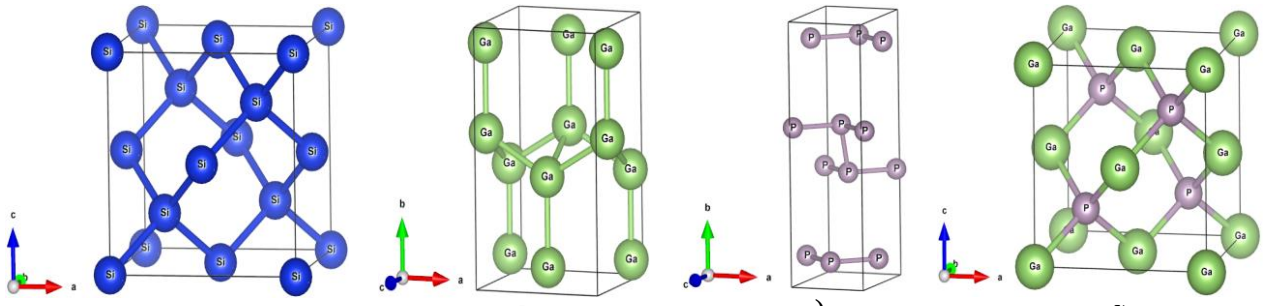
$$E_{for}(Ga_{Si}^{-} + P_{Si}^{+}) = E_{for}(Ga_{Si}^{-}) + E_{for}(P_{Si}^{+}) \quad (5)$$

4. GaP molecular substitution (neutral).

$$E_{for}(GaP) = E_{tot}(GaP) - E_{tot}(bulk) + \mu_{Si} - \mu_{Ga} - \mu_{P} \quad (6)$$

Analysis and Results

Figures 1 presents the crystal structures used in this work to define the host lattice and the elemental and compound reference systems. a) shows the diamond-cubic structure of Si, which serves as the pristine host lattice for all supercell calculations. b) illustrates the orthorhombic crystal structure of α-Ga, adopted as the reference phase for elemental gallium. c) displays the orthorhombic layered structure of black phosphorus, used as the reference phase for elemental phosphorus. d) depicts the zincblende crystal structure of GaP, consisting of tetrahedrally coordinated Ga and P atoms, which provides the structural model for GaP incorporation into the Si lattice. All structures are shown with their conventional unit cells and crystallographic axes for clarity.



a) b) c) d)

Figure 1. Conventional unit cells: a) Si, b) α-Ga, c) black-P, d) GaP

Table 1 summarizes the total energies of the elemental and compound reference systems calculated within density functional theory, together with the corresponding bulk chemical potentials used in the formation-energy analysis. The second column lists the total energies of the conventional unit cells for diamond-cubic Si, orthorhombic α-Ga, orthorhombic black phosphorus, and zincblende GaP.

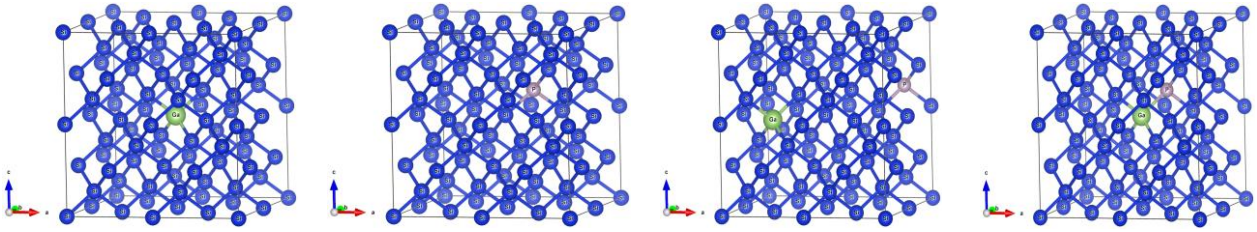
Table 1. Calculated energies of the elemental and compound.

System	E_{tot} of system, [eV]	Bulk chemical potential μ [eV/atom or eV/GaP]
Silicon	-858.978121113504	-107.372265139188
α-Gallium	-14249.3184707808	-1781.1648088476
Black Phosphorus	-1436.52742138857	-179.565927673571
Gallium Phosphide	-7846.431915535	-1961.60797888375

The third column reports the bulk chemical potentials, obtained by normalizing the total energies to a single atom for elemental phases or to one GaP formula unit for the

compound phase. These bulk chemical potentials serve as reference values in the calculation of substitution and formation energies for Ga-, P-, and GaP-related configurations in the Si lattice.

Figure 2 shows the relaxed 2×2×2 Si supercell configurations used to model different substitutional doping scenarios. a) presents the Ga-doped Si supercell, where a single Si atom is replaced by a Ga atom. b) shows the P-doped Si supercell with one substitutional P atom replacing a Si atom. c) illustrates the isolated Ga and P co-doped configuration, in which Ga and P atoms substitute two Si atoms at spatially separated lattice sites within the same supercell. d) depicts the bonded (molecular) Ga–P substitution, where a neighboring Ga–P pair replaces two adjacent Si atoms, forming a Ga–P bond within the Si lattice. In all cases, the conventional cubic supercell and crystallographic axes are indicated for reference, and atomic positions correspond to fully relaxed geometries.



a) b) c) d)

Figure 2. The doped supercells: a) Ga-doped Si, b) P-doped Si, c) isolated GaP doped Si and d) GaP-doped Si.

Table 2 summarizes the total energies of the pristine and doped 2×2×2 Si supercells and the corresponding formation energies of the doped configurations. The first row reports the total energy of the pristine Si_{64} supercell, which is used as the common reference. The second part of the table lists the total energies of the doped supercells containing a single Ga atom ($Si_{63}Ga_1$), a single P atom ($Si_{63}P_1$), isolated Ga and P substitutions within the same supercell ($Si_{62}Ga_1P_1$, atomic), and a bonded GaP pair substituting two neighboring Si atoms ($Si_{62}(GaP)_1$). The final column gives the formation energy of each doped configuration, defined as the total-energy difference between the doped and pristine supercells, with appropriate normalization according to the substitution scheme. All energies are reported in electronvolts, and the listed structures correspond to fully relaxed geometries.

Table 2. Total energies of pristine and doped 2×2×2 Si supercells and the corresponding formation energies of Ga-, P-, and GaP-related substitutions.

System	**E_{tot} of pristine 2x2x2-supercell, [eV]**	
Si_{64}	-6871.82524986559	
System	**E_{tot} of doped supercell, [eV]**	**E_{for} of doped supercell, [eV]**
$Si_{63}Ga_1$	-8538.89143773582	6.72635583818169
$Si_{63}P_1$	-6950.59821239791	-6.57929999793257
$Si_{62}Ga_1P_1$ (atomic)	-8617.6584368929	0.147055840249124
$Si_{62}(GaP)_1$	-8618.04560974477	-0.234153636387276

Although isolated P substitution in Si is found to be energetically favorable, this configuration is not expected under liquid-phase epitaxy conditions. At the growth temperature (~970 °C), P is present in the melt predominantly in the form of GaP units rather than as isolated atoms. Consequently, the relevant incorporation pathway is molecular GaP substitution, which is also found to be energetically favorable in our calculations.

Conclusions

The obtained results provide important insights into the thermodynamic stability of the observed phases and serve as a foundation for the development of synthesis strategies for new semiconductor solid solutions.

In particular, the analysis clarifies the role of molecular substitution and charge compensation in stabilizing GaP incorporation within the silicon lattice under experimentally relevant growth conditions.

References:

[1] Seredin P.V., Goloshchapov D.L., Khudyakov Y.Y. et al., “Structural and spectroscopic studies of epitaxial GaAs layers. grown on compliant substrates based on a superstructure layer and protoporous silicon,” *Semiconductors*, vol. 55, № 1, 2021, pp. 122–131.

[2] Saidov A.S., Saparov D.V., Usmonov Sh.N., Kutlimratov A., Abdiev J.M., Kalanov M., Razzakov A.Sh., and Akhmedov A.M. “Investigation of the Crystallographic Perfection and Photoluminescence Spectrum of the Epitaxial Films of $(Si_2)_{1-x}$ $(GaP)_x$ $(0 \leq x \leq 1)$ Solid Solution, Grown on Si and GaP Substrates with the Crystallographic Orientation (111),” *Advances in Condensed Matter Physics*, 2021, p. 3472487. DOI: 10.1155/2021/3472487

[3] Giannozzi P. et al., “QUANTUM ESPRESSO: a modular and open-source software project for quantum simulations of materials,” *J. Phys.: Condens. Matter.* 21, 2009, p. 395502.

[4] Giannozzi P. et al., “Advanced capabilities for materials modelling with Quantum ESPRESSO,” *J. Phys.: Condens. Matter.* 29, 2017, p. 465901.

[5] Perdew J.P. et al., “Restoring the Density-Gradient Expansion for Exchange in Solids and Surfaces,” *Phys. Rev. Lett.* 100, 2008, p. 136406.

[6] Schlipf M., and Gygi F. “Optimization algorithm for the generation of ONCV pseudopotentials,” *Comput. Phys. Commun.* 196, 2015, pp. 36–44.

UDC: 621. 315. 592;537.311.322

MECHANISMS FOR CONTROLLING THE I-V CHARACTERISTICS OF HETEROJUNCTION DIODES UNDER THE INFLUENCE OF A MAGNETIC FIELD

Majidova Gulnoza Nurmukhamedovna
Associate Professor (PhD), Namangan State Technical University, Islam Karimov Street, 12, Namangan 160103, Uzbekistan
m.gulnoza.1985@gmail.com

Annotatsiya. Ushbu maqolada magnit maydon ta’sirida geteroo‘tishli diodlarning volt-amper xarakteristikalarini boshqarishda mexanizmlari ko‘rib chiqilgan. Bunda tok tashuvchilar zichligini kamayishi yoki ortishi Lorens kuchiga bog‘liqligi ko‘rsatilgan. Hosil bo‘lgan Xoll kuchlanishi hisobiga potensial to‘siq balandligi o‘zgargan. Rekombinatsiya tezliklarini tok tashuvchilar yo‘nalishini og‘dirgani sababli ortishi yoki kamayishiga olib kelishini tushuntirilgan. Bu esa tok tashuvchilarning konsentrasiyasini qayta taqsimlashini ko‘rsatilgan.

Kalit so‘zlar: *geteroo‘tish, rekombinasiya, generatsiya, harakatchanlik, Xoll kuchlanishi, magnitoqarshilik, VAX-volt-amper xarakteristika.*

Аннотация. В статье рассматриваются механизмы управления вольт - амперными характеристиками гетеродиодов под воздействием магнитного поля. Показано, что уменьшение или увеличение плотности носителей тока зависит от силы Лоренца. Высота потенциального барьера изменяется под действием возникающей Холловской ЭДС. Объяснено, что скорость рекомбинации увеличивается или уменьшается из-за отклонения направления движения носителей тока. Показано, что это приводит к перераспределению концентрации носителей тока.

Ключевые слова: *гетеропереход, рекомбинация, генерация, подвижность, напряжение Холла, магнитосопротивление, ВАХ -вольт-амперная характеристика.*

Abstract. This article examines the mechanisms for controlling the current-voltage characteristics of heterodiodes under the influence of a magnetic field. It is shown that the decrease or increase in the current carrier density depends on the Lorentz force. The height of the potential barrier changes under the influence of the resulting Hall EMF. It is explained that the recombination rate increases or decreases due to the deviation in the direction of the current carrier motion. This is shown to lead to a redistribution of the current carrier concentration.

Keywords: *heterojunction, recombination, generation, mobility, Hall voltage, magnetoresistance, CVC-current -voltage characteristic.*

Introduction

Currently, studying the influence of magnetic fields on p-n junctions is a key area of research in semiconductor physics and optics. Research in this area is aimed at

improving the electrical and optical properties of p-n junctions and creating opportunities for their effective use. Magnetic fields can have a variety of effects on p-n junctions, particularly when studying their electromagnetic properties.

Literature Review

In particular, a magnetic field can alter the current flowing through p-n junctions, which affects the efficiency of p-n junctions or their conductivity. The influence of a magnetic field is studied, in particular, using the Hall effect. The Hall effect helps analyze the separation of electrons and holes in heterojunctions under the influence of a magnetic field [1].

Studying the influence of magnetic fields on the operation of semiconductor devices consisting of heterojunctions, such as diodes and transistors, contributes to the development of magnetoresistive (MR) and nuclear magnetic resonance (NMR) technologies.

Such research, in turn, enables high-speed operation and increased energy efficiency in semiconductor devices. Investigating the influence of magnetic fields on p-n junctions is leading to the study of new materials, particularly the properties of p-n junctions in two-dimensional materials (graphene, molybdenum disulfide, etc.) and nanostructures. These materials may exhibit new properties when treated with a magnetic field [2-3].

Research Methodology

This paper analyzes the physical processes occurring when a magnetic field acts on a p-n junction diode. In the absence of a magnetic field on a p-n junction diode, the electric field in the space charge region and diffusion processes in the p- and n-regions, depending on the state of equilibrium, continue to exchange charge carriers under the influence of the field until the number of diffused charge carriers equals the number of transferred charge carriers (see Figure 1) [4].

The width of the space charge field and the height of the p-n junction potential barrier are the same across the diode's p-n junction cross-section.

When a magnetic field is applied to the diode's p-n junction, electrons and holes are deflected perpendicular to the magnetic field and the direction of the current. The resulting Hall voltage radically alters the space charge field at the diode's p-n junction [5]. The thickness of the space charge field and the height of the p-n junction potential barrier remain variable in different regions of the p-n junction cross-section. The change in the width of the space charge field in the diode's p-n junction under the influence of a magnetic field is schematically shown in Figure 2.

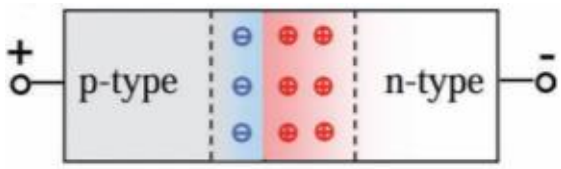


Figure 1. Width of the space charge field of a p-n junction in the absence of a magnetic field.

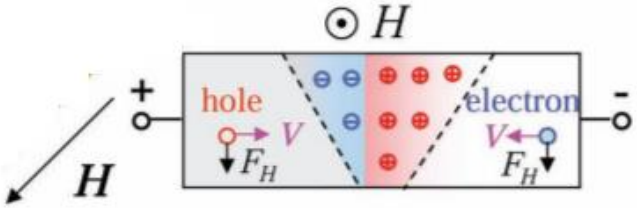


Figure 2. Change in the width of the p-n junction band under the influence of a magnetic field.

Under the influence of the Lorentz force, the trajectories of electrons and holes in the n- and p-regions are curved, leading to a shift of charges toward the edges of the sample. This alters the potential barrier, causing a sharp change in the resistance of the p-n junction. The resistance increases, leading to a decrease in current. The height of the potential barrier increases [6].

Analysis and Results

Shockley's expression, used for ideal diodes, takes on a different form when a magnetic field is applied.

$$j = j_s\left(e^{\frac{e\phi_0}{kT}-\frac{e}{kT_e}\left(\phi_0-U-U_1+\frac{aR_xJB}{l}\right)}\text{-}1\right). \quad (1)$$

Taking into account the resistance of the base of the p-n junction of the diodes, expression (1) is replaced by (2).

$$j = j_s\left(e^{\frac{e\phi_0}{kT}-\frac{e}{kT_e}\left(\phi_0-U-U_1+J\left(R_b+\frac{aR_xJB}{l}\right)\right)}\text{-}1\right) \quad (2)$$

If we compare the change in VAX of an ideal diode, we can observe the following (Figure 3).

It has been observed that the diode current amplitude (VAX) changes even when an external magnetic field is applied. As the magnetic field B increases, the diode current amplitude shifts toward lower currents and higher voltages in the JU plane. An increase in the magnetic field leads to a decrease in the current passing through it, even when a high voltage is applied to the diode [7].

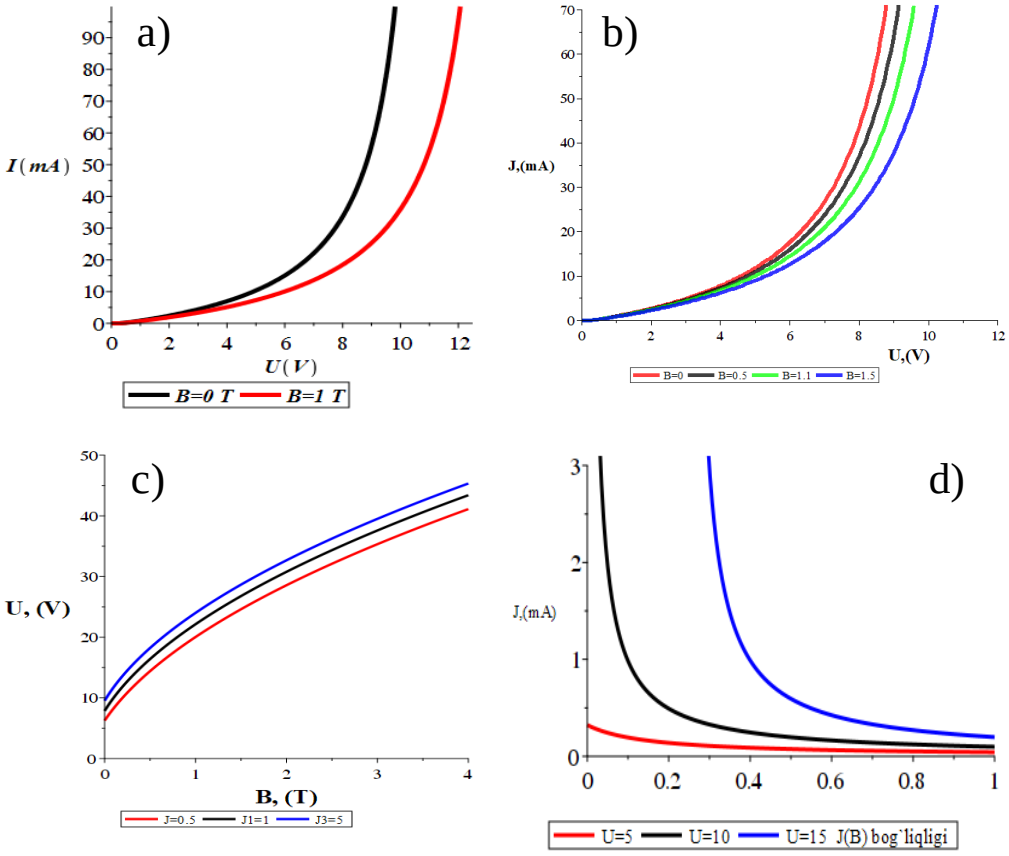


Figure 3. a) VAX obtained using the Shockley formula and under the influence of a magnetic field. b) Change in VAX under the influence of a magnetic field. c) Dependence of U on B for different current values. d) Dependence of J on B for different voltage values.

The graphs obtained above show that the decrease in current under the influence of a magnetic field is due to a decrease in the mobility of charge carriers in the sample. Because these charge carriers are subject to the Lorentz force, they are deflected from their original direction, which leads to a decrease in their effective velocity. It is clear that the graphs shift downward due to the decrease in current at high voltages [8].

At the same time, the sample resistance increases. The height of the potential barrier increases as additional potential is created due to the Hall effect. This increases the height of the initial potential barrier. Consequently, the current decreases due to magnetoresistance.

When a current is applied to a heterojunction diode, the voltage changes with increasing field strength. This means that if we select different sample currents and analyze the relationship between voltage and magnetic field.

We know that if the sample is not subject to a magnetic field, the relationship between current and voltage follows the Chokly equation: as current increases, voltage increases logarithmically. When a magnetic field is applied, the diode's resistance increases due to decreased carrier mobility. Increasing current leads to an increase in voltage under the influence of a magnetic field. This occurs due to the increase in base resistance. For any current, the voltage is higher in the presence of a magnetic field than in its absence [9].

Conversely, the relationship between voltage and current under a given magnetic field shows that at low voltages, the number of charge carriers decreases. The current decreases because the magnetic field slows them down. At medium voltages, the magnetic field alters recombination and diffusion processes, significantly reducing the current [10]. At high voltages, the resistance effectively increases. The magnetic field reduces the current flowing through the diode when voltage is applied. This difference increases with increasing voltage because mobility decreases, resistance increases, the direction of charge carrier movement is bent due to the Lorentz force, and additional potentials appear due to the Hall effect. When voltage is applied, the current decreases as the magnetic field increases.

This occurs because the magnetic field restricts the movement of charge carriers and increases the internal resistance of the diode [11].

Conclusion

It can be seen that under the influence of a magnetic field, CVC shifts in the JU plane. When a magnetic field is applied to the p-n junction, the current decreases and the voltage increases. The Lorentz force and Hall voltage generated by the magnetic field cause the space charge field to become trapezoidal. This leads to a decrease in the current across the width of the space charge field.

References:

[1] Shalimova K.V. “Physics of Semiconductors,” M. *Energoatomizdat*, 1985, p. 113.
[2] Egiazaryan G., Stafeev V. “Magnetodiodes and magnetotransistors and their application,” M. *Radio and Communications*, 1987, p. 26.
[3] Yang D., Wang F., Ren Y. “A Large Magnetoresistance Effect in p–n Junction Devices by the Space-Charge Effect,” *Adv. Funct. Mater.*, 23, 2013, pp. 2918–2923.
[4] Zhang K., Li H., Grünberg P., Li Q. “Large rectification magnetoresistance in nonmagnetic Al/Ge/Al heterojunctions,” *Scientific Reports*, 5, 14249, 2015, pp. 1-6.

[5] Overweg H., Eggiman H., Liu M-N. “Oscillating Magnetoresistance in Graphene p–n Junctions at Intermediate Magnetic Fields,” *Nano Lett.* Vol. 17 (5), 2017, pp. 2852-2857.
[6] Kara D., Kiyikci O., Oylumlooglu G. “Effect of magnetic field on germanium p-n homojunction,” *Mugla Journal of Science and Technology*, Vol. 7 (2), 2021, pp. 1-5.
[7] Gulyamov G., Majidova G.N., Mukhitdinova F.R. “Influence of a magnetic field on the characteristics of a p-n junction diode,” *Journal of Applied Science and Engineerin*, Vol. 27, 2023, pp. 1911-1917.
[8] Gulyamov G., Majidova G.N., Mukhitdinova F.R., Madumarova S.Q. “Influence of Temperature on Characteristics of a Diode with a p-n Junction in a Magnetic Field,” *e-Journal of Surface Science and Nanotechnology.* Vol.22, Issue 3, 2024, pp. 256–260.
[9] Gulyamov G., Majidova G.N., Mukhitdinova F.R. “Changing the Voltage of the p-n Junction in a Magnetic Field,” *e-Journal of Surface Science and Nanotechnology*, Vol 21, 2023, pp. 273−277.
[10] Wang T., Si M., Yang D. “Angular dependence of the magnetoresistance effect in a silicon based p–n junction device,” *Nanoscale*, Vol. 6, 2014, pp. 3978–3983.
[11] Gulyamov G., Majidova G. “Influence of electron and phonon heating on the characteristics of solar photocells” *Romanian journal of physics* Vol. 68, (3-4), 2023, pp. 110-115.

UDC: 53, 620.3, 004.4

THE IMPACT OF CHANNEL GEOMETRY ON SELF-HEATING TEMPERATURE IN 10 nm GAAFET

Abdikarimov Xidoyat Egamberganovich
Senior Teacher, Department of Energy and information systems, Urgench State University named after Abu Rayhan Biruni
abdikarimov.xidoyat@mail.ru

Abdikarimov Azamat Egamberganovich
Assistant Professor (PhD), Department of Physics, Urgench State University named after Abu Rayhan Biruni

Annotatsiya. Ushbu maqolada galliy arsenid (GaAs) asosida yaratilgan 10 nm zatvor uzunligiga ega bo‘lgan to‘liq o‘ralgan zatvorli maydoniy tranzistor (GAAFET)da kanal shaklining o‘z-o‘zini qizdirish effektiga ta’siri tadqiq etildi. Tadqiqot Sentaurus TCAD dasturiy paketi yordamida modellashtirish asosida olib borildi. Kanal ko‘ndalang kesim yuzasi doimiy saqlangan holda kanal balandligi 12 nm dan 4 nm gacha kamaytirildi va mos ravishda kanal eni o‘zgartirildi. Modellashtirish natijalari kanal balandligining kamayishi bilan stok toki oshdi va tranzistor markazidagi temperatura o‘zgarishini ko‘rsatdi. Kanal balandligi 6 nm dan kichik qiymatlarda issiqlikning tashqi sirt orqali samaraliroq tarqalishi hisobiga tranzistorning qizish temperaturasi pasayishi aniqlanib, bu holat termodinamik muvozanat nuqtai nazaridan izohlandi.

Kalit so‘zlar: *Galliy arsenid, GAAFET, nano o‘lchamli maydoniy tranzistor, kanal geometriyasi, o‘z-o‘zini qizdirish effekti, Jaul issiqligi, issiqlik tarqalishi, Sentaurus TCAD modellashtirish.*

Аннотация. В данной работе исследовано влияние геометрии канала на эффект самонагрева в полностью охватываемом затвором полевом транзисторе (GAAFET) на основе арсенида галлия (GaAs) с длиной затвора 10 нм. Исследование выполнено на основе численного моделирования с использованием программного пакета Sentaurus TCAD. При постоянной площади поперечного сечения канала его высота уменьшалась с 12 нм до 4 нм, при этом ширина канала изменялась соответствующим образом. Результаты моделирования показали увеличение тока стока при уменьшении высоты канала, а также изменение температуры в центральной области транзистора. Установлено, что при значениях высоты канала менее 6 нм температура самонагрева транзистора снижается за счёт более эффективного отвода тепла через внешнюю поверхность, что было объяснено с точки зрения термодинамического равновесия.

Ключевые слова: *Арсенид галлия, GAAFET, наноразмерный полевой транзистор, геометрия канала, эффект самонагрева, джоулево тепло, тепловыделение, моделирование Sentaurus TCAD.*

Abstract. This paper investigates the impact of channel geometry on the self-heating temperature of a 10 nm gate-length GaAs-based gate-all-around field-effect transistor (GAAFET). The study is conducted using numerical simulations in the Sentaurus TCAD environment. While maintaining a constant channel cross-sectional area, the channel height is varied from 12 nm to 4 nm, resulting in a corresponding change in channel width. The simulation results demonstrate that reducing the channel height increases the drain current and affects the temperature distribution within the transistor. It is observed that for channel heights below 6 nm, enhanced heat dissipation through the enlarged external surface area dominates Joule heat generation, leading to a reduction in the peak self-heating temperature. These findings provide valuable insights for optimizing nanoscale GaAs GAAFET designs with improved thermal performance.

Keywords: *Gallium arsenide, GAAFET, nanoscale field-effect transistor, channel geometry, self-heating effect, Joule heating, heat dissipation, Sentaurus TCAD simulation.*

Introduction

The continuous scaling of semiconductor devices has led to the rapid development of nanoscale field-effect transistors for high-frequency and high-performance electronic applications. Among various semiconductor materials, gallium arsenide (GaAs) has attracted significant attention due to its high electron mobility, wide bandgap, and superior performance in radio-frequency and microwave systems. GaAs-based field-effect transistors are widely used in mobile communication, satellite systems, radar technology, and other applications where high speed and low noise are critical requirements [1-3]. As device dimensions approach the nanometer scale, conventional planar transistor architectures face severe short-channel effects and electrostatic control limitations. Gate-all-around field-effect transistors (GAAFETs) have emerged as a promising solution to overcome these challenges by providing

excellent gate control over the channel and improved electrostatic integrity. However, the enhanced current density in nanoscale GAAFETs intensifies thermal issues, particularly the self-heating effect, which has become one of the major reliability concerns in GaAs-based devices [4, 5].

Self-heating in GaAs transistors originates mainly from Joule heating caused by high drain current flowing through the channel. Due to the relatively low thermal conductivity of GaAs compared to silicon, the generated heat is not efficiently dissipated, leading to a localized temperature rise in the channel region. This temperature increase degrades carrier mobility, reduces drain current, increases noise levels, and shortens device lifetime. Therefore, understanding and mitigating self-heating effects is essential for the reliable operation of GaAs-based nanoscale transistors [6]. Recent studies have shown that device geometry plays a crucial role in determining both electrical and thermal characteristics of nanoscale transistors. In particular, channel dimensions strongly influence current transport, heat generation, and heat dissipation pathways. While several works have investigated self-heating in GAAFETs, the impact of channel geometry under constant cross-sectional area conditions has not been sufficiently explored for GaAs-based devices. A detailed analysis of how channel height and width affect self-heating behavior is therefore necessary to optimize device design.

In this paper, a numerical investigation of self-heating effects in a 10 nm gate-length GaAs GAAFET is carried out using Sentaurus TCAD simulations. The channel cross-sectional area is kept constant while the channel height is varied, enabling a systematic assessment of geometric effects on the drain current and temperature distribution. The significance of this study lies in addressing thermal reliability challenges in nanoscale GaAs GAAFETs, which are crucial for high-frequency and high-power applications. The main objective of this work is to analyze the influence of channel geometry on the self-heating temperature and to identify optimal design conditions that minimize thermal degradation while preserving high electrical performance.

Research Methodology

In this work, a GaAs-based GGAFET with a gate length of 10 nm was modeled and investigated using the Sentaurus TCAD software. In the Sentaurus TCAD simulations, a comprehensive set of six physical models was employed to rigorously capture the complex electrical and thermal behavior of the GaAs GAAFET. These models include the Fermi-Dirac statistics model to account for carrier distribution at the nanoscale, the Shockley-Read-Hall (SRH) and Auger recombination models to describe carrier recombination mechanisms, the mobility degradation model to represent the reduction of carrier mobility due to high electric fields and impurity scattering, the lattice heating model to simulate self-heating effects and heat dissipation within the device, and the quantum confinement model to accurately reflect the effects of nanoscale dimensions on carrier energy levels and transport characteristics [7]. The integration of these models ensures that both electrical performance and thermal effects are precisely represented, providing a realistic and reliable framework for evaluating the influence of channel geometry on device behavior. Also, during the simulations, the transistor channel is made of GaAs, the gate dielectric is HfO_2, and the gate electrode is fabricated

from TiN. The source and drain regions are doped with n-type impurities at a concentration of 10^{20} cm^{-3}, while the channel is p-type doped with an impurity concentration of 10^{15} cm^{-3}, the channel cross-sectional area was kept constant at $H \cdot W = 144$ nm^2, and the impact of variations in the channel height H and channel width W on the operating temperature of the transistor was analyzed. The device structure under investigation and the current–voltage characteristics (I–V curves) obtained from the simulations are shown in Figure 1(a) and Figure 1(b), respectively.

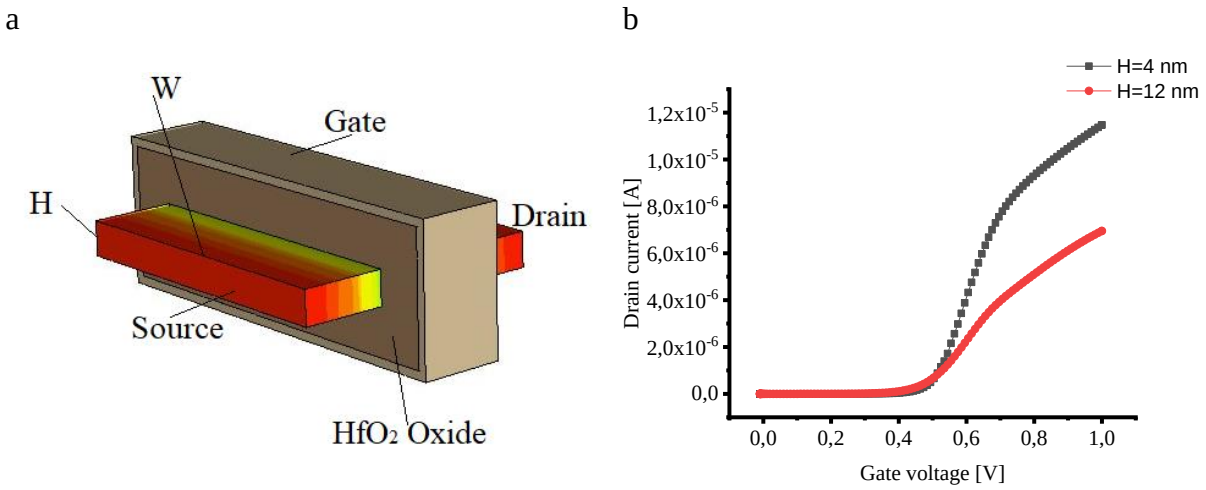


Figure 1. (a) Structure of the simulated transistor. (b) Current–voltage characteristics obtained for channel heights of 4 nm and 12 nm.

Analysis and Results

In the simulation process, the channel height was reduced from H=12 nm to H=4 nm. As a result, since the channel cross-sectional area H·W was maintained constant, the channel width increased from W=12 nm to W=36 nm. This leads to an increase in the effective gate area, which in turn results in an enhancement of the drain current. An increase in the drain current is expected to enhance Joule heating in the transistor, leading to a rise in its operating temperature.

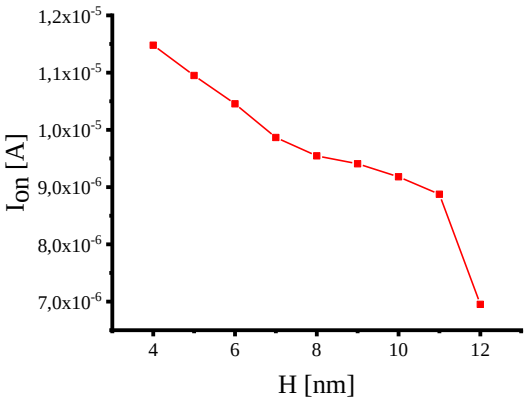


Figure 2. The impact of the channel height H on the drain current I_{on} .

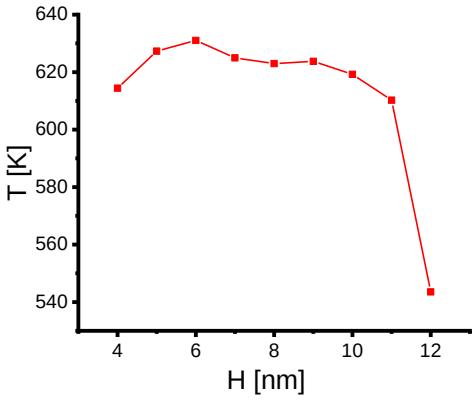


Figure 3. The impact of the channel height on the temperature at the center of the transistor.

As shown in Figure 2 and Figure 3, a reduction in the channel height results in an increase in the saturation drain current I_{on} and a corresponding rise in the temperature at the center of the transistor.

As can be seen from Figure 3, when the channel height H is reduced from 12 nm to 11 nm, the temperature at the transistor center increases sharply. In the range from 11 nm to 6 nm, the temperature rises more gradually, which correlates well with the variation of the drain current I_{on} shown in Figure 2. However, when the channel height is further reduced from 6 nm to 4 nm, although I_{on} continues to increase, a decrease in the temperature at the transistor center is observed.

To explain this behavior, it is necessary to consider the factors influencing the self-heating temperature of the transistor. First, the operating temperature of the transistor depends on the amount of Joule heat generated. The generation of Joule heat is directly related to the magnitude of the drain current flowing through the device. The generated Joule heat is then dissipated to the surroundings depending on the material properties of the transistor and its external surface area.

Conclusion

In this work, the influence of channel geometry on the self-heating behavior of a 10 nm GaAs GAAFET was systematically analyzed using TCAD simulations. The results indicate that reducing the channel height initially increases the drain current and self-heating temperature due to enhanced Joule heating. However, when the channel height is reduced below 6 nm, the increase in the effective external surface area significantly improves heat dissipation, resulting in a decrease in the peak temperature at the transistor center. This balance between heat generation and heat removal determines the steady-state operating temperature of the device. The obtained results highlight the critical role of channel geometry optimization in mitigating self-heating effects and improving the thermal reliability of nanoscale GaAs-based transistors for high-frequency and high-power applications.

References:

[1] Jean-Pierre Colinge “FinFETs and Other Multi-Gate Transistors,” *Springer*, New York, 2008.

[2] Digh Hisamoto, Wen-Chin Lee, Jakub Kedzierski, Hideki Takeuchi, Kazuya Asano, Charles Kuo, Erik Anderson, Tsu-Jae King, Jeffrey Bokor, Chenming Hu “FinFET—a self-aligned double-gate MOSFET scalable to 20 nm,” *IEEE Transactions on Electron Devices*, Vol. 47, № 12, 2000, pp. 2320–2325.

[3] Robert Chau, Bruce Doyle, Sanjay Datta, Justin Kavalieros, Katsuhiro Zhang “Advanced CMOS transistor scaling with metal gate/high-k dielectrics,” *IEEE Electron Device Letters*, Vol. 25, № 6, 2004, pp. 408–410.

[4] Jesús A. del Alamo “Nanometre-scale electronics with III–V compound semiconductors,” *Nature*, Vol. 479, 2011, pp. 317–323.

[5] Simon M. Sze, Kwok K. Ng “Physics of Semiconductor Devices,” 3rd Edition, *Wiley-Interscience*, 2007.

[6] Wei Liu, Muhammad R. Hassan, Abdulrahman M. Alian “Thermal reliability of III–V nanoscale transistors,” *Microelectronics Reliability*, Vols. 76–77, 2017, pp. 812–816.

[7] Synopsys Inc. “Sentaurus Device User Guide,” Version O-2022.06, 2022.