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Materials of International Scientific-Practical Internet Conference

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PREFACE

We are delighted to present the proceedings of the 2024 International Scientific-Practical Internet Conference "Challenges of Science," which took place on November 22, 2024, organized by the Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University, Almaty, Kazakhstan. The conference, which is being held for the seventh year, is a platform for the exchange of innovative ideas and achievements in both scientific research and production.

The conference was a forum for researchers and industry experts to study current issues in science and technology. This year's materials covered a wide range of topics, from materials science and chemical engineering to educational technologies and language learning, reflecting the interdisciplinary nature of the conference. Discussions on optimizing the properties of steel used for transportation systems, the use of diatomite in industry, and the emerging role of gamification in education were important. These articles demonstrate not only cutting-edge research but also their practical significance for various industries.

We believe that the conference was a success as a result of the joint work of participants, researchers, reviewers, and the organizing committee. In addition, we are proud to announce that the conference proceedings will be indexed by authoritative databases, including CrossRef, e-libray.ru and ROAD (ISSN 2707-9481), ensuring that the conference proceedings reach a global audience. With the support of UNESCO's Communication and Information Sector, these proceedings are being published worldwide under a Creative Commons license, further promoting open access to scientific knowledge.

We look forward to future editions and invite all researchers and scholars to participate in the conference in 2025. This event will continue to be a milestone in scientific and technological progress, encouraging global collaboration and exchange of ideas.

On behalf of the Organizing Committee, I would like to thank everyone who contributed to the success of the conference. Your participation is essential for the continued growth and impact of this scientific platform.

Prof., Dr. **Bagdaulet Kenzhaliyev**
Chief-in editor
On behalf of the organizing Committees
Almaty, the Republic of Kazakhstan
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On the optimal ratio of the hardness of wheel and rail steel, ensuring minimal wear of the wheel-rail friction pair

Abstract: In this work, to identify the optimum between the hardness of the wheel and the rail, which ensures minimal wear, methods were used to determine wear by mass loss (volumetric wear) and by micrometric measurement of the size of the imprint (linear wear). It has been shown that the optimal range of wheel and rail hardness, determined by measuring (reducing) the size of the indentation, is in the range of 1.38-1.55. This interval practically confirms the wear identified by mass loss of 1.41-1.58. Based on these data, it is recommended to use the average value of the ratio between them, namely, 1.39-1.56 (HVк556-655, HVp400-420), which does not violate the objectivity and accuracy of measurements, both when determining volumetric and linear wear. It is noted that there is no magic relationship between the hardness of a wheel and a rail; there is only an optimal hardness for wheels and rails, determined by several internal (chemical composition, structure, properties, etc.) and external (friction coefficient, degree of slippage, presence or absence of lubrication, axle loads, etc.) factors.

Keywords: wheel, rail, hardness ratio, friction pair, wear, weighing, sample mass, measurement, print size.

Introduction

One of the determining factors in the development of the economy of Kazakhstan is railway transport, which, according to experts, accounts for up to 70-75% of freight turnover and 50% of passenger traffic in the republic. Under these conditions, increasing the operational wear resistance and durability of wheel pairs, the main element of which are solid-rolled wheels, is an urgent task of great practical importance (Bogdanov & Zakharov, 2014; Balanovsky, 2016). Analysis of the operational resistance of the "wheel-rail" friction pair shows that the cause of wear of such joints is friction, which results in repeated deformation of the contacting areas of the surfaces, their strengthening and softening, heat release, changes in micro- and substructure, development of adhesion processes, fatigue, corrosion and other physical and chemical processes.

The complexity of the processes in the contact zone has led to the emergence of different theories of external friction and wear. A unified theory explaining the wear mechanism in the "wheel–rail" friction pair has not yet been created (Samotugin et al., 2016; Kuksenkova & Polyakov, 2021).

Many factors simultaneously influencing the wear of wheels and rails have led to the hypothesis that the main reason for intense wear and a significant reduction in the service life of wheelsets is a violation of the optimal ratio of hardness of the materials of wheels and rails. However, practice shows that there is no strictly established optimal ratio of the hardness of wheels and rails (their obligatory equality or excess of the hardness of one of the elements by a strictly fixed percentage, etc.) (Larin, 1986).

Based on special laboratory tests of roller samples, taking into account slippage equal to 2%, a ratio of at least 1.2 was established (20% excess of the hardness of the wheels relative to the hardness of the rails). The results of these tests, which determine the required hardness ratio of the "wheel-rail" friction pair, and the proposed idea of the causes of intense wear of wheel pairs (violation of the required hardness ratio), do not agree well with the actual results during operation. Therefore, at present, the question of the ratio of hardnesses of the "wheel-rail" friction pair remains the subject of discussion among researchers and production workers, and debate continues about the optimal level of hardness of the wheel and rail (Vorobyov & Benkova, 2015).

Note that in real production conditions, obtaining direct experimental data on optimizing the hardness of rails and wheels is a complex technical and economic task. This is due to the long duration and labour intensity of industrial tests, due to the need to exhaust the service life of the unit under study, its periodic disassembly, and the difficulty of measuring the wear of products (parts).

Materials and research methods

To identify the optimum between the hardness of the wheel and the rail, two methods were used in this work: a) determination of wear by weight loss (volumetric wear); and b) determination of wear by micrometric measurement of the size of the print (linear wear).

a) Determination of wear by weight loss (volumetric wear);

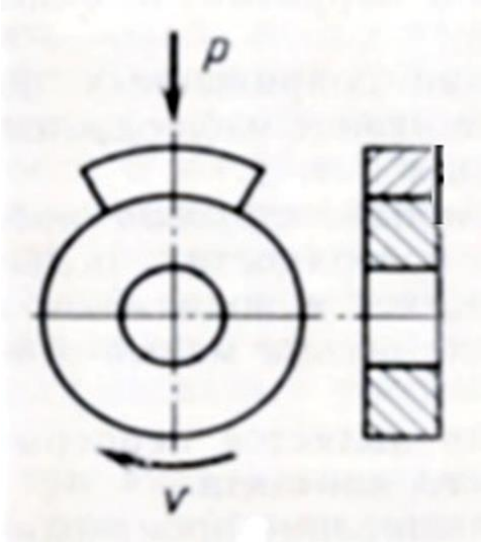

Figure 1. Roller wear test diagram and liner when the roller rotates (Lakhtin, 1984)

We used roller samples with a diameter of 40 mm and a width of 8 mm from wheel steel containing 0.64% C, cut from the rim of a solid-rolled wheel, and hardened by plasma hardening. As a counter-body, we used liners 5 mm thick and 10 mm wide made of rail steel containing 0.81% C (Fig. 1).

Wear resistance was determined by weighing the mass of the sample before and after testing. The measure of wear was the loss of mass of the sample, for which the sample was weighed before and after testing with an accuracy of 0.0002 g after thoroughly rubbing with felt with gasoline, and then with technical alcohol. Weight loss g*m^2/h, where g is the weight loss in grams, m2 is the wear surface; h – is wear time.

The surface hardness of the rail samples varied in the range of 345-455 HV (Table 1). This is justified by the fact that this range of hardness covers possible fluctuations in hardness (350-405HV) of P65-type length rails. The hardness of the wheel samples varied from 275 HVk to 900 HVk. The depth of the hardened layer for wheel steel samples is ~1.5 mm.

Table 1. Influence of the ratio of wheel and rail hardness on the wear resistance of the "wheel metal – rail metal" pair

Option No.	Wheel hardness HVk,	Hardness rail, HVp	Attitude HVк / HVp	Volumetric wear, g.		
				sample wheel steel	sample rail steel	total wear and tear
1	263	430	0,61	1,10	0,21	1.31(original state)
2	275	345	0,80	0,95	0,24	1.19
3	380	362	1,05	0,73	0,26	0.99
4	505	377	1.35	0,58	0,22	0.80
5	**560**	**397**	**1.41**	**0,37**	**0,23**	**0.60**
6	**615**	**410**	**1,50**	**0,33**	**0,25**	**0.58**

7	**675**	**425**	**1,58**	**0,29**	**0,21**	**0.50**
8	860	440	1,95	0,48	0,44	0.92
9	900	455	1,98	0,51	0,49	1.00

From Table 1 it is clear that the minimum total wear falls on the ratio 1.41-1.58 [hardness of the wheel HVk / HVr (560/675), rail (397/425)]. The wear of wheel samples in the hardness range 275-505 (HVк/HVр) is 0.95+0.73+0.58 = 2.26 g, the rail in the hardness range 345-377 (HVк/HVр) is 0.24+0.26+0.22 = 0.72 g, which is 3. 1 time more than with a ratio of 1.41-1.58. Note that the experiments used samples with hardness beyond the limits established by the standard, which is explained by the need to obtain a complete picture of the wear resistance of the wheel and rail.

The total wear of wheel and rail steel samples increases when the wheel is hardened to high hardness (over 860-900HV), which can cause spalling of the hardened layer and cracking. Hardening a wheel to a relatively low hardness (275-505HV) leads to an increase in total wear, mainly, as noted, due to wheel wear (Table 1). Thus, the experiments carried out show that the optimal ratio of wheel and rail hardness, ensuring minimal wear in terms of mass loss, is the ratio of 1.41-1.58.

Selected hardness ratios of wheel samples can be obtained by plasma hardening (by changing the current strength, the length of the plasma arc, the flow rate of the plasma-forming gas (argon), the diameter of the gas ceramic nozzle and other technological parameters) in real operating conditions of the rolling stock, which brings laboratory tests closer to production ones and is of great practical importance.

Table 2 shows changes in microhardness and emerging structures during plasma hardening. It can be seen that in the surface layer 1.55 mm thick, a mixed-layer structure is formed with a decreasing microhardness during the transition from martensite with acicular morphology to a ferrite-pearlite structure in the central layers.

Table 2. Changes in microhardness and structure of the strengthened layer

Distance from top ness, mm	**Microhardness, HV 02**	**Microstruk tour**	**Distance from top ness, mm**	**Microhardness, HV 02**	**Microstruk tour**
0,25	850	Martensite	1,00	585	Sorbitol + perlite
0,40	802		0,80	557	
0,70	685	Martensito-troostite	1.25	427	Perlite
0,95	615	Troosto-sorbitol	1.55	372	Pearlite + ferrite
0,97	613		1.70	345	Pearlite + ferrite

b) Determination of wear by measuring the size of the print (linear wear)

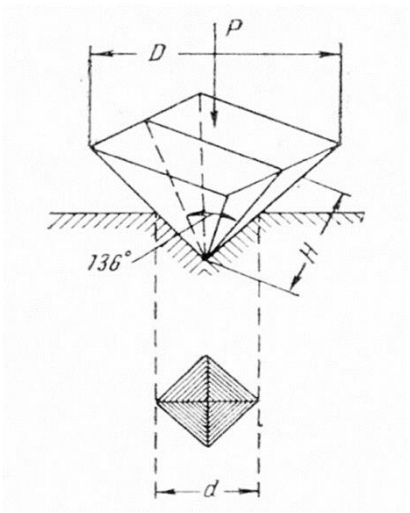

Figure 2. Scheme imprinting with a diamond pyramid

As noted above, measuring wear by weight loss is a complex task that requires a long time, which is a disadvantage of this method. Therefore, in the experiments we used the micrometric measurement method, which is successfully used to determine linear wear. This method is based on precise micrometric measurements of the size of the print using instrumental microscopes before and after the wear of the test samples (Metal Science and Heat Treatment of Steel. Directory, 1983).

To measure hardness, the Vickers method (HV) was used, in which a diamond tip in the shape of a tetrahedral pyramid is pressed into the surface under study, giving a more objective and accurate assessment of the hardness of metallic materials (Fig. 2).

The essence of the method is that depressions in the form of an imprint are applied to the working surface, and by reducing the size of the imprint, the amount of linear wear is judged. The prints were made using a four-fold diamond pyramid with a square base and an apex angle of 1360 between opposing faces. To obtain such pyramids, a PMT-3 microhardness tester was used, on which the reduction in the size of the print was measured.

The indentation depth h was determined by the formula:

$$h = d / 2 \sqrt{2} \operatorname{tg} (\alpha / 2), \qquad (1)$$

where α is the angle at the top of the pyramid between opposite faces; d is the length of the print diagonal.d = 0,5 (d_1+d_2). At α =1360 the value is h=0.143d. Linear wear is defined as the difference between the indentation depth before and after the test Δh =h1–h2 = 0.143(d1–d2) at α = 1360, where h1 is the indentation depth before the test, h2 is the same after the test. The accuracy of measuring linear wear by micrometric measurements before and after wear using fingerprints is 0.3 µm. The diagonal dimensions of the applied prints are in the range of 1-10 microns.

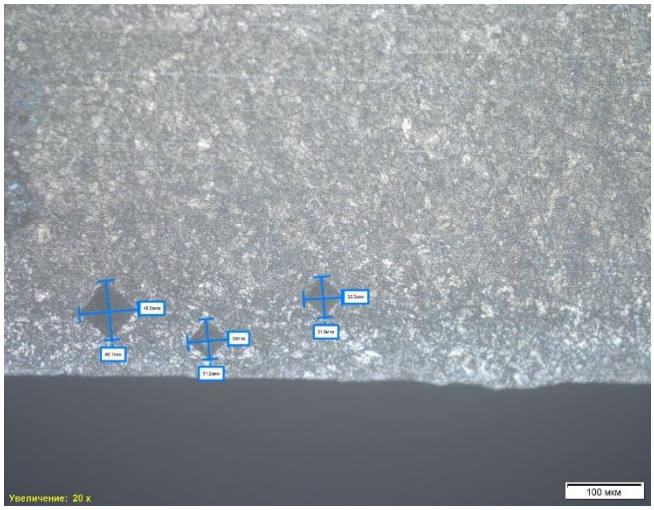

Figure 3. Measuring the length of diagonal prints using Thixomet

The amount of linear wear was determined using the Thixomet program - a computer image analyzer, which allows you to obtain the necessary information automatically, which increases the objectivity and accuracy of the assessment (Fig.3). The wear test mode, the test steel samples, and their geometric dimensions are taken to be the same as in the method of determining wear by weight loss.

Table 3. Determination of linear wear by micrometric measurements before and after wear of samples

Option No.	Wheel hardness HVk,	Rail hardness, HVp	Attitude HVк / HVp	Linear wear, µm		
				wheel steel sample	sample rail steel	Totalny
1	271	427	0,.63	10,0	3,2	13,2 (original state)
2	370	395	0,94	9, 6	3,5	13.1
3	394	375	1,05	8, 7	3,5	12.2

4	450	380	1,18	7, 8	3,6	11.4
5	**555**	**400**	**1,38**	**3,5**	**3,1**	**6.6**
6	**604**	**411**	**1,47**	**3,1**	**3,3**	**6.4**
7	**655**	**420**	**1,55**	**3,8**	**3,5**	**7.3**
8	868	445	1,95	5,1	4,6	9.7

The data obtained (Table 3) show that the optimal ratio of wheel hardness (HVk555 / HVr655 and rail HVk400 / HVr420) is in the range of 1.38-1.55. With this ratio, linear wear of both wheel and rail samples has a minimum value (3.1-3.8 µm). It can be seen that hardening the wheel to high hardness (over 868HV) leads to intense wear of both elements of the friction pair (wheel -5.1 microns, rail -4.6 microns); When the wheel rim is hardened to a relatively low hardness of 370-450HV, wheel wear increases up to 2.3 times than in the optimal hardness range of 555-565HV. (9.6+7.7+6.8=24.1 µm versus 3.5+3.1+3.8= 10.4 µm). It is also noteworthy that the wear of wheel and rail steel samples increases, respectively, to 5.1 microns and 4.6 microns with a wheel-to-rail hardness ratio of 1.95 (HVk 868/HVp445).

Thus, the optimal range of wheel and rail hardness, determined by reducing the indentation size, is in the range of 1.38-1.55. This interval practically confirms the wear identified by the mass loss of 1.41-1.58. Based on these data, it is recommended to use the average value of the ratio between them, namely 1.39-1.56 (HVк556-655, HVp400-420), which does not violate the objectivity and accuracy of measurements, both when determining volumetric and linear wear.

A comparative analysis of these results with known methods (where the ratio of the hardness of the wheel and the rail is assumed to be equal to unity) shows that to ensure minimal wear in this work, a range of hardness ratios is recommended. Let us note that the recommended range of hardness ratios practically coincides both when determining volumetric and linear wear. It would not be a great exaggeration to note that there is no magic relationship between the hardness of a wheel and a rail; there is only an optimal hardness for wheels and rails, determined by several internal (chemical composition, structure, properties, etc.) and external (friction coefficient, degree of slippage), presence or absence of lubrication, axle load, etc.) factors (Kanaev, 2020; Kanaev et al., 2023).

It is also important to note that the technical result of the proposed method for determining the optimal ratio of the hardness of wheel and rail steel is to obtain a rational range of wheel and rail hardness, in which the total wear of the wheel and rail is reduced by up to 2 times. Analysis of the experimental data obtained shows that the indicated reduction in the total wear of the wheel and rail is realized mainly due to a decrease in wheel wear by 2.3 times with practically unchanged rail wear in the studied range of surface hardness.

Conclusions

The optimal range of wheel and rail hardness, determined by reducing the size of the indentation, is in the range of 1.38-1.55. This interval practically confirms the wear identified by the mass loss of 1.41-1.58. Based on these data, it is recommended to use the average value of the ratio between them, namely 1.39-1.56 (HVк556-655, HVp400-420), which does not violate the objectivity and accuracy of measurements, both when determining volumetric and linear wear.

Research results show that an increase in wheel hardness during plasma treatment above 860÷900 HV under real operating conditions leads to chipping of the hardened layer of the wheel and intense wear of the rail. Hardening the rim and wheel flanges to a relatively low hardness of 275÷505 HV is ineffective since wear resistance improves slightly.

The results of laboratory tests presented in the article and the ideas expressed on the optimal ratio of the hardness of the wheel-rail friction pair should be tested in production operating conditions using the artificial base method based on micrometric measurements before and after wear.

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Impact of online language learning on psychological well-being

Abstract: The topic of the impact of online language learning on psychological well-being is gaining increasing attention due to the shift towards digital learning platforms. Online language learning offers convenience, flexibility, and a wide range of resources, which can positively influence individuals' self-confidence, cultural understanding, and sense of achievement. This study examines the influence of online language learning platforms on psychological aspects. The study was conducted through a google form survey consisting of 10 questions in Almaty, Kazakhstan. Research shows that using online language learning platforms can make people feel happier and less stressed. Learning a new language online reduces loneliness and provides confidence. These platforms can also help improve communication skills and understanding of different cultures. Setting goals, tracking progress, and receiving rewards on these platforms can help keep people motivated and interested in the learning process. The results, presented through tables and detailed analysis, indicate the positive impact of online language learning on reducing feelings of isolation, enhancing stress levels, and improving communication skills. The findings shed light on the potential benefits of online platforms in promoting psychological well-being through accessible learning opportunities.

Keywords: students, online platforms, learning, psychology, stress, motivation, communication.

Introduction

The advent of technology and the accessibility of online platforms have greatly influenced how people learn languages, leading to a significant shift from traditional classroom settings to online language learning platforms. This topic holds importance as it explores the potential positive effects that online language learning can have on individuals' psychological well-being. Language learning has long been associated with numerous cognitive benefits, such as improved memory, attention span, and problem-solving skills. However, the impact of language learning on psychological well-being has only recently garnered attention. Online language learning has become increasingly popular due to its convenience, flexibility, and wide variety of learning resources available. Blake (2008) discussed the role of technology in foreign language learning. Although the study did not directly address psychological well-being, it highlighted the potential of digital classroom technologies in transforming language learning experiences, which could have implications for psychological outcomes.

One aspect of psychological well-being that can be positively influenced by online language learning is self-confidence. As individuals acquire new language skills and gain proficiency through online platforms, their self-confidence in their language abilities can significantly improve. This boost in self-confidence can extend beyond language skills and positively impact other areas of life, such as social interactions, career opportunities, and personal growth. A study by Bai and Wang (2023) found that growth mindset, self-efficacy, and intrinsic value are important factors in promoting self-regulated learning and English language

learning achievements. As such, understanding the role of affective variables and informal digital learning of English can provide insights into learners' willingness to communicate in a second language (Lee & Drajati, 2019).

Online language learning also offers opportunities for increased cultural understanding and empathy. Engaging with different languages and cultures via online platforms can broaden one's horizons, fostering a sense of cultural awareness and empathy towards others. Wang (2018) emphasized the role of online platforms in broadening individuals' horizons and fostering a sense of cultural awareness and empathy towards others. Similarly, Gao and Zhang (2020) supported this notion, emphasizing that online language learning provides opportunities for increased cultural understanding and empathy. This exposure to diverse perspectives can lead to greater acceptance, tolerance, and respect for others, thus enhancing psychological well-being. Furthermore, online language learning can provide individuals with a sense of achievement and fulfilment. As they set learning goals, track their progress, and witness their language skills evolve, a sense of accomplishment is derived, which contributes to overall psychological well-being. This feeling of achievement can motivate individuals to continue learning and exploring new languages, providing a long-lasting positive effect on mental and emotional well-being. However, it is also important to acknowledge the potential challenges and limitations of online language learning on psychological well-being. Some individuals may experience feelings of isolation or lack of motivation due to the absence of direct human interaction in online learning environments. Additionally, self-discipline and effective time management may be necessary to ensure effective learning and prevent feelings of overwhelm or frustration.

Online language learning holds great potential for positively impacting individuals' psychological well-being by boosting self-confidence, promoting cultural understanding, and fostering a sense of achievement. The convenience, flexibility, and abundant resources available through online platforms make language learning more accessible and engaging. Despite potential challenges, the benefits of online language learning on psychological well-being cannot be overlooked. Further research and exploration of this topic are essential to fully understand the extent and nuances of its impact.

***Research question*:**

How do online language learning platforms affect adult learners' mental well-being?

Review of literature

The study examines the psychological dimensions that shape users' experiences on these platforms, focusing on stress reduction, motivation and engagement, personal development, social connection, and cognitive benefits. By understanding how different platforms impact these dimensions, we can identify their potential benefits, limitations, and implications for individuals' psychological well-being. The classification is based on an analysis by social psychologists J.A. Bargh and McKenna Kyle (2004), who have described psychological well-being, such as self-esteem and satisfaction with life. Table 1 describes the classification of online platforms based on psychological impact. It is divided into the following categories: stress reduction, motivation and engagement, personal development, social connection and cognitive benefits. The table highlights the consideration of researchers towards the categories.

Table 1. Classification of online platforms

Stress Reduction	the efficacy of such stress-reducing features and their potential to alleviate stress and anxiety.	Marchand (2012)
Motivation and Engagement	both internal and external motivational factors play a role in student engagement and learning outcomes	Cerasoli et al. (2014)
Personal Development	basic human needs for growth and meaning, indicating their crucial role in shaping an individual's personal development journey	Nguyen (2021)
Social Connection	a fundamental element of the relationship, encompassing cognitive, emotional, behavioral, and social aspects.	Vivek et al. (2012)

Cognitive Benefits	improvements in cognitive function, providing support for the cognitive benefits associated with specific training interventions.	Jaeggi et al. (2011)

Stress Reduction

One of the important elements analyzed is the impact of online platforms on users' stress levels. Platforms that offer stress-reducing activities, such as mindfulness and relaxation exercises, can contribute significantly to users' mental well-being. Stress and anxiety are prevalent among university students, particularly as a result of the COVID-19 pandemic. Wang and Zhao (2020) found that Chinese university students experienced higher levels of anxiety due to the pandemic, while Fawaz and Samaha (2021) reported that e-learning platforms have led to depression and anxiety disorders among undergraduate university students. In response to these concerning findings, stress management programs have been identified as essential tools in preventing and treating burnout among students and professionals (Romani & Ashkar, 2014).

To address the mental health challenges faced by university students, the efficacy of online platforms in reducing stress and anxiety has been explored. Online mindfulness courses are effective in reducing stress, anxiety, and depression. Similarly, mindfulness and cognitive-behavioral therapy-based interventions have shown promise in reducing stress, anxiety, and depression (Boursier et al., 2020). Furthermore, the mindfulness-based stress reduction (MBSR) program has been found to improve well-being and relaxation states in a longitudinal study (Krusche et al., 2013). However, mixed evidence has been found for the use of mindfulness-based interventions in reducing psychological distress in undergraduate medical students (Varker et al., 2019). Online platforms offering stress-reducing activities, such as mindfulness and relaxation exercises, have the potential to alleviate stress and anxiety among university students. Nevertheless, further research is needed to address the mixed evidence regarding the efficacy of such interventions and to identify the most effective strategies for reducing stress and anxiety.

Motivation and Engagement

Motivation and engagement are crucial factors in determining users' overall experience on online platforms. This dimension explores how platforms can facilitate goal-setting, progress tracking, and rewards to enhance users' motivation and engagement levels. Peters, Calvo, and Ryan (2018) highlight the significance of designing digital experiences to promote motivation, engagement, and well-being. They emphasize the role of digital interfaces in enhancing user experience and suggest that incorporating features for goal-setting, progress tracking, and rewards can positively impact user motivation and engagement. Reeve and Lee (2014) provide further insights into the relationship between motivation and engagement. They found that changes in motivation anticipate changes in engagement. Moreover, they tested the reciprocal relation that changes in students' classroom engagement led to corresponding longitudinal changes in their classroom motivation. This indicates that engagement and motivation are interrelated and mutually influence each other.

Overall, the studies reviewed provide valuable insights into the role of motivation and engagement on online platforms and highlight the significance of designing user-centered experiences to promote sustained engagement and positive user outcomes.

Personal Development

Online platforms that focus on personal development have gained significant popularity. The aspect investigates the way platforms can facilitate users' self-improvement through features such as educational content, skill-building exercises, and personal growth tracking. By analyzing the effectiveness of these tools, this research aims to shed light on how online platforms can be used as valuable resources for personal development. Nawrot & Doucet (2014) discuss the importance of time management support on online learning platforms to engage massive open online course (MOOC) students. They emphasize the need for features that facilitate effective time management to enhance student engagement and improve learning outcomes. This finding highlights the need for online platforms focusing on personal development to incorporate time management tools to better engage users and support their self-improvement efforts. Moreover, Irvine et al. (2015) conducted a randomized controlled trial to evaluate the effectiveness of a mobile web app in self-managing low back pain. The study demonstrated the potential of mobile applications in promoting self-management of health issues, suggesting that online platforms for personal development could leverage mobile technology to deliver interventions aimed at improving users' well-

being. In addition, Woerkom & Meyers (2018) discuss the effects of a strength intervention on personal growth initiative. This study provides evidence of the positive impact of interventions aimed at strengthening personal growth. The findings suggest that online platforms for personal development could incorporate similar interventions to empower users and promote their growth in various aspects of their lives. From the importance of time management support to the potential of mobile applications, image recognition, and personalized interventions, the findings suggest various avenues for enhancing the effectiveness of these platforms.

Social Connection

Human beings have an intrinsic need for social interaction, and online platforms can play a pivotal role in fulfilling this need. This dimension examines how platforms enable users to connect with others, fostering social relationships and enhancing social support networks.

Tomasello (2014) argues that human thinking and behavior are deeply rooted in social interaction. He emphasizes the importance of collaborative and cooperative activities in shaping human cognition, suggesting that social interaction is fundamental to human nature. Choudhury and De (2014) delve into mental health discourse on Reddit, focusing on self-disclosure, social support, and anonymity. Their research sheds light on how online platforms allow for social interaction and support, particularly in the context of sensitive topics such as mental health. Oh, Ozkaya and LaRose (2014) investigate the relationship between online social networking and life satisfaction. They emphasize the positive impact of online supportive interaction and perceived social support on users' overall life satisfaction, highlighting the role of online platforms in providing social support. By integrating and synthesizing the provided research findings, this literature review contributes to a deeper understanding of how online platforms facilitate human social interaction.

Cognitive Benefits

Online platforms can also provide cognitive benefits, such as improving cognitive skills, memory retention, and problem-solving capabilities. This feature explores the potential of different platforms, including educational applications and brain-training games, to enhance users' cognitive abilities. Papanastasiou et al. (2018) examined the effects of virtual and augmented reality on students' twenty-first-century skills and highlighted the positive impact of these technologies on cognitive abilities. These findings suggest that online platforms, including virtual reality applications, can contribute to the enhancement of cognitive skills among users. However, Sala and Gobet (2017) provided contradictory evidence, suggesting that video game training does not enhance cognitive ability. The comprehensive meta-analytic investigation conducted by Sala, Tatlidil, and Gobet (2017) raises questions about the effectiveness of video game training in improving cognitive skills. This contradictory evidence highlights the need for further research to clarify the cognitive benefits of different types of online platforms. The existing literature provides valuable insights into the cognitive benefits of online platforms, but several knowledge gaps exist. First, the long-term effects of online platform interventions on cognitive abilities require further investigation. Sala and Gobet (2017) emphasized the need for studies focusing on the sustainability of cognitive improvements resulting from online platform use.

The literature reviewed in this study provides a foundation for future research on the cognitive benefits of online platforms and highlights the importance of addressing existing knowledge gaps to advance our understanding of the potential of different platforms in improving cognitive skills, memory retention, and problem-solving capabilities.

Research Methodology

Population and sample

The population of the study is male and female aged 18 to 25 years. These are mainly students and workers in various fields interested in learning foreign languages. This age category was chosen to determine the influence of online platforms on the psychological aspects of the individual. Many of them were positive about the introduction of online platforms in the context of accessible learning.

Design of the study

The data collection tool of the study is a survey consisting of ten items that fall under three categories. The first category is about the influence of online platforms on stress reduction aspects. The second category determines the influence on motivation and further satisfaction with the results. The impact of online platforms on communication skills is represented in the third category. The survey was

conducted anonymously and sent to Google Forms. The pie charts obtained after answering the survey were grouped into tables for later analysis in the results section.

Research Results

The results demonstrate data of the respondents' answers about the three categories in the questionnaire. The impact of online learning platforms on stress reduction, motivation and communication skills was studied. The tables are followed by detailed paragraphs that explain how respondents answered ten items in the questionnaire.

Table 2. Impact of online platforms on stress reduction

Variable	*Level*	*Counts*	*Total*	*Proportion*	*p*
Online language learning has helped reduce feelings of isolation and loneliness in my life.	Agree	7	17	0.412	0.629
	Disagree	1	17	0.059	< .001
	Neutral	6	17	0.353	0.332
	Strongly Agree	2	17	0.118	0.002
	Strongly disagree	1	17	0.059	< .001
The flexibility of online language learning has positively influenced my stress levels.	Agree	6	17	0.353	0.332
	Disagree	2	17	0.118	0.002
	Neutral	5	17	0.294	0.143
	Strongly Agree	3	17	0.176	0.013
	Strongly disagree	1	17	0.059	< .001
Regular learning with the usage of online platforms has positively impacted my overall mental well-being	Agree	5	17	0.294	0.143
	Disagree	3	17	0.176	0.013
	Neutral	7	17	0.412	0.629
	Strongly Agree	1	17	0.059	< .001
	Strongly disagree	1	17	0.059	< .001

Table 2 illustrates the respondents' answers about the influence of online learning platforms on stress reduction. 41.2% of respondents (p = 0.629) agree with the statement that online learning platforms have helped them reduce feelings of isolation and loneliness. Only 5.9% of respondents (p < 0.01) showed disagreements at this point. Responses to the second statement show that the majority of respondents, 35.3% (p = 0.332) agree that the introduction of such platforms reduces stress levels. However, 11.8% of respondents disagree (p = 0.002).

Table 3. Impact of online platforms on motivation

Variable	*Level*	*Counts*	*Total*	*Proportion*	*p*
Learning languages online has positively impacted my overall sense of accomplishment and self-esteem.	Agree	7	17	0.412	0.629
	Disagree	2	17	0.118	0.002
	Neutral	5	17	0.294	0.143

Variable	*Level*	*Counts*	*Total*	*Proportion*	*p*
Online language learning platforms have increased my motivation to learn and explore new cultures	Strongly Agree	3	17	0.176	0.013
	Agree	6	17	0.353	0.332
	Disagree	2	17	0.118	0.002
	Neutral	2	17	0.118	0.002
I feel a sense of achievement by online language learning journey.	Strongly Agree	7	17	0.412	0.629
	Agree	9	17	0.529	1.000
	Neutral	3	17	0.176	0.013
Online language learning has positively affected my ability to adapt to new challenges	Strongly Agree	5	17	0.294	0.143
	Agree	9	17	0.529	1.000
	Disagree	1	17	0.059	< .001
	Neutral	5	17	0.294	0.143
	Strongly Agree	1	17	0.059	< .001
	Strongly disagree	1	17	0.059	< .001

Note. Proportions tested against value: 0.5.

Table 3 demonstrates the respondents' answers about the second category. Most respondents (p = 0.629) tend to agree with statements that this process has a positive effect on their motivation. It indicates strong statistical significance in agreement with the statement. Even though 11.8% of respondents (p < 0.118) showed disagreement in this aspect, we can still see a positive attitude towards online platforms.

Table 4. Impact of online platforms on communication skills

Variable	*Level*	*Counts*	*Total*	*Proportion*	*p*
Learning languages through online platforms has improved my cognitive abilities and problem-solving skills.	Agree	7	17	0.412	0.629
	Disagree	2	17	0.118	0.002
	Neutral	8	17	0.471	1.000
Online language learning has increased my confidence in my communication skills.	Agree	13	17	0.765	0.049
	Disagree	1	17	0.059	< .001
	Neutral	2	17	0.118	0.002
	Strongly disagree	1	17	0.059	< .001
Online language learning has provided me with a connection with fellow language learners	Agree	7	17	0.412	0.629
	Neutral	6	17	0.353	0.332
	Strongly	4	17	0.235	0.049

Variable	*Level*	*Counts*	*Total*	*Proportion*	*p*
	Agree				

Note. Proportions tested against value: 0.5.

Table 4 demonstrates the majority of respondents' answers and their optimistic attitude concerning the development in this particular aspect. 76.5% of respondents (p = 0.049) showed the tendency of the impact of online platforms on the increase of confidence in communication skills. Moreover, the respondents state improvements in problem-solving skills.

Research Discussion

The findings presented in this study shed light on the positive impact of online language learning on individuals' psychological well-being and communication skills. The results indicate that a majority of respondents agree that learning languages through online platforms has improved their cognitive abilities, problem-solving skills, and confidence in communication. This aligns with previous research emphasizing the role of online platforms in providing social support and enhancing overall life satisfaction.

Researchers have studied various psychological outcomes (Burke et al., 2010; Lavrinenko et al., 2019; Arpentieva et al., 2019) that provide data on feelings of loneliness, and life satisfaction. Our findings reveal the data of online language learning and its connections with fellow language learners, fostering a sense of community and support. This sense of community is crucial for individuals, especially in times of isolation and loneliness. The interaction with other students who share the same intentions would become beneficial and develop social skills. This interconnectedness amplifies the learning experience, promoting open-mindedness and cultural exchange. A group of other researchers indicates the failure of online social networking and its positive outcomes (Liu, X., & LaRose, R., 2008). The results of the study demonstrated the negative effect of online platforms towards school life satisfaction. However, our findings suggest that online language learning can serve as a valuable resource for personal development, offering opportunities for self-improvement and skill enhancement. Online language learning has revolutionized the way individuals connect, learn, and develop. This transformative mode of education fosters a sense of community and support among language learners while offering opportunities for personal growth and skill enhancement. With its flexibility, accessibility, and technological integration, online language learning continues to empower individuals on their journey towards acquiring new language proficiencies.

Conclusions

The study delved into the impact of online learning platforms on motivation, stress reduction, and mental health, ultimately revealing an optimistic perspective towards these platforms and their integration into everyday human life. The findings of this study strongly support the introduction and widespread use of online learning platforms in our lives. These platforms not only bolster motivation and enthusiasm for learning but also provide opportunities for stress reduction and foster positive mental health. The convenience, flexibility, and inclusive nature of online learning platforms make them invaluable tools for individuals seeking personal and professional growth. With further advancements and enhancements, these platforms have the potential to revolutionize education and transform the lives of learners worldwide.

Research Recommendations

It is recommended that educators and online platform developers prioritize the influence of online learning platforms on learners' mental well-being. More research is needed about this issue to develop the learning process and put the findings into action.

Research Limitations

The study was conducted in the form of a survey. People from 18 to 25 years old, of different professions, were interviewed. The study only included a specific demographic group (e.g., young adults) in

Almaty, Kazakhstan. The study may not be generalizable to other populations with different preferences or needs. The survey included three main reasons: stress reduction, motivation and communication skills. The study only tested a psychological aspect.

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Language as a mirror of the people

Abstract: This article explores the connection between language and culture, arguing that language is indeed a mirror of the people. By analyzing linguistic features and expressions, we uncover the essence of society, its history, and values. Viewing language as a reflection of collective experience, we understand that it not only conveys information but also expresses identity and cultural heritage. Language serves as a reflection of a society's culture, values, and collective identity. In this article, we endeavor to explore the challenges encountered by educators in the classroom while instructing a foreign language. Through comprehensive examination and analysis, we aim to identify the various hurdles that teachers confront in this endeavor. By delving into factors such as linguistic differences, cultural barriers, student engagement levels, and resource limitations, we seek to shed light on the multifaceted nature of these obstacles. Additionally, we strive to provide insights and potential strategies for overcoming these challenges, thereby facilitating more effective foreign language instruction in educational settings.

Keywords: mirror, people, linguistics, identity, students, interculture.

Introduction

Language serves as a fundamental medium for communication, profoundly influencing how individuals perceive and interpret their surroundings. The longstanding debate over whether languages influence cognitive processes has captivated scholars and intellectuals for generations. Would our thought patterns be uniform if we all shared the same language? This article seeks to explore this intricate topic, utilizing examples, specifics, and personal anecdotes derived from experiences with English and the author's native tongue. In the past few decades, the central position of teachers ensuring the quality of education has become increasingly acknowledged internationally and language plays a key role in education (Zharylkassyn, 2023).

Starting with linguistic relativity, commonly referred to as the Sapir-Whorf hypothesis, it suggests that the structure and lexicon of a language can influence how its speakers perceive and understand the world. Various languages encode unique cultural subtleties and viewpoints, thereby shaping the cognitive processes of their speakers. For example, the Inuit community possesses numerous terms for snow, reflecting their deep relationship with the environment. This linguistic diversity enables a more nuanced comprehension of their surroundings, a depth of understanding that might be absent in languages with more restricted vocabulary.

Moreover, languages can shape thought patterns by influencing how individuals express concepts and emotions. For example, some languages, like Japanese, have elaborate systems of honorifics that convey social hierarchies and respect. This linguistic feature not only reflects cultural values but also encourages individuals to think in terms of social relationships and hierarchy. In contrast, languages like English may prioritize directness and individualism, influencing thought processes towards clarity and independence.

Personal experiences with English and my native language further highlight the idea that linguistic diversity promotes diversity in cognitive structures. Being multilingual, I have noticed subtle differences in the way I express emotions in English compared to my native language. The English language, with its rich vocabulary for describing emotions, often facilitates more detailed and explicit expression of feelings. On the other hand, my native language may rely on context and nonverbal cues to promote a different approach to expressing emotions. However, the question of whether thinking would be uniform if we all spoke the same language is not a straightforward one. While language undeniably shapes thought, it is not the sole determinant. Cultural, social, and individual factors also contribute significantly to cognitive processes. Even within a single language, diverse dialects and regional variations can lead to distinct thought patterns. A dialect is a type of language that is used as a means of communication between people connected by the same territory. Scientists and linguists are still arguing whether there are dialects in Kazakhstan. We will not get involved in this dispute, but we note that there are words among southerners that northern Kazakhs never use. For instance, an English speaker from the southern United States may have a different linguistic and cultural perspective compared to a speaker from the northern region.

The relationship between language and thought is intricate and multifaceted. Languages, with their unique structures and vocabularies, undoubtedly influence the way individuals perceive and interpret the world. However, the idea that a universal language would homogenize thought oversimplifies the intricate interplay of cultural, social, and individual factors. The diversity of languages enriches human cognition, offering unique lenses through which we view our surroundings. The question of whether languages help would the way we think is a dynamic and ongoing exploration, transcending the boundaries of linguistic and cognitive studies. In the Education sector, there are several obstacles faced by non-native speaker students who learn a foreign language. Although, they currently have got their first language to help them learn a foreign language such as English (Songbatumis, 2017).

There is a need to link theoretical reasoning with my own practice. As an English teacher at school faces various challenges, ranging from student engagement to administrative pressures. One difficulty is addressing diverse learning styles within a single classroom, requiring tailored approaches to cater to individual needs. Grappling with limited time poses another hurdle, as educators strive to cover a comprehensive curriculum while ensuring thorough understanding. Additionally, managing classroom behavior and fostering a positive learning environment can be demanding, impacting both teacher and student morale. The dynamic nature of the educational environment, marked by constant changes and the integration of technology, underscores the need for ongoing adaptation. Moreover, external influences such as standardized testing requirements often overshadow the holistic learning journey. English teachers find themselves navigating a delicate balance between meeting assessment demands, adhering to curriculum standards, and fostering a genuine passion for literature among their students. This article explores the challenges faced by English educators in maintaining this equilibrium, highlighting the complexities involved in providing a comprehensive and enriching learning experience amidst evolving educational paradigms and external pressures (Sokip, 2020).

***Research question*:**

What specific insights did the survey reveal regarding the obstacles faced by teachers both inside and outside the classroom, as well as the challenges encountered by students in learning a foreign language?

Research procedure

In this article the challenges faced by teachers and students when teaching and learning a foreign language, particularly English. Conducting an online survey to gather teachers' opinions is a practical approach to understanding these challenges. English language teachers from public schools in Almaty (Kazakhstan) were recruited to participate in the survey.

Research results and discussions

The use of new information technologies in language classrooms can indeed serve as a powerful tool for increasing student interest and overcoming language barriers. Developing a variety of skills such as reading, spelling, speaking and listening through these technologies demonstrates a holistic approach to

language learning that meets a variety of learning needs (Liton, 2016). In the segment focusing on challenges encountered by teachers beyond the classroom, we aimed to pinpoint the obstacles they confront. We enumerated several difficulties encountered by students outside formal instructional settings, such as the lack of interactive whiteboards, subject-specific textbooks, and their incongruence with age-appropriate characteristics. In the section addressing hurdles, our objective was to ascertain the difficulties faced by students within the classroom environment. Via online inquiries, we gauged teachers' viewpoints regarding students, finding that: a) Kazakh schoolchildren's timidity emerges as the primary hindrance to speech skill development; b) integrating ICT into the classroom should facilitate fostering students' autonomy tailored to their physiological, intellectual, and psychological attributes; c) the utilization of novel technologies in practical applications introduces a fresh cognitive engagement avenue for students, leading to the discovery of new knowledge. In the questionnaire's opening section, it became evident that teachers encounter notable difficulties within the classroom environment. These challenges revolve around fostering students' fundamental communication skills in English for real-world application, ensuring the regular availability of educational resources, and establishing appropriate benchmarks for learning objectives. (Fig. 1).

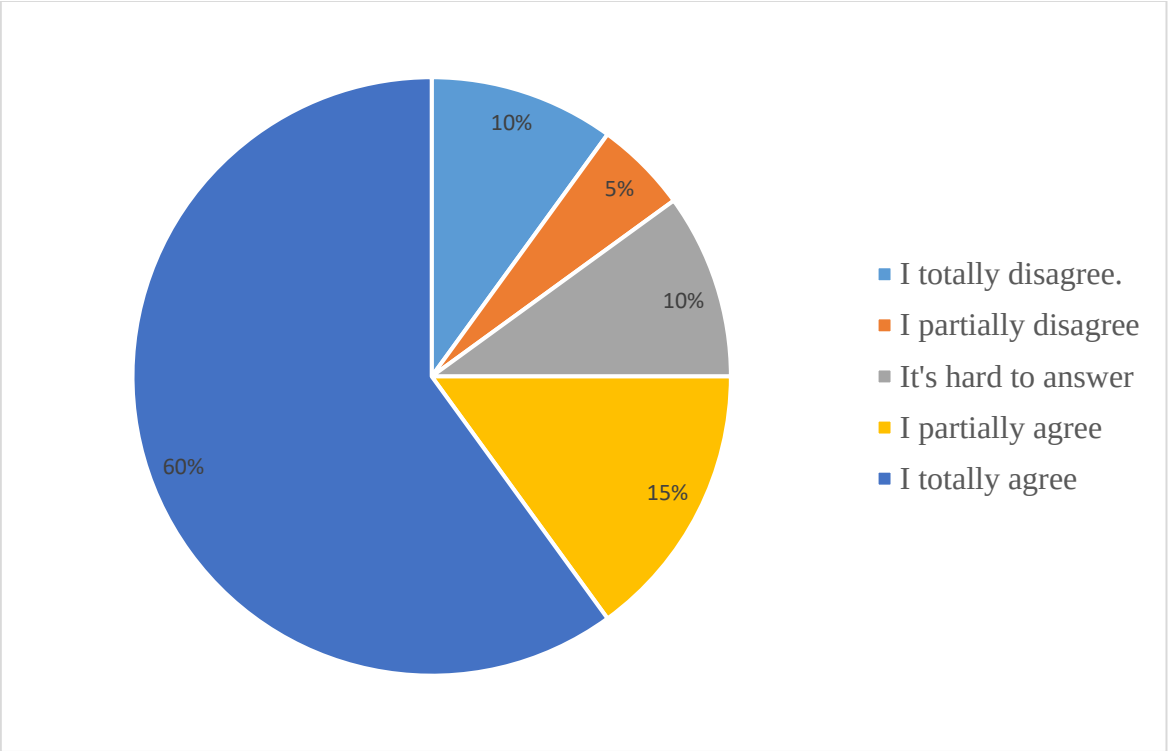

Fig. 1. Problems faced by teachers in the classroom

Most respondents (60%) stated their use of modern information technologies in class. This method is seen as effective in boosting student interest in English and breaking down language learning barriers. Employing diverse types of activities, whether individual, paired, group-based, or whole-class, is deemed a practical approach in achieving these objectives. Furthermore, the removal of obstacles encountered in foreign language instruction through effective methods is contingent upon the proficiency of the teacher (Fig. 1).

The findings from the second part of the questionnaire revealed that a majority of respondents (53%) identified several challenges encountered by teachers outside the classroom. These include the absence of interactive whiteboards, inadequacies in subject-specific textbooks aligning with age-appropriate characteristics, and inadequately equipped language classrooms for foreign language instruction. Within this segment of the survey, teachers also indicate their agreement or disagreement with the data collected during interviews with students (Fig. 2.)

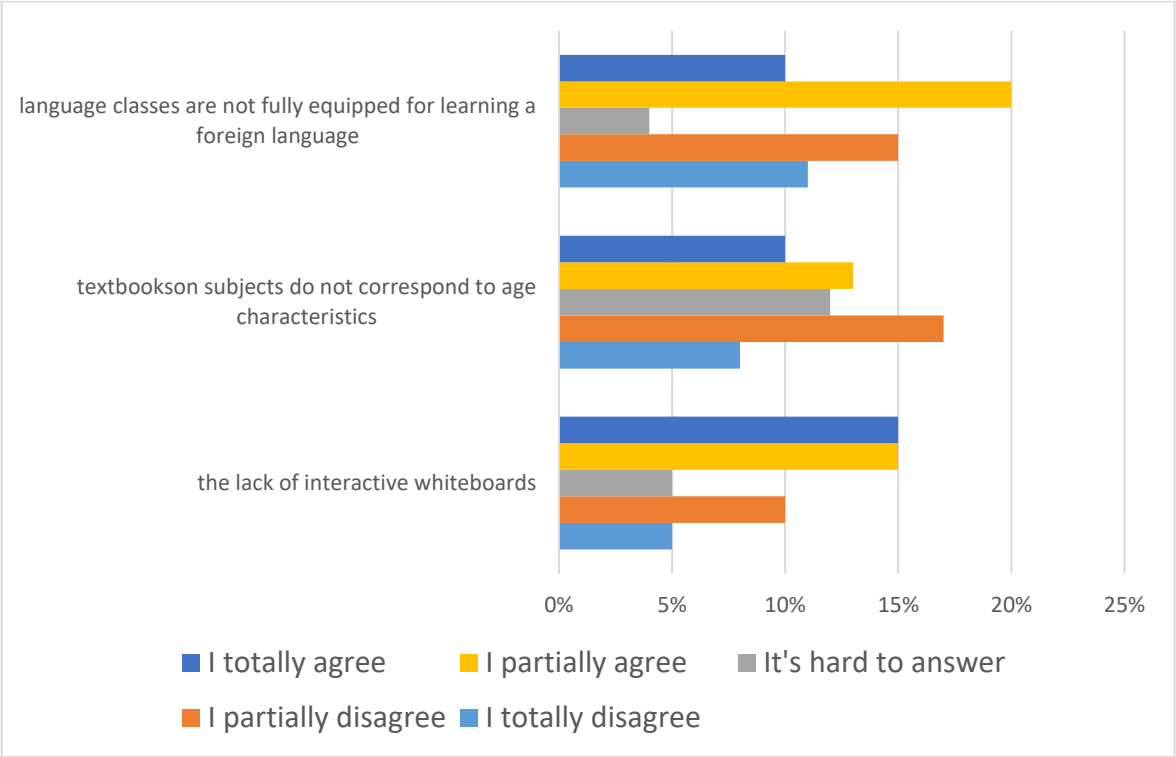

Fig. 2. Problems faced by teachers outside the classroom

In the third phase of the survey, a significant majority of participants, comprising 60% of the respondents, emphasized several key challenges encountered by teachers. Specifically, they identified student shyness, characterized by a reluctance to actively engage in classroom activities or participate in discussions. Additionally, teachers expressed concern over students' self-doubt, indicating a lack of confidence in their own abilities to grasp and apply the lesson material effectively. Furthermore, a prevalent issue noted by respondents was the insufficient interest displayed by students towards the lesson topics, hindering their motivation to fully immerse themselves in the learning process. These findings shed light on the multifaceted nature of challenges faced by teachers in fostering an engaging and conducive learning environment for their students (Fig. 3).

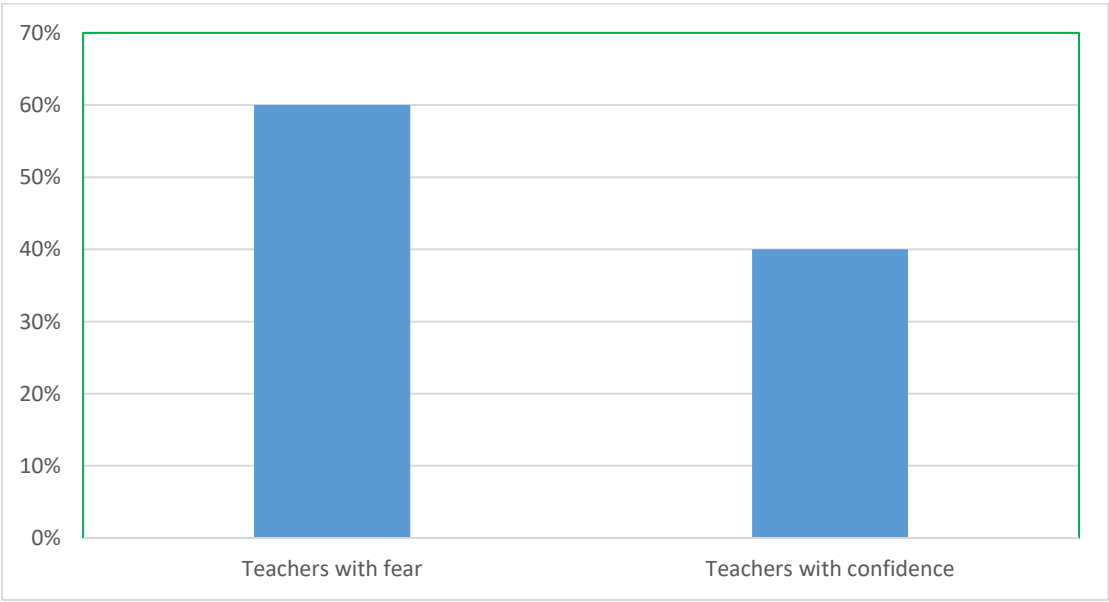

Fig. 3. Problems faced by teachers are shyness, self-doubt and lack of sufficient interest in the topic of the lesson

The analysis of the questionnaire revealed several barriers in English language teaching. Firstly, shyness emerges as a significant obstacle. Many students, especially beginners, harbor apprehensions about their ability to speak the language correctly, leading to feelings of insecurity and shyness. Despite completing homework assignments, some students may still feel uncomfortable interacting with their peers, hampering their fluency development in English. Secondly, the lack of time presents another major hurdle. Even with well-structured and effective lessons, students need sufficient time to apply and practice what they've learned. Without regular practice, retention of lesson content diminishes rapidly. Thus, allocating adequate time for students to develop their English language skills is crucial for their progress.

Roth (2015) discussed the concept of representation, which links meaning and language to culture through reflective, intentional, and constructive approaches. This perspective highlights the ways in which language reflects and constructs cultural norms, values, and beliefs, thus serving as a mirror of the people in a given society. Yeshurun et al. (2017) found that brain responses to the same event tend to cluster among people who share the same perspective. This finding suggests that language as a form of communication not only reflects individual beliefs, but also has the potential to shape shared perspectives and cognitive responses within a community.

As a result, we would like to note that there are many obstacles in teaching a foreign language, from technical problems to stimulating the student. Our research has shown that motivation is necessary to overcome most of the difficulties in learning a foreign language. In addition, the use of ICT in teaching foreign languages plays an important role. Student shyness, lack of time, textbooks with difficult tasks, etc. - it was found that such problems have a negative impact on the level of English proficiency the language of the student. In solving these problems, it was found that barriers are eliminated only when teaching methods languages gain the interest of students by using effective new technologies in language teaching. The results of this study will be of great help to English language teachers in all secondary schools. In addition, the use of the proposed barriers to teaching English in this study may help students become better proficient in English in the future. In general, in order to overcome obstacles faced by students when teaching them English.

Conclusions

To sum up, a teacher must constantly improve his professional skills. Moreover, as we have seen in the course of our research, it is the teacher who must overcome the negative habits inherent in any student when learning a language. Today, as we have already mentioned, we have highlighted some elements of removing barriers that we face when teaching a foreign language. However, this research will continue in the future, completely removing barriers to teaching English and demonstrating effective work. This is due to the fact that barriers to learning English are one of the most pressing problems in the direction of high-quality learning of this language. Based on the data provided during the conducted research, it became clear that it is necessary to eliminate barriers in teaching English, and during such elimination it is necessary to work intensively, always demonstrating the skill of the teacher.

Research recommendation

Although the research findings discussed above provide valuable insights into the relationship between language and culture, there are still gaps in knowledge that require further research. Future research should focus on exploring how language serves as a mirror of different cultural perspectives and how it influences the construction of shared meanings and beliefs in diverse communities.

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A Bibliometric Review on Exploring Digital Literacy Assessment Dynamics in Education

Abstract: The increasing role of technology in education underscores the need for strong digital literacy skills among teachers. However, assessing these skills in pre-service teachers remains an under-researched area. This study employed a quantitative approach with the help of RStudio, analyzing 664 articles (2015-2024) to investigate trends and patterns in digital literacy assessment for teacher education. The analysis revealed a robust field with a 5.07% annual growth rate and strong author collaboration (only 58 single-authored works). Average citations per document (24.08) indicated impactful research, with China emerging as a leading contributor. Beyond mere skills testing, keyword analysis uncovered broader research themes like education, e-learning, and digital technologies. Network analyses further highlighted the interdisciplinary nature of the field. This study emphasizes the need for comprehensive assessment tools encompassing the multifaceted aspects of digital literacy to ensure teacher students' preparedness for the modern educational landscape.

Keywords: digital literacy, cognitive tests, teacher, students, education.

Introduction

Digital literacy has emerged as a critical skill set for educators in today's technologically driven society (Sheriyev et al., 2016; Falloon, 2020, Ahmad, 2020; Sharma, Suri, Sijariya & Jindal, 2023). As classrooms increasingly integrate digital tools and resources, teachers are expected to possess related necessary competencies to effectively leverage these technologies for instructional purposes (Bowman, Vongkulluksn, Jiang & Xie, 2022). However, despite the growing recognition of the importance of digital literacy in teacher education, there remains a notable gap in the availability of robust assessment tools tailored to evaluate teacher students' digital instructional skills (Castellví, Díez-Bedmar & Santisteban, 2020).

Digital Literacy Skills for Teacher Students. Digital literacy encompasses a broad range of skills, including the ability to access, evaluate, and utilize digital information effectively and responsibly (Pangrazio, Godhe & Ledesma 2020; Reddy, Sharma & Chaudhary 2022; Rohde et al., 2023). In the context of teacher education, digital literacy extends beyond basic technical skills to encompass pedagogical knowledge and the ability to integrate technology into teaching practices, (Reddy, Sharma, Chaudhary, 2020). Researchers

emphasize the importance of preparing future educators to navigate digital environments, communicate digitally, and critically evaluate online resources (Morgan, Sibson, & Jackson, 2022). A teacher-student who masters digital literacy skills, especially instructional technologies, has already a strong aspect of career readiness. In the modern era, teachers are expected to leverage cutting-edge instructional technologies to enhance rich teaching-learning experiences (Alenezi, 2023; Pepkolaj and Dhimitri, 2023; Begimbetova, 2022).

Assessing Digital Literacy Skills. To assess digital literacy skills, one has to consider first the various aspects involved, especially other intricate competencies, (Sillat, Tammets & Laanpere, 2021). On this matter, Tomczyk (2020) also hinted that the context of assessing those skills is very crucial. According to those researchers, individuals, groups, and systemic levels of digital competence involvement should be considered (List, 2019). While recognizing the needs and urgency in assessing digital literacy competencies, Perdana et al. (2019) highlight the need for educational assessments to be tailored to the diverse needs and abilities of learners.

In the same perspective, the rapid evolution of digital technologies necessitates ongoing research into the level of digital literacy skills a modern teacher should have (Su, 2023). Older generation teachers might have been left behind and their learners maybe even better (Gómez-Trigueros, Ruiz-Bañuls & Ortega-Sánchez, 2019), but this does not mean that they should not try to have basics of digital literacy skills to render their lessons more appealing to students (Akayoglu, Satar, Dikilitas, Cirit & Korkmazgil, 2020; Begimbetova, Retnawati, Triyono, & Imangalieva, 2023). Digital literacy tests or other related assessment forms should be varied for teachers and students. But the field of developing accurate digital literacy skills tests for teachers, old generation or modern, students, or even library staff is an under-explored field, (Komlayut and Srivatanakul, 2017). The implementation of e-learning systems has been shown to significantly upgrade the quality of learning, as demonstrated by Kassymova et al. (2021) and Mutarah et al. (2024).

However, works related to students' digital literacy assessment started emerging. There is a new stream of integrating digital literacy into educational curricula, which is a very essential consideration to broaden students' horizons during this digital era (Gruszczynska, Merchant, & Pountney, 2013). For instance, Öncül (2021) suggested the development of context-specific batteries to assess first-year university students' digital literacy skills, which echoes (Martínez-Bravo, Sádaba Chalezquer, & Serrano-Puche, 2022) findings about the challenges of conceptualizing digital literacy and the need for multiple frameworks to situate digital competencies effectively. To measure digital literacy, a researcher is challenged to navigate diverse definitions, address context-specific needs, and ensure equitable access, which often requires multidisciplinary expertise.

Despite acknowledging the importance of digital literacy in teacher education, researchers find it challenging to assess pre-service teachers' or students' digital proficiency (Stockless, Villeneuve, Bisaillon, Fournier & Venant, 2022). Unlike traditional subjects like reading and mathematics, digital literacy lacks a standardized curriculum (Pangrazio, Godhe & Ledesma, 2020; Rusydiyah, Purwati & Prabowo, 2020; Nikou & Aavakare, 2021). As a result, digital competencies cognitive tests might have kept varying significantly, if UNESCO had not established a digital literacy framework that most researchers adapt or modify according to their contexts (Khan, Sarwar, Chen, & Khan, 2022). In addition, digital literacy skills tests might cover a broader spectrum of skills, including technical proficiency, media literacy, online safety, and problem-solving, (Martínez-Bravo, Sádaba-Chalezquer & Serrano-Puche, 2022).

Conversely, determining the most relevant digital literacy skills to assess and developing valid and reliable measurement tools pose challenges. Existing measures often focus on basic computer skills or fail to capture the complex or multifaceted nature of digital literacy context amid the existing divide between those who access digital information easily from those who do not due to their economic background (Falloon, 2020; List, Brante & Klee, 2020). Since digital literacy has economic implications (Kass-Hanna, Lyons & Liu, 2022), standardized tests are hard to develop. Consequently, there is a need for the development of comprehensive assessment tests that can effectively assess the diverse dimensions or layers encompassed by digital literacy without loosening the contexts of those assessment tools.

On the cognitive aspect, the development of robust tests to assess digital literacy proficiency requires careful consideration of various factors, including test validity, reliability, and alignment with learning objectives. Researchers emphasize the importance of incorporating authentic tasks and real-world scenarios to assess digital skills in context (Pellegrino et al., 2001; Jonassen & Rohrer-Murphy, 1999). Additionally, cognitive tests should be designed to measure higher-order thinking skills, such as problem-solving, critical

thinking, and information literacy, which are essential components of digital literacy (Mishra & Koehler, 2006; Voogt et al., 2011).

Digital Literacy Higher Order of Thinking Skills. Developing Higher-Order Thinking (HOT) digital literacy skills tests aims to collect information about a test taker's ability to analyze, evaluate, and apply digital information effectively, (Utama & Nurkamto, 2020). Research suggests that integrating HOTS into assessment tasks can provide a more comprehensive understanding of students' digital literacy proficiency (Anderson & Krathwohl, 2001; Bloom, 1956). Furthermore, the development of cognitive tests should aim to foster the development of these critical thinking skills among teacher students, enhancing their capacity to engage with digital technologies in meaningful ways (Dede, 2007; Jonassen, 2000).

This bibliometric analysis article aims to analyze patterns and trends in the scientific literature related to pre-service teachers' or teacher students' digital literacy competencies testing.

The research questions guiding this research are:

1) How are digital literacy skills related to the publication and citation performances of researchers/authors, institutions/universities, countries, and journals?
2) How can digital literacy skills testing related scientific works be mapped spatially?

Research Methods

This is a bibliometric analysis research that uses quantitative methods to report on the impact, distribution, and development metrics of studies related to measuring teachers-to-be digital literacy skills. The dataset used records from the Scopus database that were collected based on these search queries and filters:

TITLE-ABS-KEY (digital AND literacy AND skills AND cognitive AND tests AND for AND teacher AND students AND PUBYEAR > 2014 AND PUBYEAR < 2025 AND (LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "ARTS") OR LIMIT-TO (SUBJAREA, "MULT")) AND (LIMIT-TO (EXACT KEYWORD, "Education") OR LIMIT-TO (EXACTKEYWORD, "Higher Education") OR LIMIT-TO (EXACTKEYWORD, "Online Learning") OR LIMIT-TO (EXACTKEYWORD, "Digital Literacy") OR LIMIT-TO (EXACTKEYWORD, "Educational Technology") OR LIMIT-TO (EXACT KEYWORD, "Digital Competence") OR LIMIT-TO (EXACTKEYWORD, "Digital Technologies") OR LIMIT-TO (EXACTKEYWORD, "Pre-service Teachers") OR LIMIT-TO (EXACTKEYWORD, "Digital Reading") OR LIMIT-TO (EXACTKEYWORD, "Digital Skills") OR LIMIT-TO (EXACTKEYWORD, "TPACK") OR LIMIT-TO (EXACTKEYWORD, "Distance Education") OR LIMIT-TO (EXACTKEYWORD, "Digital Devices").

The number of records used is n=664 documents or articles in the English language. Two main types of analysis were carried out, namely the:

- publication and citation performances of researchers/authors, institutions/universities, countries, and journals;
- digital literacy skills testing related works spatial representation or mapping, especially the interaction between authors, concepts or keywords, and citations

Research Results

In Figure 1 below, it can be seen that the dataset offers information on scholarly publications between 2015 and 2024. It comprises 664 articles, with an annual growth rate of 5.07%. The average article age is 3.29 and the citation average is 24.08 times per document.

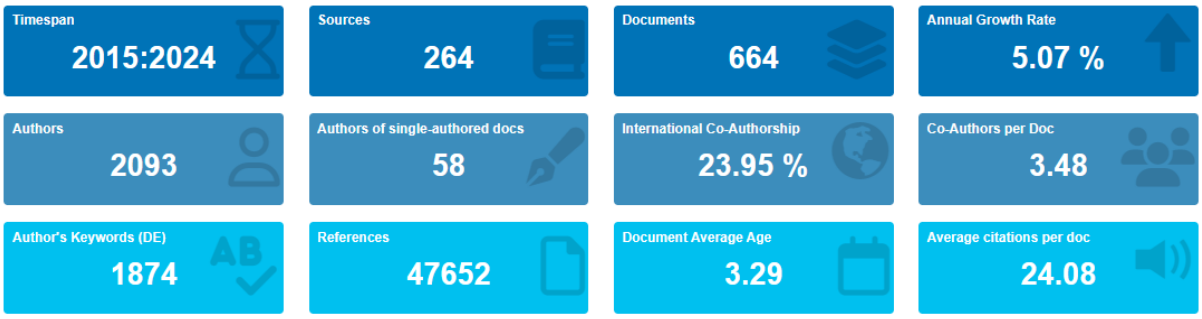

Figure 1. Main Information

The dataset also includes information on 47,652 references and 2093 authors. Interestingly, collaboration on research peaked at 23.95% and among the 664 documents, only 58 were single-authored.

As far as Figure 2 is concerned, it pictorially displays authors' production from 2015 to 2024. The most productive year, thus the peak interest in the digital literacy skills tests, was 2023 whereby 159 articles about digital literacy testing were produced; the least productive year about this research interest was registered in 2015 during which only 25 articles were produced.

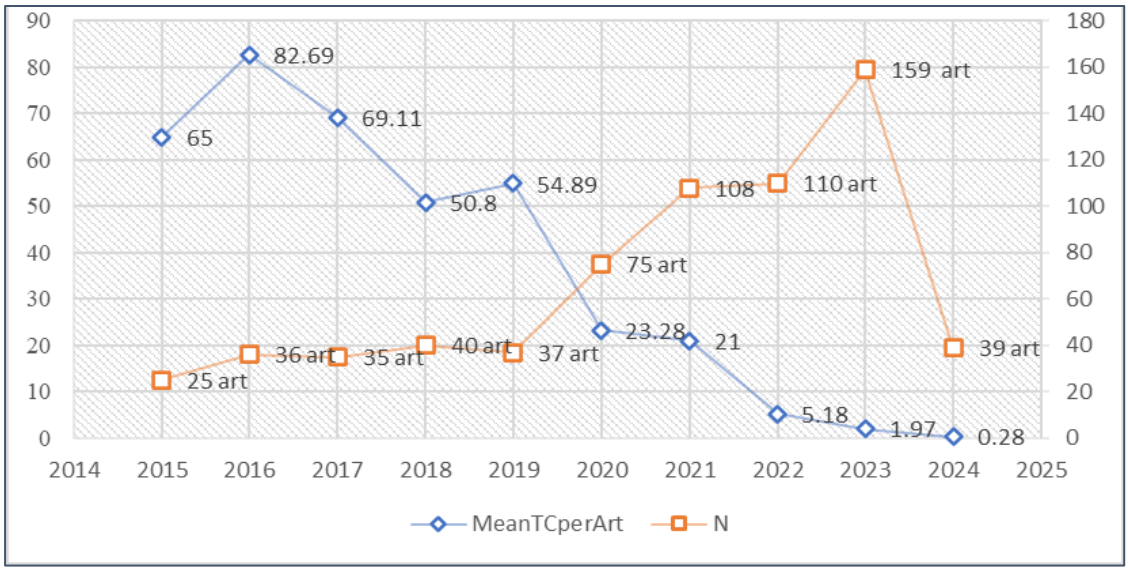

Figure 2. Article Production from 2015-2024

In terms of being cited, the highest total citation mean per article was in 2016, whereas for articles written outside the target timespan, this article had an average total mean citation per article of 82.69 and the sink citations sank flat to a total citation per article mean is 0.28 were previous works total. So, a peak shift in research focus was noticeable in 2023.

Affiliation Overtime. This section is about the publication output of various universities across different years. At the University of Tübingen, the peak years of interest in digital literacy measurement were 2023 and 2024 with 30 articles published by researchers based on that university each year. Similarly, a notable jump in publication output at the University of Granada became even between 2021 and 2024 where a consistent output of 17 articles was observed yearly. As far as the University of Granada is concerned, its staff published 17 per year between 2020 and 2024 while the University of California on its turn output 18 articles per year between 2022 and 2024. Equally, the publication output for the University of Sanford was 18 articles for years 2023 and 2024 while 17 were published in 2022. The last but not the least affiliation with a notable interest in the topic is the University of Taiwan. Its staff's interest in digital literacy skills testing picked up constantly from the year 2021 and stabilized up to 2024 and 16 articles were published annually.

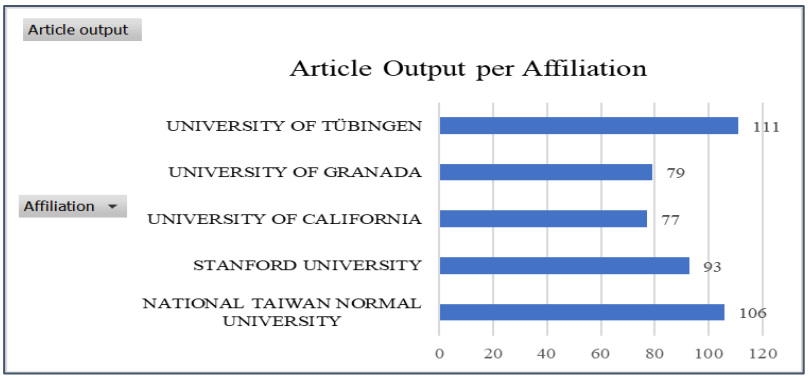

Figure 3. Article Publication Output

Based on the timespan 2015-2024, the affiliation with many publications about digital literacy skills assessment is the University of Tübingen with 111 articles published, followed by the University of Taiwan which outputs 106 articles. The University of Sanford staff published up to 93 articles on that matter, while the University of Granada and that of California researchers published 79 and 77 respectively.

Corresponding Author's Countries. Figure 4 outlines the distribution of articles, Source Citation Potential (SCP), Multiple Citation Potential (MCP), Frequency (Freq), and MCP Ratio across different countries. For instance, the US ranks highest in terms of articles with 80, followed by China with 56 articles. However, when considering the SCP and MCP, which indicate the potential impact of publications, China exhibits a higher MCP ratio of 0.232 compared to the USA's 0.125, implying that Chinese publications are more likely to receive multiple citations.

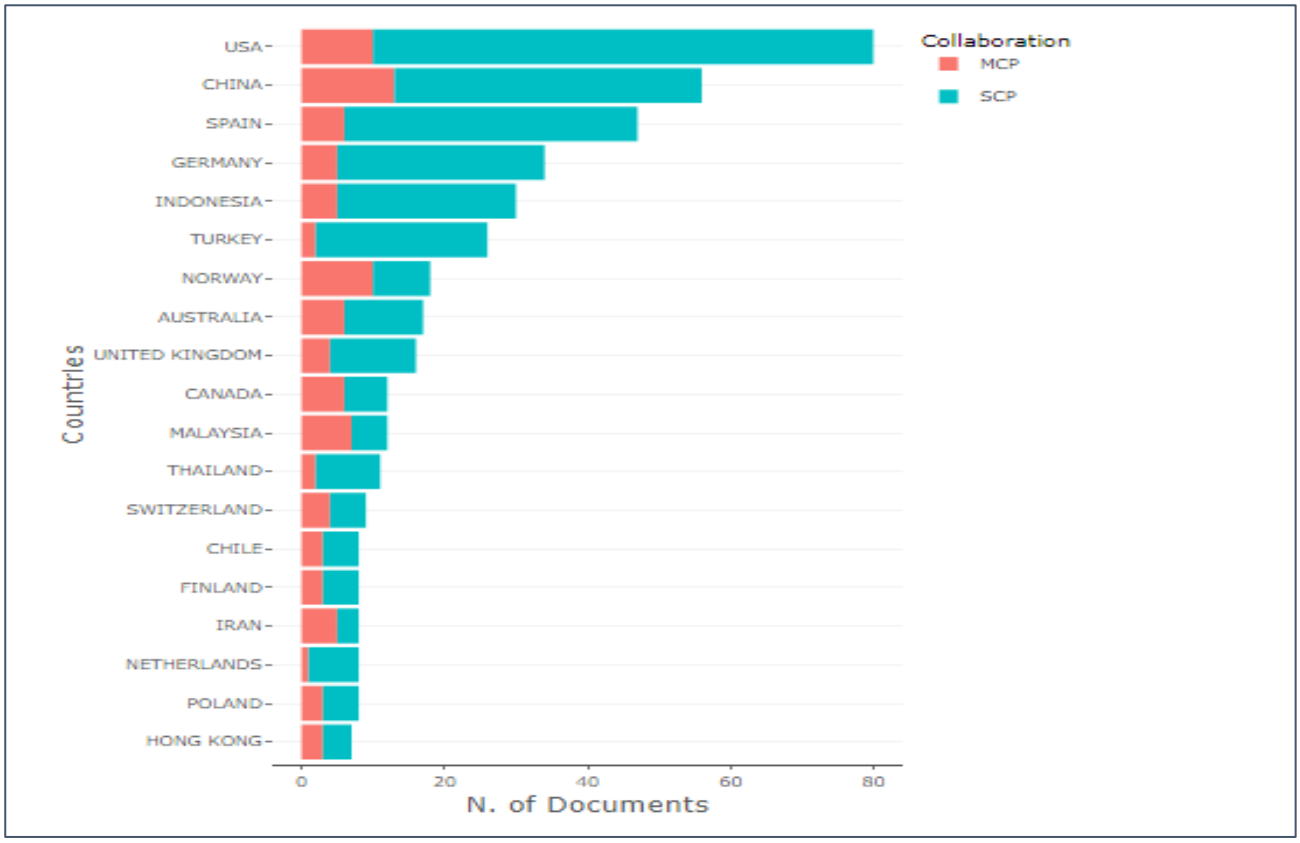

Figure 4. Corresponding Author's Countries

Norway, although having fewer articles, stands out with a remarkably high MCP ratio of 0.556, suggesting that its publications have a higher probability of being cited multiple times. So, that figure shows explicitly the digital literacy skills related to research productivity and citation impact of various countries, which transcends implicitly in a form of comparison and assessments of their scholarly contributions on a global scale on that research interest.

Word Clouding. Table 1 lists keywords related to the field of interest: digital literacy skills. But as it can be seen, although the filtering process ensured the inclusion of digital literacy testing or cognitive tests, Table 1 barely has any keywords related to testing, measuring or assessing digital literacy skills.

Table 1: Relevant Digital Literacy Skills Keywords

Keyword	Frequency
computer aided instruction	30
education computing	26
educational technology	24

digital devices	21
academic performance	19
digital technologies	17
information literacy	14
online learning	14
human computer interaction	13
Internet	13
digital literacies	12
digital skills	12

Figure 5. Word Cloud

What is more, it does not mention teacher students or pre-service teachers, however, the word cloud has bold education, student, learning, teaching, and then e-learning. This means that digital literacy skills cognitive tests, especially for students in teacher education programs have not held researchers' attention.

The keywords bolded in the word cloud also indicate that they are the ones trending. Although the interest is about digital literacy skills tests or measurement, is a field of the broader term "education", and "teaching", which are "human" unique activities where "male" or "female" "students" learn in person or through "e-learning", in the latter scenario "educational technologies" through computer-assisted.

With that said, other possible interpretations, especially those that are theoretically-based can be made. Indeed, connections can be established between "digital literacies" and "students": after all, the subjects whose digital literacy skills are tested are those students. In the same view, "e-learning" or 'online learning both serve an "education" agenda.

Clustering by Coupling. For the data collected, the coupling map determined the existence of 8 groups, but 4 are worth commenting:

1) The one with the second highest frequency (52), first centrality and impact respectively of 0.4o and 3.17 is the *students - conf 25.5% education - conf 13% digital literacies - conf 75%* coupling. Its centrality or most important keyword (75%) is "digital literacies".
2) The coupling *_education - conf 7.4% computer science - conf 25% digital environment - conf 33.3%_* hosts the second most weighing keyword "digital environment" (33%.3), and 2nd highest impact 2.56.
3) This is another coupling built-in *education - conf 25.9% e-learning - conf 28.9% self-efficacy - conf 66.7%_*its most weighing keyword or centrality is "self-efficacy". What is special about this grouping is its highest frequency in the dataset (62); this implies that e-learning requires self-efficacy or how the two serve educational purposes a balance between the two is kept intact; its impact is 1.74.
4) *_Students - conf 17.6% e-learning - conf 21.1% education - conf 13%_* with impact of 1.71 and anchored in the "e-learning" centrality or weighing keyword, this coupling shows how e-learning plays a non-neglectful role: it is one of the means through which students can access education and learn. Figure 9 illustrates how the 4 groups close the perpendicular line:

Figure 6: Clustering by Coupling

These findings demonstrate the diverse dynamics at play within educational contexts, emphasizing the significance of digital literacy, digital environments, self-efficacy, and e-learning in modern educational practices.

Co-occurrence Network. Figure 7 provided data outlines various educational themes, categorized into clusters based on their relevance. Cluster 1 primarily encompasses topics related to technology and instructional methods, such as "e-learning," "engineering education," and "digital literacies." Cluster 2 focuses on broader educational concepts like "education," "students," and "teaching," indicating a holistic approach to pedagogy. In contrast, Cluster 3 delves into more specific areas such as "learning," "human behaviour," and "academic performance," suggesting a deeper exploration of psychology and human development within education.

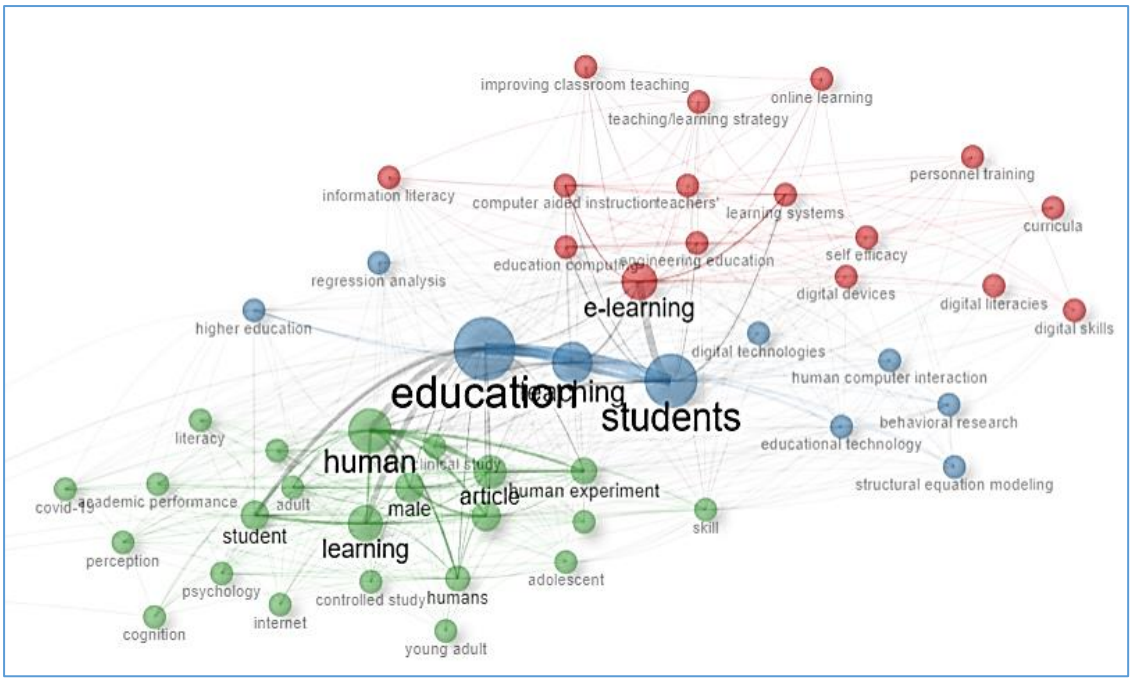

Figure 7. Co-occurrence Network

Each cluster offers insights into different facets of the educational landscape, ranging from technological advancements to human-centric approaches, providing a comprehensive view of the diverse dimensions within the field of education.

Thematic map. Figure 8 presents a comprehensive analysis of educational themes based on occurrence frequencies and centrality measures. Noteworthy occurrences include "education" with 167 instances, "students" with 137, and "teaching" with 94, indicating their prevalence in scholarly discourse. Centrality metrics such as betweenness centrality, closeness centrality, and PageRank centrality provide insights into the prominence of these topics within the educational domain.

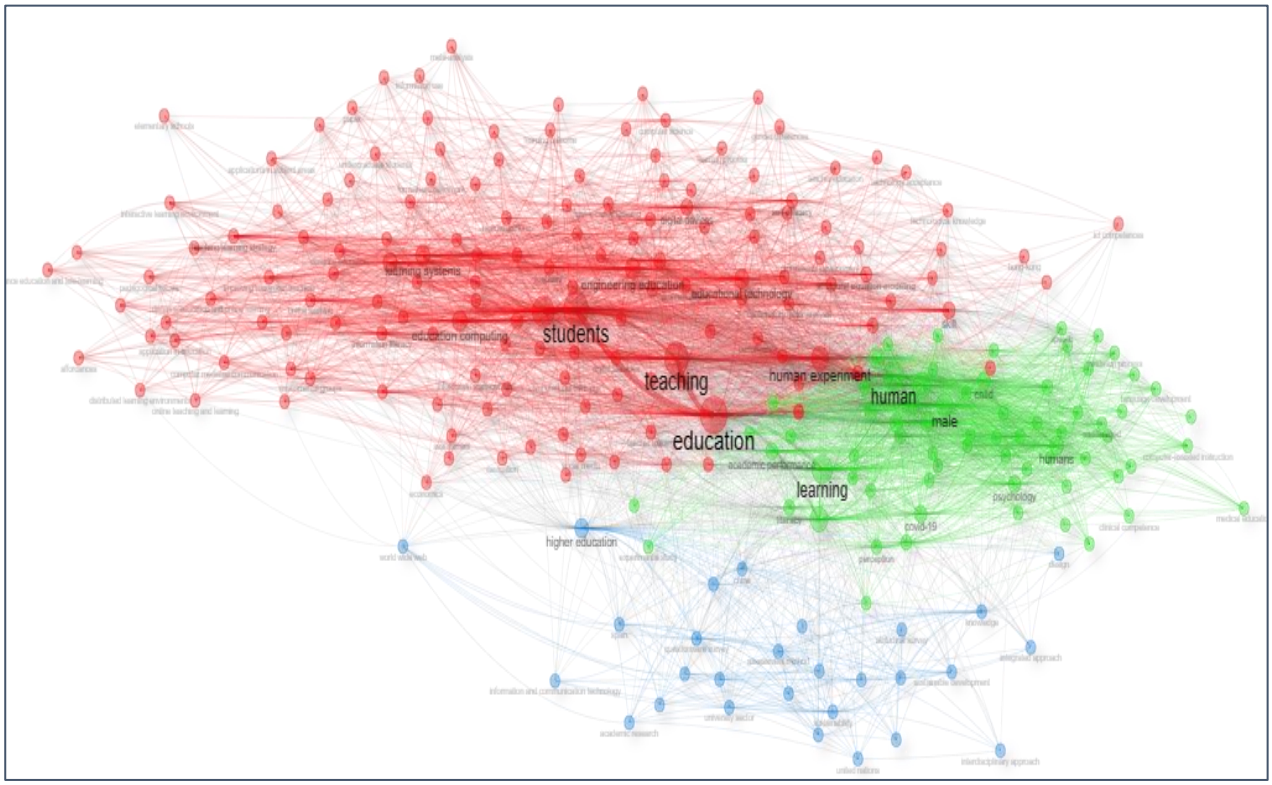

Figure 8. Thematic map

For instance, "education" exhibits high centrality measures across all metrics, with betweenness centrality at 203.53, closeness centrality at 0.0020, and PageRank centrality at 0.0491. This suggests that "education" plays a crucial role as a central theme in educational research, being frequently referenced and interconnected with other topics.

***Factorial Analysis*.** In this factorial analysis of documents within the realm of education and related fields, a multidimensional perspective reveals significant insights. Each document's position on two extracted dimensions, termed dim1 and dim2, underscores its unique contribution to the overall analysis. For instance, Sung et al. (2016) exhibited a moderate influence on dim2 with a score of 0.09 but had a lesser impact on dim1 with a score of -0.22. Conversely, Abbas et al. (2019) demonstrated a stronger influence on dim1 (0.09) but a contrasting impact on dim2 (-0.53).

These dimensions not only facilitate the clustering of documents but also gauge their relative importance within the factorial space. Such analyses provide a structured approach to understanding complex datasets, offering researchers valuable insights into underlying patterns and relationships.

Co-citation Network. The exported data contains information about nodes (likely representing authors or publications) along with their cluster assignments and network metrics such as Betweenness, Closeness, and PageRank. These metrics provide insights into the importance and centrality of each node within its respective cluster.

Node and Cluster Assignment: Each node is labeled with its name or identifier and assigned to one of the clusters (1, 2, 3, 4, or -1 and -2, possibly representing outliers or separate groups).

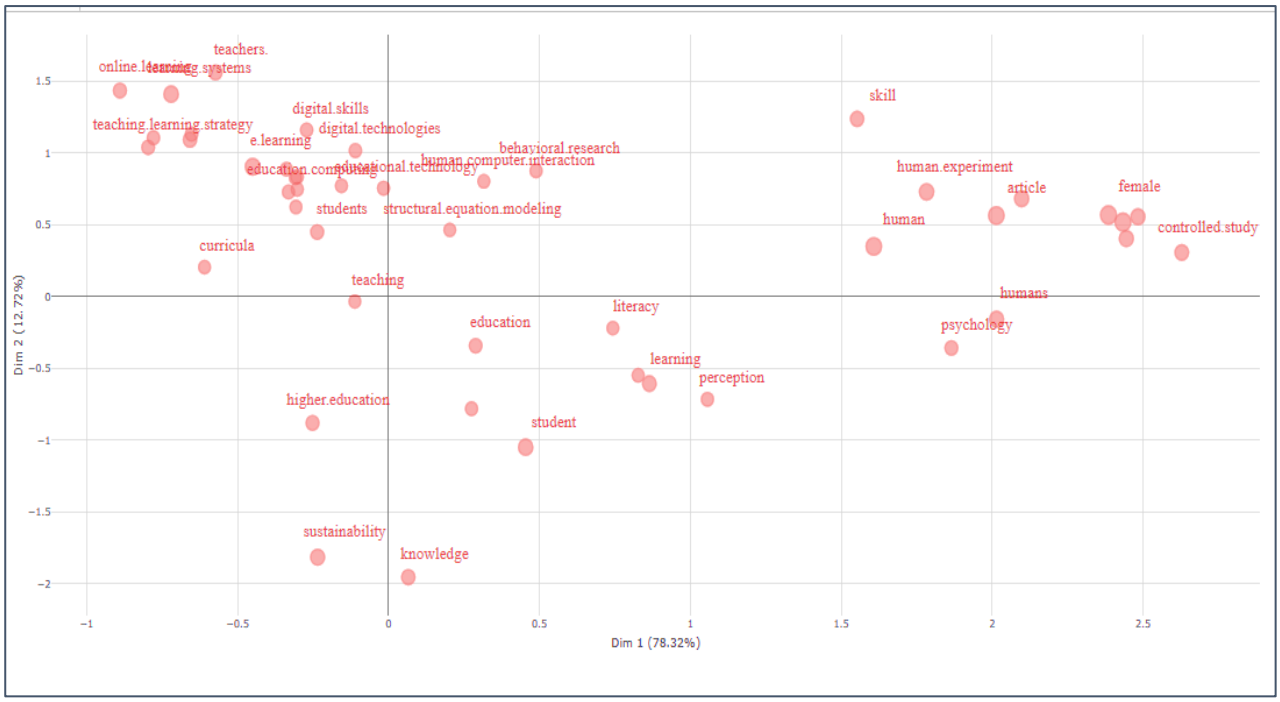

Figure 9. Factorial analysis

Betweenness Centrality: This metric measures the extent to which a node lies on the shortest paths between other nodes in the network. Nodes with high betweenness centrality, such as "bandura a. 1997" in Cluster 3 with a value of 446.16, act as crucial connectors within the network.

Closeness Centrality: Closeness centrality quantifies how close a node is to all other nodes in the network. Nodes with high closeness centrality, like "Scherer r. -1" in Cluster 4 with a value of 0.00775, can efficiently interact with other nodes in their cluster.

PageRank: This algorithm assigns a numerical weight to each node in the network based on the number and quality of incoming links. Nodes with high PageRank scores, such as "Scherer r. -2" in Cluster 4 with a value of 0.04591, are considered influential within their cluster.

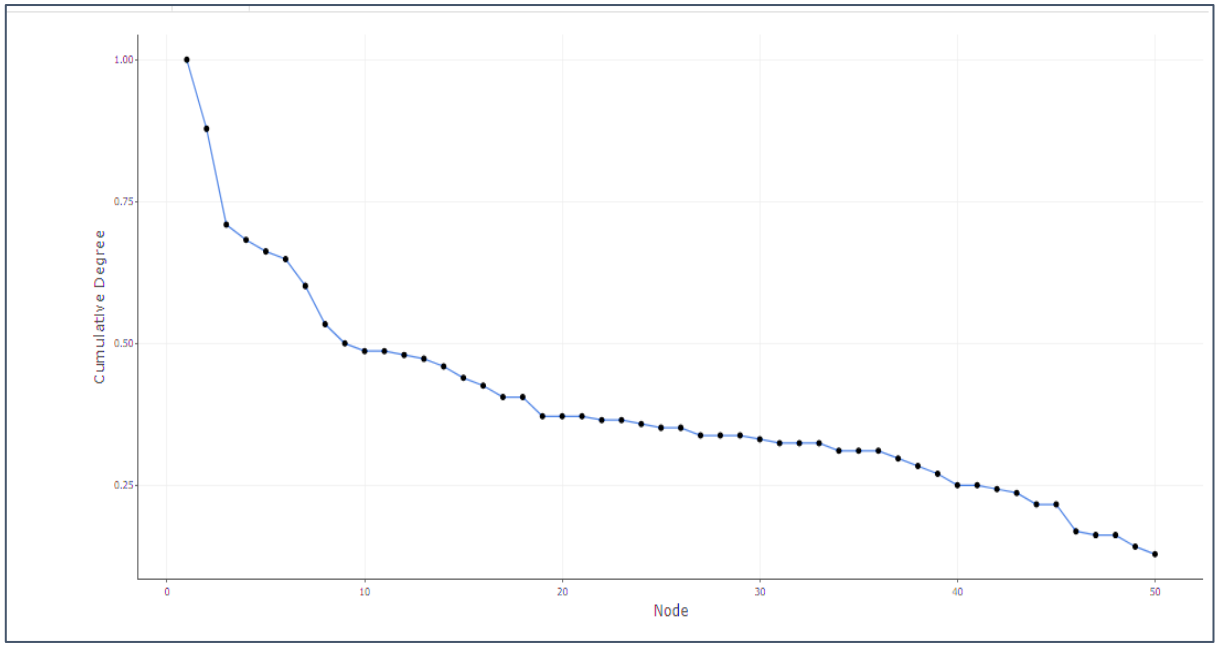

Figure 10. Co-citation Network

By examining these metrics across clusters, we can identify key nodes and understand their roles within their respective research domains. Additionally, outliers or nodes in clusters -1 and -2 might represent distinct topics or outliers within the dataset, warranting further investigation.

Research Discussion

This study delved into the world of research on assessing digital literacy skills in future teachers. The researchers, like detectives following a trail of clues, used a technique called bibliometrics to analyze a mountain of academic articles. Their investigation was driven by two burning questions:

The Power of Digital Literacy. Does having strong digital literacy skills affect how well a researcher's work gets published and recognized by others? The analysis revealed a surge in studies on testing these skills, highlighting a growing concern for ensuring future teachers are digitally fluent. The research community also displayed a strong spirit of collaboration, unsurprising given the multifaceted nature of digital literacy assessment in teacher education. Interestingly, a trend emerged: some countries and universities published more on the topic, while others garnered more citations for their work. This finding emphasizes the importance of both the quantity and quality of research – not just how much is published, but also how influential it is. Citation metrics act as a window into the impact of research, allowing us to see how much other researchers are using and building upon someone's work. In essence, this paints a vivid picture of a dynamic and collaborative research landscape, where valuable contributions flow from a diverse range of researchers, institutions, and nations across the globe.

Mapping the Landscape. The researchers took their analysis a step further by asking: Can we map where research on digital literacy skills testing is geographically concentrated? Here, they employed special mapping techniques to visualize the geographical spread and collaborative networks within the research community. This approach illuminated areas with high research activity and collaboration hotspots, revealing which institutions were working together the most. However, the benefits extended beyond simply identifying global trends and prolific institutions. The mapping also unearthed budding collaborative networks, fostering interdisciplinary connections that are crucial for advancing knowledge in this domain. It even pinpointed "research deserts," areas with limited scholarly activity. This knowledge is vital because it allows for targeted interventions and collaborative efforts to bridge these knowledge gaps and encourage wider research participation.

By incorporating spatial mapping techniques, the researchers gained a richer understanding of the global research landscape. Visualizing the geographical distribution of research activity provided valuable insights into trends, collaborative networks, and emerging research clusters. This knowledge empowers researchers to navigate the complex terrain of digital literacy assessment research with greater clarity and purpose.

Conclusion

In conclusion, this study serves as a beacon, illuminating the path toward a deeper understanding of how we evaluate digital literacy skills in aspiring educators. The findings depict a landscape brimming with burgeoning interest and collaborative spirit, where researchers, institutions, and nations are joining forces to unravel the intricacies of digital literacy assessment in teacher education. As the academic discourse on this topic continues to evolve, spatial mapping emerges as a powerful tool, not just for visualization, but also for fostering interdisciplinary collaborations that transcend geographical boundaries. This approach empowers researchers to identify research priorities, collaborative opportunities, and emerging trends, equipping them to navigate the complexities of digital literacy assessment research with renewed focus and direction. Ultimately, this study not only enhances our understanding of digital literacy assessment, but also lays a strong foundation for future explorations in this vital area of educational research, with the potential to inform policy, practice, and teaching methods for teacher education on a global scale.

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Evaluating Student Self-Management, Interpersonal Skills, and Academic Behaviors

Abstract: This study examines the relationships between student self-management, interpersonal skills, and academic behavior through detailed statistical analysis of survey data. The survey used a Likert scale ranging from "strongly disagree" to "strongly agree" to assess respondents' perceptions of these three areas. To analyze the data, we used the JASP Frequencies: Binomial Test function, which was specifically designed to calculate confidence intervals for the proportions of responses at each level of agreement. The analysis involved calculating 95% confidence intervals for the proportion of respondents who selected each Likert scale category for each survey item. These intervals provide a range within which the true proportion of responses may fall, offering insights into general trends and the distribution of respondents' views. In addition, we used the Vovk-Sellke maximum p-ratio to further interpret the significance of the results to help understand the strength of the evidence against the null hypothesis. This exploratory analysis not only demonstrates the variability and reliability of respondents' responses, but also provides a deeper understanding of how students' self-management, interpersonal skills, and academic behaviors are perceived at different levels of agreement. Using these statistical methods, research aims to uncover patterns and relationships in the data, thereby contributing to a deeper understanding of the factors that influence student achievement.

Keywords: self-management, interpersonal skills, academic behaviours, students, education.

Introduction

The multifaceted nature of student academic success in modern educational institutions goes beyond academic performance. Educators and researchers increasingly recognize that self-management, interpersonal skills and academic behavior play an important role in shaping students' overall educational experiences and outcomes. Understanding these factors is critical to developing effective support systems and interventions that enhance student empowerment and performance. Self-management, which includes skills such as time management, goal setting, and self-regulation, is fundamental to academic success (Sholikah et al., 2021). Self-management is an important factor in academic success, with evidence that self-directed growth goals have a significant impact on academic performance. Katz et al. (2019) found that approximately 20% of students' self-reported growth goals were directly related to their academic

performance, indicating a strong impact on achievement during reflective programs. This highlights the importance of self-management in academic settings and suggests that developing such skills can lead to improved educational outcomes. Students who manage their time and resources effectively are better equipped to meet academic demands and achieve educational goals.

In addition, Ghiasvand et al. (2017) studied a correlation between time management skills and academic motivation, indicating that students with good time management skills have lower anxiety levels and higher motivation. This finding is consistent with the notion that self-efficacy may alleviate negative emotional states such as test anxiety, which a significant percentage of students reported experiencing at moderate to severe levels. Similarly, interpersonal skills, including communication, teamwork, and conflict resolution, are critical to navigating collaborative learning environments and building positive relationships with peers and educators. Academic behaviour, which includes study habits, attendance, and engagement with course materials, directly affects student learning and outcomes. By examining how self-management and interpersonal skills intersect with academic behavior, we can better understand the factors that contribute to student achievement and well-being.

This study aims to assess these three important dimensions — self-management, interpersonal skills, and academic behaviors — through detailed statistical analysis of survey data. By classifying the survey questions into these three domains and analyzing the responses using JASP computer software, the study attempts to uncover patterns and relationships among these variables.

Research hypothesis: Students with high self-management skills will demonstrate positive academic behaviour and strong interpersonal skills. Specifically, students also report higher levels of agreement with statements related to effective academic behavior and positive interpersonal interactions. This hypothesis provides a basis for examining self-management and academic behavior and interpersonal skills and whether these dimensions of student behavior are related.

Research Methodology

The research design consists of several stages such as literature review, questionnaire development and categorization of the survey questions into three parts - self-management, interpersonal skills and academic behaviors of students. Respondents were asked to choose one of the Likert Scale multiple answers from strongly disagree, disagree, neutral, agree and strongly agree to the presented statement. Consequently, based on the obtained research results, a statistical analysis was performed. Calculations were carried out by JASP computer software (Version 0.18.3) and presented in the form of tables.

Research tools. Nyaga et al. (2014) developed the Metaprop Stata command to perform a meta-analysis of binomial data to test the proportion significantly different from the specified value. This tool allows researchers to combine and analyze binomial data from multiple scientific works. It has been widely used in various fields and has attracted the attention of several scientific studies. This study analyses the research results using the Classical Binomial Test of the JASP Version 0.18.3 computer program. Proportions tested against value 0.5. The Vovk-Sellke Maximum p -Ratio was based on the p-value, the maximum possible odds in favor of H_1 over H_o equals $1/(-e\ p\ \log(p))$ for $p \leq .37$. The Vovk-Sellke Maximum p-Ratio is a fundamental statistical concept (Sellke, Bayarri, & Berger, 2001).

Research Questionnaire and Samples. The survey was conducted among 65% of local and 35% of international students to identify student activities and motivation for future action if there is a need to change the education system. During conducting the survey, the majority of respondents admitted that they had never missed their lessons at the university. This can be concluded that they were motivated and engaged with internal interest. The sample size included 47% of the first-year and 53 % of the second-year students from the Department of Pedagogy and Psychology at Abai Kazakh National Pedagogical University in the academic year 2023-2024. The samples were randomly selected among 12% of male and 88% of female students. The survey items were 20 about Self-Management (7), Interpersonal Skills (6) and Academic Behaviors (7). The survey questions were slightly modified from analogous earlier research studies and answered in English. The Likert scale (strongly disagree, disagree, neutral, agree and strongly agree) was used to gather data about students' attitudes and opinions regarding the learning process.

Research Results and Discussions

Self-Management of Students. This part of the study aims to comprehensively explain the various factors that influence students' self-management, focusing on self-directed learning, intrinsic motivation and

self-regulation. The influence of using the Internet by students has an effectiveness of self-regulation (Lavrinenko et al., 2019). Self-directed learning is critical to student development and academic achievement. Pol, Volman, and Beishuizen (2010) pointed out that people learn better when they are in control of their learning experience, which highlights the importance of self-management in educational settings. Gureckis and Markant (2012) further supported this idea by finding significant correlations of situational interest and self-regulation with various types of activities, including behavioral, emotional, and cognitive relationships. This shows that independence in learning and the ability to regulate one's own learning process have a positive effect on student activity.

In addition, teachers' autonomy support plays an important role in influencing student engagement. Bartimote-Aufflick et al. (2016) emphasized the importance of autonomy-supportive learning, which includes intrinsic motivation and autonomy-satisfying instructional behavior that supports internalization. The authors noted that such learning experiences contribute to students' self-efficacy and overall engagement in learning activities. Muenks, Wigfield, Yang, and O'Neal (2017) and Geng, Law, and Niu (2019) emphasized the importance of intrinsic motivation to students' personality traits, self-regulation, and goal achievement. This shows that building intrinsic motivation among students is important for their overall academic and personal development.

Table 1. Self-Management

Variable	Level	Counts	Total	Proportion	p	VS-MPR*	95% CI for Proportion	
							Lower	Upper
I can resist doing something when I know I should not do it.	Agree	7	16	0.438	0.804	1.000	0.198	0.701
	Disagree	2	16	0.125	0.004	16.065	0.016	0.383
	Neutral	5	16	0.313	0.210	1.122	0.110	0.587
	Strongly Agree	2	16	0.125	0.004	16.065	0.016	0.383
I can calm myself down when I am excited or upset.	Agree	8	16	0.500	1.000	1.000	0.247	0.753
	Disagree	3	16	0.188	0.021	4.492	0.040	0.456
	Neutral	3	16	0.188	0.021	4.492	0.040	0.456
	Strongly Agree	2	16	0.125	0.004	16.065	0.016	0.383
I am a hard worker.	Agree	9	16	0.563	0.804	1.000	0.299	0.802
	Neutral	6	16	0.375	0.454	1.000	0.152	0.646
	Strongly Agree	1	16	0.063	< .001	93.747	0.002	0.302
I finish whatever I begin.	Agree	8	16	0.500	1.000	1.000	0.247	0.753
	Disagree	2	16	0.125	0.004	16.065	0.016	0.383
	Neutral	5	16	0.313	0.210	1.122	0.110	0.587
	Strongly Agree	1	16	0.063	< .001	93.747	0.002	0.302
I am diligent (hard-working and careful).	Agree	12	16	0.750	0.077	1.866	0.476	0.927
	Disagree	2	16	0.125	0.004	16.065	0.016	0.383
	Neutral	1	16	0.063	< .001	93.747	0.002	0.302
	Strongly Agree	1	16	0.063	< .001	93.747	0.002	0.302
Setbacks do not discourage me.	Agree	8	16	0.500	1.000	1.000	0.247	0.753
	Disagree	2	16	0.125	0.004	16.065	0.016	0.383
	Neutral	5	16	0.313	0.210	1.122	0.110	0.587
	Strongly Agree	1	16	0.063	< .001	93.747	0.002	0.302

Variable	Level	Counts	Total	Proportion	p	VS-MPR*	95% CI for Proportion Lower	95% CI for Proportion Upper
I can do almost all the work in class if I do not give up.	Agree	12	16	0.750	0.077	1.866	0.476	0.927
	Disagree	1	16	0.063	< .001	93.747	0.002	0.302
	Neutral	1	16	0.063	< .001	93.747	0.002	0.302
	Strongly Agree	2	16	0.125	0.004	16.065	0.016	0.383

Table 1 is the survey results showing the proportion of respondents who agree, disagree, or are neutral with the statements regarding self-management skills and their 95% confidence intervals. In the context of survey results, 95% confidence intervals indicate the range of values within which we can be 95% confident that a true population proportion lies. For example, in the self-control section, the proportion of individuals who agree to resist doing something when they know they shouldn't do it has a 95% confidence interval of 0.198 to 0.701. This means that we can be 95% confident that the actual proportion of people who are likely to resist when they know something should not be done falls within this range. Similarly, 95% confidence intervals for other survey questions provide a range of values that may include true population proportions for a given self-management and interpersonal skill.

Interpersonal Skills of Students. Interpersonal skills are essential for students because they are essential for effective collaboration, communication, and empathy. Vogler et al. (2018) found that students who participated in service learning improved their interpersonal skills. This suggests that experiential learning opportunities such as service learning can have a positive impact on the development of interpersonal skills. However, Sadiku (2015) also emphasizes the importance of concrete skills such as reading, speaking, writing and listening in the classroom. Hobgood et al. (2010) focused on the effect of active listening on students' responses, especially on the repetition of the message. This study highlights the importance of active listening as a component of interpersonal skills. Weger et al. (2010) and Jones, et al. (2019) also found that active listening has a positive effect on empathy, which is an important aspect of interpersonal skills.

Jones et al. (2019) and Abe et al. (2018) focused on the effectiveness of targeted educational programs and the implementation of improvisation to teach communication skills and build empathy. Vogel et al. (2018) provided a new model that integrates personal and professional identities related to the intersection of multiple forms of motivation, encountering and resolving value conflicts, and developing interpersonal skills.

Table 2. Interpersonal Skills

Variable	Level	Counts	Total	Proportion	p	VS-MPR*	95% CI for Proportion Lower	95% CI for Proportion Upper
I am comfortable interacting with people from a different racial or ethnic background.	Agree	5	16	0.313	0.210	1.122	0.110	0.587
	Neutral	6	16	0.375	0.454	1.000	0.152	0.646
	Strongly Agree	5	16	0.313	0.210	1.122	0.110	0.587
I can come up with new ideas.	Agree	11	16	0.688	0.210	1.122	0.413	0.890
	Neutral	2	16	0.125	0.004	16.065	0.016	0.383
	Strongly Agree	3	16	0.188	0.021	4.492	0.040	0.456
I like to imagine new ways to do things.	Agree	11	16	0.688	0.210	1.122	0.413	0.890
	Neutral	2	16	0.125	0.004	16.065	0.016	0.383

Variable	Level	Counts	Total	Proportion	p	VS-MPR*	95% CI for Proportion	
							Lower	Upper
I am a creative person.	Strongly Agree	3	16	0.188	0.021	4.492	0.040	0.456
	Agree	7	16	0.438	0.804	1.000	0.198	0.701
	Disagree	2	16	0.125	0.004	16.065	0.016	0.383
	Neutral	4	16	0.250	0.077	1.866	0.073	0.524
When my solution to a problem is not working, I try to figure out what went wrong.	Strongly Agree	3	16	0.188	0.021	4.492	0.040	0.456
	Agree	9	16	0.563	0.804	1.000	0.299	0.802
	Neutral	3	16	0.188	0.021	4.492	0.040	0.456
I try to think of many solutions when I have a problem.	Strongly Agree	4	16	0.250	0.077	1.866	0.073	0.524
	Agree	9	16	0.563	0.804	1.000	0.299	0.802
	Disagree	1	16	0.063	< .001	93.747	0.002	0.302
	Neutral	3	16	0.188	0.021	4.492	0.040	0.456
	Strongly Agree	3	16	0.188	0.021	4.492	0.040	0.456

Table 2 provides a summary of the survey results for various interpersonal skills, including comfort in interacting with people of different racial or ethnic groups, generating new ideas, imagining new ways of doing things, and creativity. These results show the proportion of individuals who expressed comfort in interacting with people from different racial or ethnic backgrounds at different levels of agreement. The confidence intervals that generate new ideas are as follows:

- For the "Agree" level: 95% CI (Confidence Interval) is between 0.413 and 0.890
- For the "Neutral" level: 95% CI is between 0.016 and 0.383
- For the "Strongly Agree" level: 95% CI is between 0.040 and 0.456

The research results found that the participants showed different levels of creativity. This suggests that participants had a range of levels of creativity, with some more inclined to agree with statements about creativity than others. The research findings show the multifaceted nature of interpersonal communication skills and various factors that influence their development among students. Historically, feminism has always been interpreted closely to the idea of unequal treatment towards women (Pertiwi et al., 2019), and upcoming research should comprehensively examine the role of individual differences, such as gender and personality traits, in the development of students' interpersonal skills.

Academic Behaviors of Students. Academic behavior plays a crucial role in students' overall academic achievement and success. Nonis and Hudson's (2010) research found that effective study habits and proper allocation of study time have a positive effect on students' academic performance. This shows that developing good study habits is essential for academic success. In addition, sleep habits have an impact on academic performance. Eliasson et al. (2010) found that earlier bedtimes and wake times had a positive effect on academic performance, suggesting the importance of healthy sleep habits in improving student academic performance. Boumosleh and Jaalouk (2017) studied the relationship between depression, anxiety, smartphone addiction and academic behavior among university students. The study found the negative effects of depression, anxiety, and smartphone addiction on students' academic behavior, highlighting the need to address mental health issues to promote positive academic behavior. Furthermore, Kecojevic et al. (2020) conducted a study on the impact of the COVID-19 outbreak on the mental health of undergraduate students. The results highlighted the adverse impact of the pandemic on students' mental health, highlighting the need for interventions to support students' mental well-being, which is critical to fostering positive academic behavior.

Tabla 3. Academic Behaviors

Variable	Level	Counts	Total	Proportion	p	VS-MPR*	95% CI for Proportion	
							Lower	Upper
I can learn the things taught in university.	Agree	11	16	0.688	0.210	1.122	0.413	0.890
	Neutral	4	16	0.250	0.077	1.866	0.073	0.524
	Strongly Agree	1	16	0.063	< .001	93.747	0.002	0.302
What we do at university will help me succeed in my life.	Agree	9	16	0.563	0.804	1.000	0.299	0.802
	Neutral	5	16	0.313	0.210	1.122	0.110	0.587
	Strongly Agree	2	16	0.125	0.004	16.065	0.016	0.383
How smart I am is something that I can change.	Agree	10	16	0.625	0.454	1.000	0.354	0.848
	Neutral	3	16	0.188	0.021	4.492	0.040	0.456
	Strongly Agree	3	16	0.188	0.021	4.492	0.040	0.456
I am good at figuring out the best solutions to problems that I am facing	Agree	7	16	0.438	0.804	1.000	0.198	0.701
	Disagree	1	16	0.063	< .001	93.747	0.002	0.302
	Neutral	6	16	0.375	0.454	1.000	0.152	0.646
	Strongly Agree	2	16	0.125	0.004	16.065	0.016	0.383
One of my goals in class is to learn as much as I can.	Agree	8	16	0.500	1.000	1.000	0.247	0.753
	Disagree	1	16	0.063	< .001	93.747	0.002	0.302
	Neutral	3	16	0.188	0.021	4.492	0.040	0.456
	Strongly Agree	4	16	0.250	0.077	1.866	0.073	0.524
I solve problems by first breaking them into smaller stepps.	Agree	7	16	0.438	0.804	1.000	0.198	0.701
	Neutral	5	16	0.313	0.210	1.122	0.110	0.587
	Strongly Agree	3	16	0.188	0.021	4.492	0.040	0.456
	Strongly disagree	1	16	0.063	< .001	93.747	0.002	0.302
I try things even I might fail.	Agree	5	16	0.313	0.210	1.122	0.110	0.587
	Disagree	2	16	0.125	0.004	16.065	0.016	0.383
	Neutral	6	16	0.375	0.454	1.000	0.152	0.646
	Strongly Agree	3	16	0.188	0.021	4.492	0.040	0.456

Table 3 presents frequencies and confidence intervals for academic behaviors related to learning, problem-solving, and self-concept. It demonstrates the following academic behaviors:

- believe in the ability to master what is taught at the university
- belief that activities at the university contribute to success in life
- understanding that intelligence is something that can be changed
- ability to find the best solutions to problems
- setting goals to maximize learning in class
- problem-solving by dividing problems into small steps
- willingness to try new things, even with the possibility of failure

The importance of proportions of agreement, neutrality, and strong agreement in the context of academic behavior provides insight into students' attitudes and approaches to learning and problem-solving. These ratios help identify patterns of academic behavior and can be used to evaluate the effectiveness of educational interventions or programs aimed at improving student attitudes and study habits. Over the past few years, many e-learning materials have been developed. Technology-enabled learning opportunities are widespread in the educational industry (Rohde et al., 2023), so future research should focus on identifying effective interventions to promote positive academic behavior, address the impact of technological advances on student engagement and learning behavior, and examine the role of teacher-student interpersonal relationships in shaping academic behavior

Conclusion and recommendation

The diversity of responses observed in the survey reflects the multifaceted nature of self-management, interpersonal skills, and academic behavior among students. This variability reflects the complex interplay between individual differences and educational experiences. The study highlights the crucial role of self-directed learning, autonomy support, and intrinsic motivation in enhancing student self-management capabilities. Educators are encouraged to develop strategies that promote independent learning and support independence, recognizing that students benefit from an environment that encourages independent thinking and self-regulation. In addition, fostering intrinsic motivation can increase student interest and self-motivation, ultimately contributing to academic achievement and personal growth.

However, the study also identifies several areas that require further investigation. For example, although surveys reveal the importance of self-management, there are gaps in understanding how different motivational factors and training methods affect self-management. Future research could examine how different educational strategies affect students' motivation and self-management skills in different contexts. Examining these aspects can provide a deeper understanding of how to adapt educational approaches to meet the diverse needs of students. By addressing existing gaps and exploring new dimensions, educators and researchers can collaboratively improve educational practices, ultimately leading to more effective and responsive learning environments.

Research limitations: The size of respondents is limited to 16 for this study as they were randomly responded. This means that it cannot be applied to the entire spectrum of the learning process. This study was completed within only one department of one university in Kazakhstan, and the findings may be influenced by individual characteristics and self-reports of the respondents. It is believed that self-reports might be inaccurate in responses.

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The use of diatomites in industrial production technologies

Abstract: General information on the distribution and reserves of diatomites in the world and Kazakhstan is presented, and their physical and chemical properties and applications are described. Diatomites have several valuable properties: high porosity, refractoriness, acid resistance, low thermal and acoustic conductivity, low bulk density and due to the large specific surface exhibit significant absorption capacity. It allows them to be used as fillers and heat-insulating materials in building technologies, filtering materials in the food industry, adsorbents in medicine, soil structuring agents, and carriers of insecticides in the agricultural sector. The technologies for obtaining several industrial products using Kazakhstani diatomites are described: as dry building mixtures, silicate bricks, foam glass, hydraulic binders, and iron oxide pigments.

Keywords: diatomites, industrial application, dry building mixtures, foam glass, iron oxide pigments.

Introduction

Distribution, reserves and industrial applications of diatomites in the world

World diatomite reserves are more than 1 billion tonnes, of which about 250 million tonnes are attributable to the United States and 110 million tonnes to China, as estimated by the US Department of the Interior (USGS) Geological Survey (Kuldeyev et al., 2020).

The volume of diatomite production worldwide is over 2.5 million tonnes per year. According to the USGS, the bulk of diatomite is produced in the USA (0.9 million tonnes - 36 % of global production), China (16 %), Denmark (12 %), Japan (6 %), Mexico (6 %) and France (3 %). The USA is the largest producer, consumer and exporter of diatomite. The CIS accounts for 4 % of the world's diatomite production (Ospanov et al., 2022).

The diatomite market in the USA is estimated at an average annual value of 180 million USD. The USA is the world's leading producer and consumer of diatomite. The main applications of diatomite in the USA are filtration - 67 %, use as cement additives - 15 %, adsorbent - 11 %, filler - 7 %, other areas, including the production of specialised pharmaceutical products - less than 1 % (Kuldeyev et al., 2020).

Diatomite is mainly used in filtration products to purify beer, spirits and wine, as well as fats and oils. It is also used in the production of absorbents, fillers, lightweight aggregates and other applications. Diatomite is used to remove microbial contaminants (e.g., bacteria, protozoa and viruses) in municipal water supply systems. Small amounts (less than 1 %) are used in specialised pharmaceutical and biomedical applications: in human blood plasma filtration, pharmaceutical processing and as a non-toxic insecticide

(Yurkov & Aksel'rod, 2005; Yıldız; 2008; Akhtar et al., 2009; Ediz et al., 2010; Flower, 2013; Ha et al., 2013; Matsunaga et al., 2017; Ahmadi et al., 2018; Nakashima et al., 2021, Kenzhaliyev et al., 2021).

The unit cost of diatomite in the US market varied widely in 2019, ranging from around $10 per tonne when used as a lightweight aggregate in Portland cement concrete to over $1,000 per tonne in specialised applications such as cosmetics, DNA extraction and others.

Diatomite is a finely dispersed sedimentary rock and is a type of siliceous (opal-cristobalite) raw material. Siliceous raw materials also include sedimentary rocks similar to diatomite in genesis and composition: opokas and trepels. Diatomite consists mainly of silica (80-90 %), aluminium and iron oxides. In diatomites, silica is represented mainly by the smallest shells of diatom algae (diatoms), the number of which in the rock can reach 10-20 million/cm^3. About 10 thousand different species of diatoms are known. Opokas have higher strength, and silica in them is represented by the smallest (less than 0.005 mm) globular and micrograined particles. Trepels resemble diatomites in appearance and opokas in microstructure.

Diatomite is a type of siliceous raw material with high porosity, poor thermal and acoustic conductivity, refractoriness and acid resistance. Diatomite is relatively inert and has high absorption capacity, large surface area and low bulk density. Due to their specific properties, diatomites are considered as multipurpose mineral raw materials and are used in various industries (see Figure 1 by Flower, 2013).

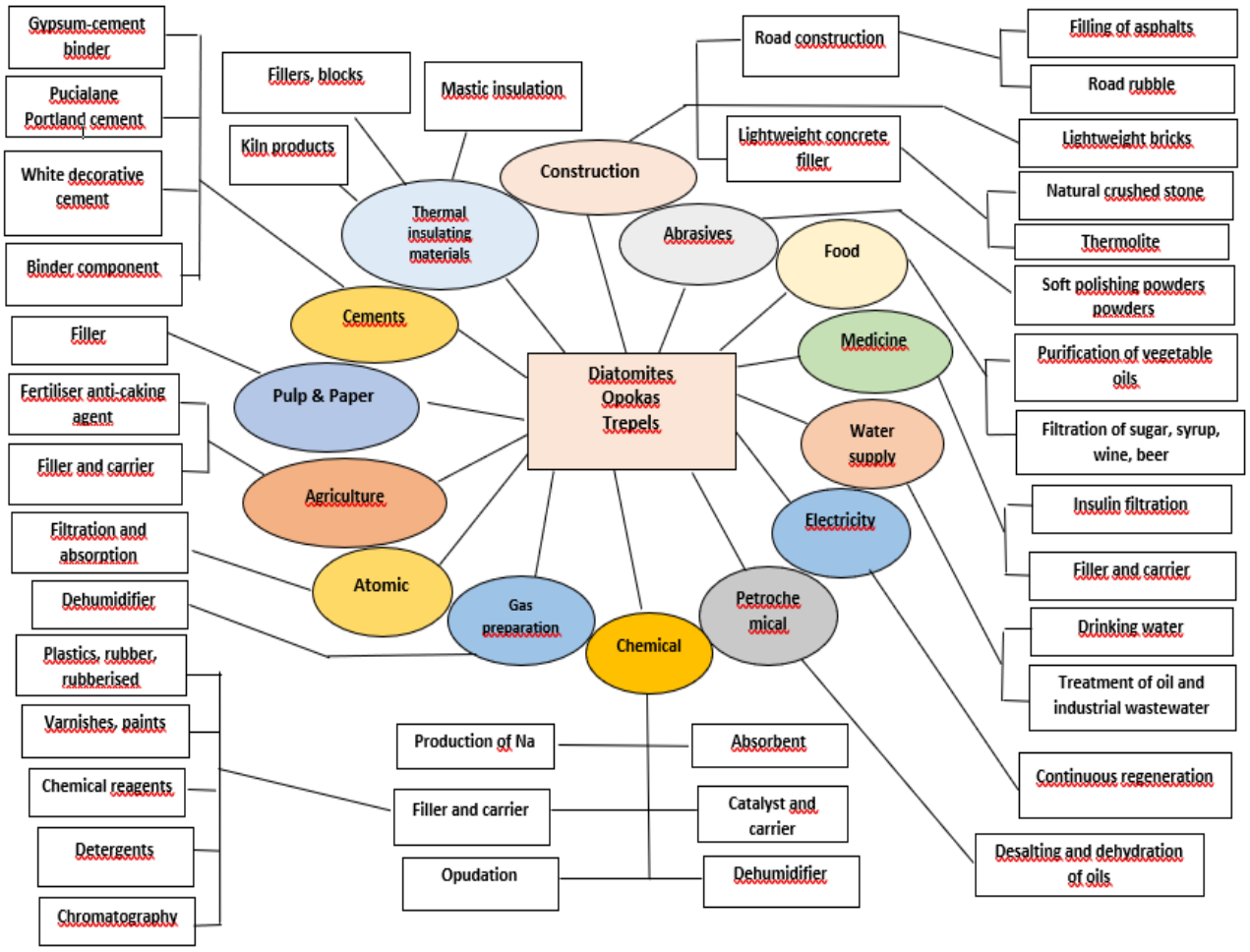

Figure 1. Applications of siliceous minerals (Flower, 2013)

Research Methods

The following methods of analysis were used to establish the composition of the initial raw materials and the obtained products: mineralogical, chemical, X-ray phase, X-ray fluorescence, electron scanning microscopy. Equipment: atomic emission spectrometer Optima 2000 DV; X-ray diffractometer D8 Advance

BRUKER, Cu α-radiation; X-ray fluorescence spectrometer Venus 200 PANalytical B.V.; electron probe microanalyser JXA-8230 (JEOL), Tamman furnace.

Research Results

Distribution, reserves and physical and chemical characteristics of diatomites from Kazakhstan

Kazakhstan has large reserves of diatomite raw materials (more than 200 million tonnes), which are concentrated in the Aktobe region and are currently involved in industrial processing on a small scale (https://avestnik.kz/diatomit-universalnyiy-i-unikalnyiy/). The main physical, chemical and mechanical characteristics of natural diatomites of the Zhalpak deposit have been studied. Samples of diatomite raw materials are characterized by a significant variation in chemical composition. SiO_2 content varies from 73.11 % in white varieties of raw materials to 25.87 % in yellow (ochre-like) ones. The Fe_2O_3 content varies from 2.36 % to 30.42 %. Sodium, potassium, magnesium, calcium, barium and aluminium silicates are also present in insignificant amounts (Figure 2).

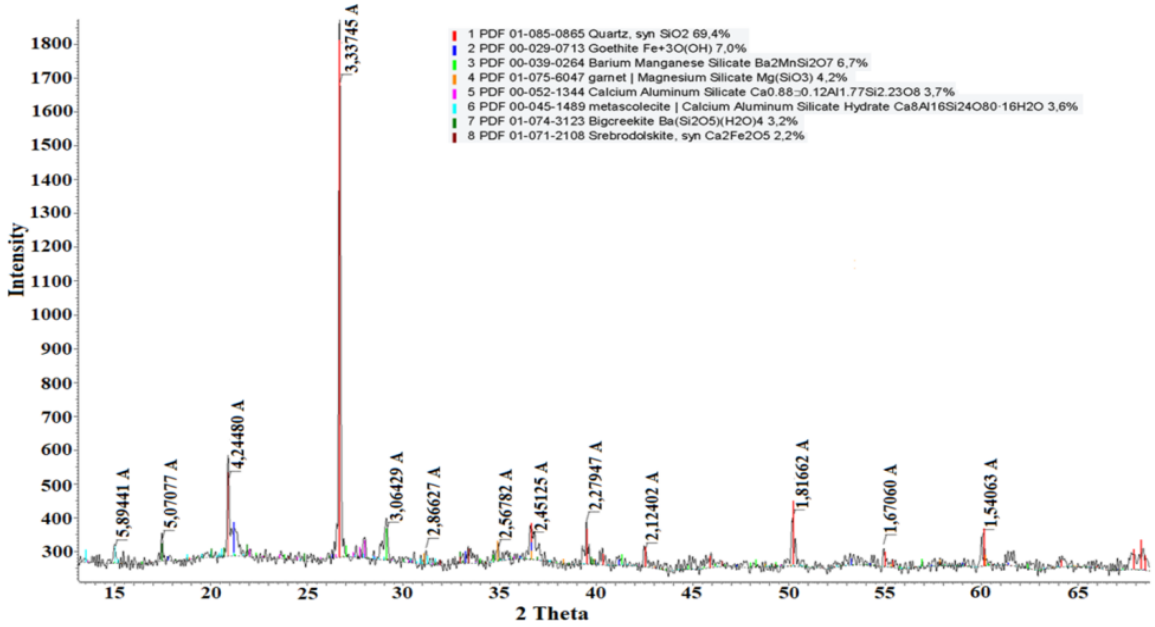

Figure 2. Diffractogram of a diatomite sample

To activate diatomite, we performed mechanical grinding and thermal activation of ferruginous varieties of diatomite in a laboratory furnace with subsequent grinding. The results of electron microscopy showed that during such thermal activation, diatomite particles acquire a spherical shape with a size of 5-10 nm (Figure 3). Thermal treatment of ferruginous forms of diatomite allowed to achieve a compressive strength of 25.2 MPa, and water absorption was 4.3 %.

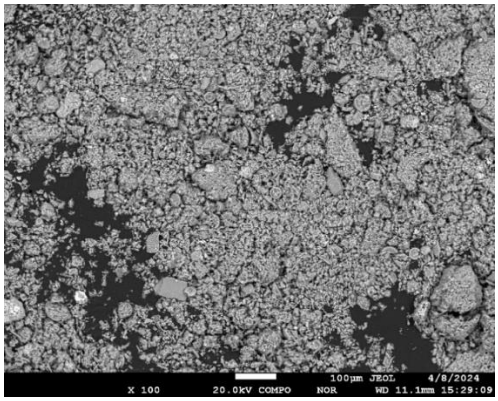

Figure 3. SEM image of a diatomite sample

Application of diatomite raw materials in the production of construction materials

The possibility of using activated diatomite in technologies for obtaining building products has been investigated. It is shown that the use of diatomite as a silicate component allows to achieve the grade of building products M 70, even without the use of autoclave conditions. The use of plasticiser and thermally activated diatomite in mixtures allows to significantly reduce water absorption of cubes. Semi-dry pressing followed by autoclave steam treatment of cubes sharply increases the compressive strength and grade of products and reduces their water absorption and specific gravity. There is a sharp increase in the strength of cubes when using thermally activated high-iron diatomite (20-30 % Fe O_{23}), which is associated with the partial formation of hydrated forms of ferrocalcites (Figure 4).

Figure 4. Samples of construction materials obtained using diatomite

Manufactured samples of cubes using thermally activated diatomite meet the indicators of GOST 379-95, required for silicate stones and bricks (GOST 379-95, 2004). The average density in the dry state is 1482 kg/m^3. The strength of adhesion with the base is 0.42 MPa. It is shown that compositions of dry building mixtures from cement, lime, ferruginous diatomite and gypsum demonstrate high plasticity when applying a layer of plaster, its rapid setting and strength when holding on a vertical surface.

The results have been obtained, indicating that the use of natural diatomite as a component for the production of expanded glass pellets from alkali-silica pellets significantly simplifies the technology of alumina production in the processing of ash from the combustion of Ekibastuz thermal coal. Marketable foam-steel pellets with a specific weight of less than 1 g/cm^3, which can be used as heat-insulating material in construction, were obtained. The studies carried out with the use of scanning electron microscopy testify to the uniform cellular structure of the obtained foamed glass.

Based on ferruginous varieties of diatomite, it is possible to obtain two-component iron oxide paint pigments of micro-dispersed spherical form, which can find application in construction.

To determine the possibility of obtaining highly dispersed particles of iron oxide pigments of spherical shape from ferruginous varieties of diatomites of the Zhalpak deposit, the material composition and thermal and mechanical treatment of samples of diatomite raw materials were studied to obtain a product suitable for use as a pigment, as well as the composition and properties of the obtained pigments.

X-ray phase analysis of samples of ferruginous diatomite obtained after their preliminary thermal and mechanical treatment was carried out. It is established that iron is in the form of jarosite in the initial sample, in the sample after hydrothermal treatment and calcination of jarosite. in the form of hematite. The phase composition of iron-containing components of pigment samples was determined.

Technological solutions for the utilisation of the mineral part of refined ferrochrome slag with obtaining construction products on its basis have been found. Application as reducing agents of aluminium powder in the amount of 2 g per 1 g of water-soluble chromium and 4 g $FeSO_4 \cdot 4H_2O$ per 1 g of water-soluble chromium allows to reduce the content of water-soluble chromium at soaking of cubes up to MAC values (Figure 5).

The dough mass when filling the cube moulds has high plasticity and allows taking a cast with the smallest fragments, which can be used in the manufacture of artistic products of complex shapes.

The technology of RFC slag utilisation allows to obtain not only metal concentrate, but based on the mineral part - various construction products: finishing sheets similar to SML (silico-magnesium sheets) and SCL (silico-calcium sheets), art castings, material for filling excavations in mines and quarries.

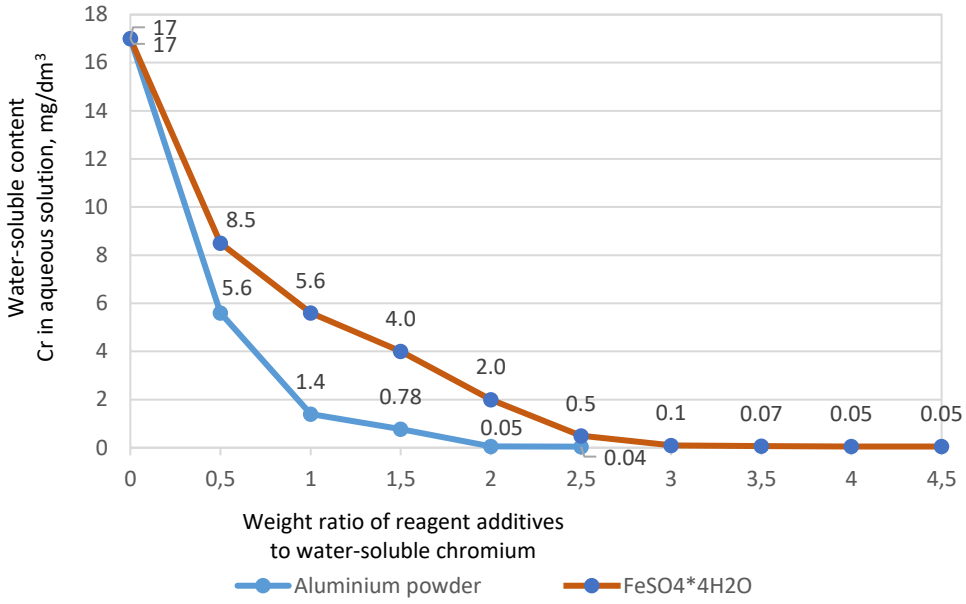

Figure 5. Effect of reagent additives on reduction of water-soluble chromium content

Tests on obtaining porous building rubble from the mineral part of RFC slags and natural diatomite were carried out, which showed that the most optimal conditions are the weight ratio in the mixture mineral part of slag/diatomite 2:1, which allows to synthesise strong light ferrosilicon-fluxing glass with good crushing strength, comparable to the strength of expanded clay. The optimum firing temperature is 1150 °C, which allows for obtaining light glass-like pellets with the lowest specific mass and the highest crushing strength.

The results of tests on obtaining magnesia building products (cubes, tiles) showed the possibility of utilisation of the mineral part of RFC slag (refined ferrochrome) after extraction of metal concentrate from RFC slag with obtaining building finishing tiles based on compounds similar to Sorel types of cement. The best characteristics of crushing strength (12.5 MPa) and water absorption (6.2 %) are obtained from the paste having in its composition: weight ratio of slag: $MgSO_4 \cdot H_2O$ - 4.38:1; addition of diatomite, % - 20.0; addition of liquid glass - 1.0; addition of carbomethylcellulose (M70) - 1.0.

Use of diatomites as a component of ferrosilicate-calcium binder in metallurgy

Based on chrome concentrate, mineral part of RFC, ferruginous diatomites and special coke at temperatures of 1050-1200 °C complex pellets with increased strength (up to 5325 N/pellet), not absorbing moisture and not losing mechanical strength when wet, which is associated with the formation of cementitious glass phase were obtained. It is not necessary to grind the components included in the pellet formulation to 0.07 mm, 0.25-0.1 mm is enough, as high strength is achieved by the formation of fluxing ferrosilicate-calcium glass phase.

The new technology of production of complex chrome pellets allows to effective utilize the mineral part of RFC slag with transformation of toxic hexavalent chromium into harmless glass mass; to carry out pre-reduction processes directly in the roasting process by obtaining partially metallized pellets; to solve the problems of dispersibility of initial materials; to utilize substandard pellet fragments (-0.3 cm) with production of additional conditioned products. The highest strength of pellets was achieved with ferruginous diatomite, which can be explained by the ultrafine dispersed form of iron oxide in diatomite and the high rate of formation of ferrosilico-calcium glass phase at relatively low firing temperatures.

The formation of ferrosilico-calcium glass phase, providing strength and lowering the melting temperature of chrome pellets during firing and melting in electric arc furnaces is caused by the formation of such compounds as magnesium hedenbergite and chloritoid-A.

Conclusion

Methods of obtaining various construction products based on diatomites have been developed: silicate bricks, dry building mixtures, iron oxide pigments, foam glass; binders for hardening chrome pellets; carriers of mineral fertilizers; reagents for treatment of wastewater from hydrogen sulphide. New data on

application of ferruginous variety of diatomites as the main component of dry building mixtures and highly dispersed particles of iron oxide pigments of spherical shape are received. The use of diatomites in the synthesis of silico-calcium-iron-magnesium compositions - effective binders in the production of hardened pellets based on finely dispersed chrome raw materials is proposed.

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Wastewater treatment from hydrogen sulphide using iron-containing coagulant

Abstract: The increase of sulphate content in natural water sources due to anthropogenic causes leads to a corresponding increase of sulphate and sulphide concentrations in wastewater. Biochemical reactions occurring in sewage systems of sulphate reduction to sulphides and their subsequent oxidation to sulphuric acid cause microbially induced acid corrosion of concrete pipes. In addition, biochemical processes occurring in wastewater are accompanied by the release of toxic gases, including hydrogen sulphide, which adversely affect the human body. The methods based on the binding of hydrogen sulphide into insoluble metal sulphide are recognised as promising for the treatment of sulphide-containing waters. For the realisation of the process, it is offered to use iron compounds as the least toxic and relatively cheap reagents. The complex coagulant based on ferric diatomite, sodium ferrite and iron compounds for the treatment of wastewater from hydrogen sulphide is developed. Test tests of iron-containing coagulant have been carried out: at a flow rate of sewage 2.73 m^3/hour, optimal dose of reagent 90 mg/l the concentration of hydrogen sulphide in treated water is 1.07 mg/l, which is close to the maximum permissible concentration (MPC) values for sewage - 1 mg/l.

Keywords: wastewater, diatomites, industrial applications, dry mixes, foam glass, iron oxide pigments

Introduction

At present, there is a tendency to increase the sulphate content in natural water sources, which leads to a corresponding increase in the concentration of sulphates and sulphides in wastewater. Hydrogen sulphide-induced corrosion of concrete sewer pipes is a serious problem for water utilities worldwide (Zhang et al., 2008; Hvitved-Jacobsen et al., 2013; Pikaar et al., 2014; Aminuddin et al., 2024).

The content of hydrogen sulphide and sulphides in waters due to their toxicity is standardised: the MPC of hydrogen sulphide for water bodies of household and drinking and domestic water use is 0.05 mg/dm^3, for wastewater sent for biological treatment - 1 mg/l, for the air of settlements, is 0.008 mg/m^3.

There are various methods of neutralisation of hydrogen sulphide dissolved in sewage: physical-chemical, chemical and biological. In several works for removal of hydrogen sulphide natural diatomite and iron compounds were used (Simon et al., 2002; Majeda et al., 2004; Wu et al., 2005; Sun et al., 2013; Myrzalieva et al., 2021; Ospanov et al., 2022).

Physico-chemical methods based on separation from the water of molecular hydrogen sulphide in a gas phase under appropriate conditions, for example, by the creation of the big surface of the interface (film degassing), increase of temperature of water (thermal deaeration), lowering of pressure to a level at which water boils without additional heating (vacuum degassing).

In waters with pH>8.5 hydrogen sulphide is mainly in the form of sulphide and hydrosulphide and for its transfer in molecular form for the subsequent degassing it is necessary to acidify water to pH 5 and below. A negative side effect is the release of hydrogen sulphide into the atmosphere.

Chemical (reagent) methods of hydrogen sulphide extraction with its subsequent utilisation in the form of sulphur-containing precipitates are based on oxidation of sulphides to elemental sulphur by oxidising reagents (oxygen, ozone, hydrogen peroxide, chlorine, chlorine dioxide, sodium hypochlorite, chlorine lime, iodine, manganese dioxide, potassium permanganate). To extract sulphur from water, sedimentation, filtration, and flotation are used. The reagents used require high specific consumption, many of them require special safety measures during their storage and use. The main disadvantages of using oxidising reagents are associated with secondary contamination of aqueous solutions with manganese compounds, chlorides and peroxides, which harm the environment. Methods of chemical precipitation of hydrogen sulphide are based on its property to form water-insoluble sulphides with the majority of metals. In practice the method is realised by treatment of water with iron-containing coagulants, as a result of interaction with which iron sulphide insoluble in water is formed, accumulated in special settling tanks. It is concluded that methods based on the use of iron-containing reagents are one of the promising ones for the removal of hydrogen sulphide from wastewater.

Removal of sulphides from oil refinery wastewater by chemical precipitation has been investigated (Ren et al., 2021; Kenzhaliyev et al., 2021; Myrzalieva et al., 2022). Wastewater samples were taken from the treatment facilities of an oil refinery. Physicochemical treatment of industrial wastewater was carried out using conventional coagulants $FeCl_3 \cdot 6H_2O$ and $FeSO_4 \cdot 7H_2O$ and alkaline reagents $Ca(OH)_2$ and $CaCO_3$, which were applied to both untreated wastewater and model wastewater, with the addition of sulphides. Sulphide removal efficiency (96-99 %) was achieved when Fe^{2+} ions were used together with $Ca(OH)_2$ as an auxiliary precipitant.

Studies on the removal of S^{2-} ion from sodium aluminate solutions by sodium ferrite have been carried out (Li et al., 2016). The synthesis of sodium ferrite and its behaviour in sodium aluminate solutions containing S^{2-} have been described. The desulphurisation rate can reach about 70 % within 60 min. at a molar ratio of iron to sulphur of 1:1 to 1.5:1. The efficiency of the process depends on the activity of $Fe(OH)_3$ formed during the hydrolysis of sodium ferrite.

The synthesis of a reagent containing alkali metal ferrates and alkali is described in (Orekhova A.I. et al., 2014). The main components of the reagent are potassium ferrate K_2FeO_4 (25.2-40.3 wt.%) and alkali KOH (47.2-68.1 wt.%). It was found that the high oxidising ability of the reagent is related to the presence of ferrate, and high adsorbing ability - to the formation of a highly dispersed precipitate of iron (III) hydroxide.

Composite inorganic coagulants are mixtures of inorganic aluminium- and iron-containing coagulants. Composite reagents are produced by mixing individual components, processing of mixed raw materials or production waste. The use of the latter allows to additionally solve environmental problems related to waste utilisation.

Thus, iron compounds are estimated as one of the most effective for neutralisation of hydrogen sulphide in wastewater. Speed and completeness of process of interaction of dissolved hydrogen sulphide with iron compounds to a great extent is determined by a form of finding of iron hydroxides in water solutions. As effective desulphators can be considered composite iron-containing reagents.

Research Methods

The following methods of analysis were used to determine the composition of the initial raw materials and the obtained products: mineralogical, chemical, colorimetric X-ray phase, and X-ray fluorescence. Equipment: atomic emission spectrometer Optima 2000 DV; X-ray diffractometer D8 Advance BRUKER, Cu α-radiation; X-ray fluorescence spectrometer Venus 200 PANalytical B.V.

Analyses were carried out according to the method of measuring concentrations of hydrogen sulphide in wastewater by photometric method. The method is based on the interaction of hydrogen sulphide and sulphides with products of oxidation of N, N-dimethyl-p-p-phenylenediamine with iron (III) salt with formation of methylene blue, extraction of the obtained dye with chloroform in the presence of sodium dodecyl sulfate and measurement of optical density of the coloured solution at a wavelength of 656 nm.

Research Results

The experimental setup was mounted at the canal after the grate up to the sand trap. The scheme of the installation is presented in Figure 1. The capacity of the installation was 2.73 m^3/hour.

The unit worked in the following mode: Wastewater after the grid from the canal with the help of pump (1) goes to the tank (2) with a constant head. A 227-litre iron barrel was used as a tank. The reagent flow rate is regulated using a gate valve. Then the wastewater is directed to the mixer (3), where the solution of complex iron-containing reagent and air are supplied. The sketch drawing of the mixing tank is given in Appendix A. Preparation of the solution of complex iron-containing reagent takes place in the solution tank (4), where the necessary amount of dissolved reagent is loaded. Air is supplied to the mixer by compressor (5). In the mixer, the wastewater is mixed with the reagent, and then enters the flaking chamber (6), where coagulation takes place under the influence of the reagents added to the wastewater. A sketch drawing of the flaking chamber is given in Appendix A. After the flaking chamber, the water enters the settling tank (7), where the wastewater is stabilised and the flake sludge settles to the bottom, while the treated water flows into the canal.

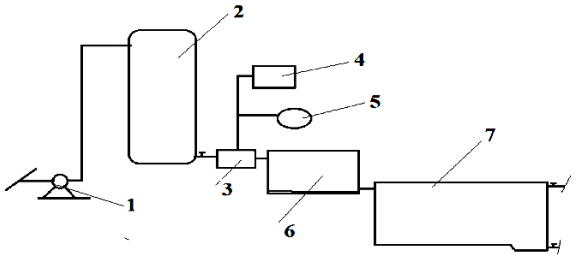

Figure 1. Schematic diagram of the experimental setup

There were 15 experiments of 1-2 days duration on 3 modes of operation of the experimental unit.

Mode 1: Wastewater flow rate 2.73 m^3/hour, dose of complex iron-containing reagent 40 mg/l.

Mode 2: Wastewater flow rate 2.73 m^3/hour, dose of complex iron-containing reagent 90 mg/l.

Mode 3: Wastewater flow rate 2.73 m^3/hour, dose of complex iron reagent 120 mg/l.

Preparation of the solution of complex iron-containing reagent took place in the solution tank, where the necessary amount of reagent and clean tap water was loaded.

The experimental unit was operated in flowing mode, wastewater flow rate was measured by volumetric method. The residence time of wastewater in the mixer was 2 min, in the flaking chamber - 30 min., in the settling tank - 60 min. Samples for analysis were taken after the tank as source water and after the settling tank as treated water. Sampling was done manually according to general rules.

Water chemistry analyses were performed for the following parameters: suspended solids, phosphate, iron, hydrogen sulphide, sulphate and pH. Each series corresponded to different technological regimes; the dose volume of complex iron-containing reagents was changed.

The results of wastewater analysis after coagulant application for the following parameters: suspended solids, phosphates, iron, hydrogen sulphide, sulfates and pH depending on the dose of complex iron-containing reagent are shown in Table 1, Figures 2 - 4.

Table 1. Summarised results of the test trials

Name of indicators	pH	Hydrogen sulphide	Suspended solids	Phosphates	Iron	Sulphates
1 mode: Wastewater flow rate 2.73 m^3 /hour, dose of complex iron-containing reagent 40 mg/l.	7.5 7.4	3.52 2.65 E = 24.6 %	439.0 309.0 E = 29.6%	10.2 6.3 E = 38.2%	2.53 3.83	52.0 67.5
2 mode: Wastewater flow rate 2.73 m^3 /hour dose of complex iron-containing reagent 90 mg/l.	7.7 7.6	3.52 1.07 E = 69.6 %	302.0 192.0 E = 36.4%	4.3 0.2 E=95.3%	2.95 4.16	79.2 94.2
3 mode: Wastewater flow rate 2.73 m^3 /hour, dose of complex iron-containing reagent 120 mg/l.	7.6 7.5	3.52 1.59 E = 54.8 %	289.6 175.0 E = 39.6%	3.4 0.2 E = 94.1%	2.07 5.94	106.6 261.9

Note: in the numerator source water, in the denominator treated water; E - efficiency of wastewater treatment from chemical compounds and suspended solids.

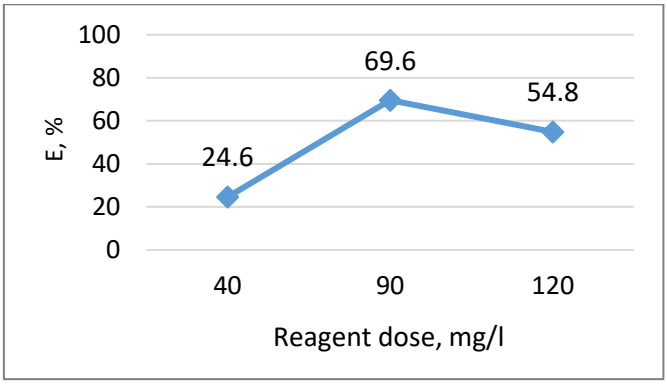

Figure 2. Reduction of hydrogen sulphide content in wastewater depending on the dose of iron-containing reagent

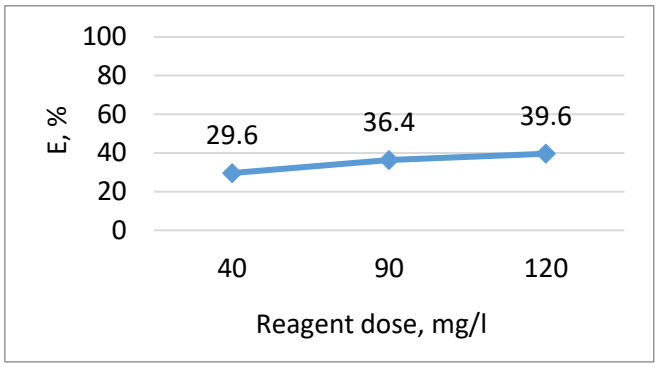

Figure 3. Reduction of suspended solids in wastewater depending on the dose of iron reagent on the dose of iron-containing reagent

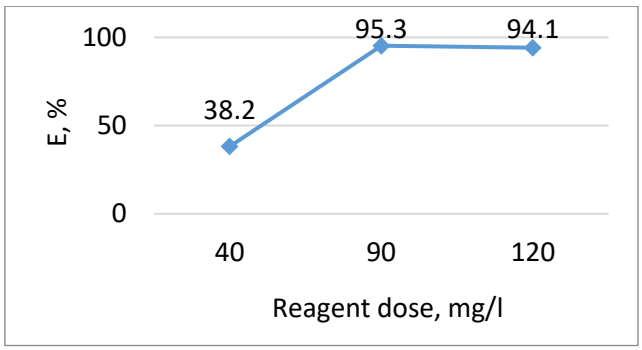

Figure 4. Reduction of phosphate content in wastewater depending on the dose of iron reagent on the dose of iron-containing reagen**t**

Thus, by the results of test tests of complex iron-containing reagent, it is concluded that for treatment of wastewater from hydrogen sulphide it is expedient to use complex iron-containing reagent. The best indicators of clearing from hydrogen sulphide are reached on experimental installation at a flow rate of wastewater 2.73 m^3/hour, optimum dose of complex iron-containing reagent 90 mg/l - average value of concentration of hydrogen sulphide in initial water made 3.52 mg/l, in treated water – 1.07 mg/l. Reduction of hydrogen sulphide concentration made 69.6 %.

The best performance of phosphate purification was achieved at the experimental unit at the wastewater flow rate of 2.73 m^3/hour, the optimal dose of complex iron-containing reagent 90 mg/l - the average value of phosphate concentration in the source water was 4.3 mg/l. and in treated water - 0.2 mg/l. The reduction of phosphate concentration was 95.3 %.

Conclusion

The method of obtaining complex coagulants is proposed. As initial components sodium ferrite-aluminate, natural ferruginous diatomite and technical iron sulfate are used. Sodium ferrite-aluminate is produced based on waste alumina production of ferruginous sands by sintering with soda ash at 1000-1100 ^oC. The ratio of initial components is determined experimentally depending on the composition of the wastewater. Technological parameters of the application of complex coagulants in the process of wastewater treatment from hydrogen sulphide are developed. Experiments with 3 modes of operation of the experimental unit have been carried out. The residence time of wastewater in the mixer was 2 min, in the flaking chamber 30 min, and in the settling tank 60 min. Experimentally it is established that the optimum consumption of complex iron-containing reagents at removal of hydrogen sulphide and phosphates is 90 mg/l. The method of reception of complex iron-containing reagents for the treatment of wastewater from hydrogen sulphide is economical due to the use of accessible raw sources.

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On the possibility of processing technogenic flotation raw materials of Kazakhstani deposits with the use of a modified collector

Abstract: The purpose of work - flotation processing of copper-lead-zinc tailings using a modified collector - a mixture of modified butyl xanthate and aeroflot in combination with N-allyl-o-isobutylthionocarbamate. According to the results of X-ray fluorescence analysis in the initial sample of flotation enrichment tailings, the content of lead was 0.048%, copper - 0.03%, zinc - 1.501%, iron - 2.863%. The main part of tailings is represented by rock-forming minerals: quartz, calcite, talc, chrysotile, albite, clinochlore, muscovite, dolomite, and pyrite. The optimal basic reagent scheme of tailings flotation was selected: degree of regrind 78% of -0.040 mm class, sodium butyl xanthate consumption 150 g/t, T-92 frother consumption 80 g/t. Under the selected regime, a collective copper-lead-zinc concentrate was obtained containing 2.0% copper at 67.11% recovery; 1.6% lead at 62.02% recovery; 3.2% zinc at 62.02% recovery; 7.0% iron at 41.67% recovery; 4.1 g/t gold at 54.45% recovery. The reagent scheme of flotation of copper-lead-zinc tailings with the application of a modified collector was tested. Its application allows for increased recovery in the collective copper-lead-zinc concentrate: copper - by 9.63%, lead - by 8.41%, zinc - by 9.2%, iron - by 2.73%, gold - by 3.57%. At the same time the consumption of modified collector, compared to butyl xanthate, is reduced by 33%, and the consumption of basic foaming agent T-92 is reduced by 25%.

Keywords: anthropogenic waste, flotation, modified collector, concentrate.

Introduction

Search and development of new more selective reagent-assemblers to improve the flotation process is one of the priority tasks in the creation of innovative technologies for the flotation separation of substances and minerals. Involvement in the processing of large volumes of hard-to-enrich raw materials requires the use of new technological methods and reagent regimes (Wang et al., 2022; Hornn et al., 2021; Wang & Liu, 2021). Uneven dissemination, fine intergrowth of ore minerals among themselves and with rock minerals, unfavorable ratio of separated minerals considerably complicate obtaining high technological parameters of enrichment (Ignatkina & Bocharov, 2010; Kenzhaliyev, 2019; Semushkina & Narbekova, 2021). The analysis of existing enrichment schemes shows that a significant part of metals in tailings (raw materials of complex composition with low metal content) cannot be effectively extracted using the methods used for primary raw materials. In general, ore dressing tailings are represented by finely groundmass, with the lack of a clear structure, heterogeneity of material composition, mutual

sprouting of minerals, variability of physical and chemical properties of mineral surfaces under the influence of oxidation, corrosion, leaching and some other processes (Semushkina et al., 2023). The creation of general principles for selecting compositions of collectors for selective flotation of separated minerals, and the development of reagent regimes based on the use of a combination of collectors of different ionogenicity remains an urgent task (Ryaboy, 2011; Bocharov et al., 2010; Semushkina et al., 2021). The following combinations of sulfhydryl collectors are known: collectors with the same solidophilic group, but with different lengths of the hydrocarbon radical (ethyl and butyl xanthates, etc.); collectors with different solidophilic groups (xanthates and dithiophosphates, dithiophosphates and mercaptobenzothiozoles, etc.); ionic and nonionic collectors (xanthates and dixanthogenides; xanthates and thionocarbamates; dithiophosphates and dialkyl sulfides, etc.) (Ignatkina et al., 2022; Ignatkina et al., 2010; Ignatkina, 2011).

Studies have shown that a selectively acting combination of ionogenic sulfhydryl scavengers should consist of 35% of weak and 65 % of strong scavengers. In practice, the most commonly used combination of weak and strong ionogenic sulfhydryl scavengers is a 1:1 mass ratio. As non-ionogenic components disulfides, thionocarbamates, esters of xanthogenic acids, thioamides, dialkyl sulfides, etc. are used. (Zharolla et al., 2020). There are different points of view on the mechanism of action of the combination of weak and strong collectors, but most agree that the effect of action is associated with the formation of adsorption layer on the surface of the separated minerals. Abramov A.A. formulated the principle of the optimal ratio of chemical and physical forms of sorption of collectors on minerals for successful flotation (Ignatkina, 2016; Turysbekov et al., 2022). Current wastes of enrichment plants and previously formed technogenic mineral formations are promising georesources, which can be effectively developed at the current level of engineering and technology development (Bulaev & Melamud, 2015; Kondratyev et al., 2014).

Hundreds of millions of tons of flotation tailings, which contain significant amounts of non-ferrous and noble metals, are accumulated in the tailings ponds of Kazakhstan enrichment plants processing various ores. In the conditions of significant depletion of balance reserves of ores of Kazakhstan deposits and reduction of their quality, enrichment wastes can be considered as an additional source of metals, despite their lower content of valuable components compared to ore.

Research methods

The following scientific and analytical equipment was used to perform the research: X-ray diffractometer D8 ADVANCE, X-ray fluorescence spectrometer Venus 200 PANalyical B.V., atomic emission spectrometer Optima 2000 DV, electron scanning microscope JEOL JXA-8230, FT-IR spectrometer "Avatar 370". Also, in the process of work technological equipment was used: ball mill 40ML-000PS; flotation machine FML; photometric sedimentometer FSh-6K; disperser T18 ULTRA-TURRAX; eraser for samples MM-1. The objects of research were copper-lead-zinc tailings of Kazakhstani deposit and modified collector. A mixture of modified butyl xanthate and aeroflot in combination with N-allyl-o-isobutyl thionocarbamate was used as a modified collector for efficient processing of flotation dressing tailings. Modified butyl xanthate and aeroflot were obtained based on Kazakhstani raw materials - modified syrup oil, a waste product of alcohol production.

Results and discussion

The research on studying the mineral and granulometric composition of flotation enrichment tailings and development of technological modes of flotation of flotation enrichment tailings with the use of basic flotation agents was carried out.

According to the results of mineralogical analysis, the main mass in the sample of flotation enrichment tailings is: quartz α-SiO_2, calcite $CaCO_3$, talc $Mg_3Si_4O_{10}(OH)_4$, chrysotile $Mg_6Si_4O_{10}(OH)_8$, albite $NaAlSi_3O_8$, muscovite $KAl_2Si_3AlO_{10}(OH)_2$, pyrite FeS_2.

Chemical, spectral, X-ray fluorescence and X-ray phase analyses were done. X-ray phase analysis was performed on a D8 Advance diffractometer (BRUKER), α-Cu emission. The results of X-ray phase analysis are presented in Table 1.

Atomic emission qualitative spectral analysis was carried out, which showed that flotation enrichment tailings contain: Si – very much; Fe - very much; Mg - very much; Ca – much; Al – much; Na – intensive lines; Mn - intensive lines; Ti - intensive lines; Cr - ≥ 0.03 %; Ni - ≥ 0.003 %; Bi - ≤ 0.001 %; Cu - ≤ 0.05 %; Pb - ~ 0.05 %; Zn - > 1.0 %; As – не обнаружен; V - ≥ 0.01 %; La - ~ 0.001 %; Sb - undetected; Ga - ~ 0.001 %; Ag - ~ 0.003 %.

Table 1. Results of X-ray phase analysis of flotation enrichment tailings

Compound Name	Formula	Distribution, %
Quartz, syn	SiO_2	63.2
Albite (heat-treated)	$Na(AlSi_3O_8)$	14.0
Clinochlore	$(MgFe)5Al(Si_3Al)O_{10}(OH)_8$	7.2
Pyrite	FeS_2	3.5
Sphalerite, syn	ZnS	2.9
Muscovite	$KAl_2(AlSi_3)O_{10}(OH)_2$	2.6
Dolomit	$Ca\ Mg(CO_3)_2$	2.4
Magnesium Carbonate	$Mg(CO_3)$	2.4
Calcium Carbonate	$CaCO_3$	1.8
Sodium Silicat Hydrate	$Na_2SiO_3 \cdot 5H_2O$	3.8

The spectrum of the initial tails (Figure 1) was obtained on a FTIR spectrometer "Avatar 370", in the spectral range of 4000-250 cm^{-1} from the preparation as a suspension on vaseline oil in KRS-5 windows. The spectrum of vaseline oil was taken as a comparison spectrum. Experiment attachment: Transmission E.S.P. Composition of flotation enrichment tailings - main content:

Quartz α-SiO_2 – 1166, 1085, 797, 779, 694, 512, 464, 396, 372 cm^{-1}.

Calcite $CaCO_3$ – 1792, 1419, 882п, 713 cm^{-1}.

Sphalerite ZnS – 292 cm^{-1}.

Muscovite $KAl_2[(OH,F)_2 | AlSi_3O_{10}]$ – 1034 cm^{-1}.

Mineral type Rhipidolith (Prochlorit) – $(Mg, Fe, Al)_3\ [(OH)_2 | Al_{1,2\ -\ 1,5}\ Si_{\ 2,8\ -\ 2,5}O_{10}]\ Mg_{\ 3}\ (OH)_6$ - 3566, 3426, 983п, 649п, 464 cm^{-1}.

Possibly present:

Pyrite FeS_2 – 350р cm^{-1}.

Albit $Na[AlSi_3O_8]$ – 1166, 1034, 1005, 983п, 649, 609, 464 cm^{-1}.

Anorthite $Ca[Al_2Si_2O_8]$ – 1166, 1085, 669 cm^{-1}.

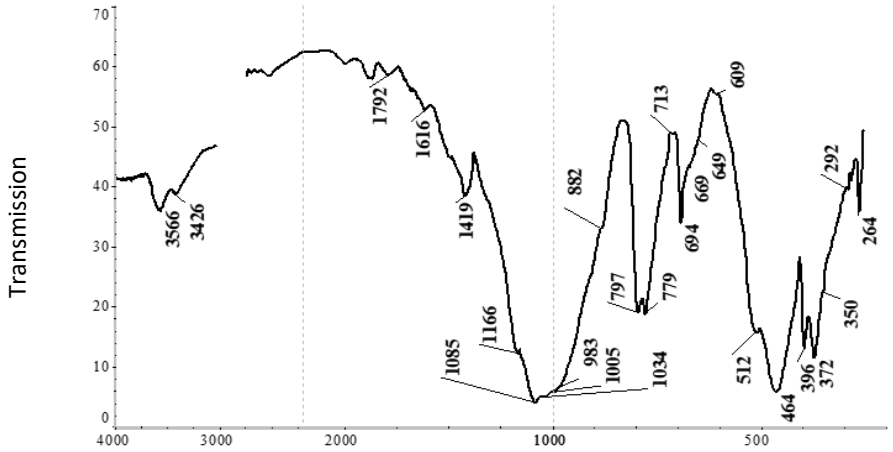


Fig. 1. Infrared spectrum of flotation enrichment tailings

X-ray fluorescence analysis of tailings was performed on a Venus 200 PANalyalytical B.V. (PANalytycal B.V., Holland) X-ray fluorescence spectrometer with wave dispersion. The results of the analysis are presented in Table 2.

Table 2. Results of X-ray fluorescence analysis of flotation enrichment tailings

Analyte	Calibration status	Compound formula	Concentration	Unit	Calculation method	Status
O	Calibrated	O	51.548	%	Calculate	BgC; DC
Na	Calibrated	Na	0.163	%	Calculate	BgC; DC; LoR
Mg	Calibrated	Mg	3.343	%	Calculate	BgC; DC
Al	Calibrated	Al	4.104	%	Calculate	BgC; DC
Si	Calibrated	Si	26.859	%	Calculate	BgC; DC
P	Calibrated	P	0.035	%	Calculate	BgC; DC
S	Calibrated	S	1.192	%	Calculate	BgC; DC
Cl	Calibrated	Cl	0.008	%	Calculate	BgC; DC
K	Calibrated	K	0.958	%	Calculate	BgC; DC
Ca	Calibrated	Ca	1.933	%	Calculate	BgC; DC
Ti	Calibrated	Ti	0.170	%	Calculate	BgC; DC
V	Calibrated	V	0.010	%	Calculate	BgC; DC; LoR
Cr	Calibrated	Cr	0.027	%	Calculate	BgC; DC
Mn	Calibrated	Mn	0.122	%	Calculate	BgC; DC
Fe	Calibrated	Fe	2.863	%	Calculate	BgC; DC; LoR
Ni	Calibrated	Ni	0.010	%	Calculate	BgC; DC
Cu	Calibrated	Cu	0.030	%	Calculate	BgC; DC
Zn	Calibrated	Zn	1.501	%	Calculate	BgC; DC
Rb	Calibrated	Rb	0.004	%	Calculate	BgC; DC
Sr	Calibrated	Sr	0.007	%	Calculate	BgC; DC
Zr	Calibrated	Zr	0.005	%	Calculate	BgC; DC
Ba	Calibrated	Ba	0.194	%	Calculate	BgC; DC
Pb	Calibrated	Pb	0.048	%	Calculate	BgC; DC

According to the results of X-ray fluorescence analysis in the initial sample of tailings of flotation enrichment, the content of lead was 0.048 %, copper - 0.03 %, zinc - 1.501 %, iron - 2.863 %. Chemical analysis showed that the sample of the studied tailings contained 0.05 % copper; 0.06 % lead; 1.1 % zinc; 52.3 % SiO_2; 2.3 % total iron; 8.1 % Al_2O_3; 2.5 % CaO; 8.7 % MgO.

Samples of investigated tailings were analyzed on electron-probe microanalyzer JXA-8230 of JEOL company. The results of the microanalysis are shown in Figures 2-5.

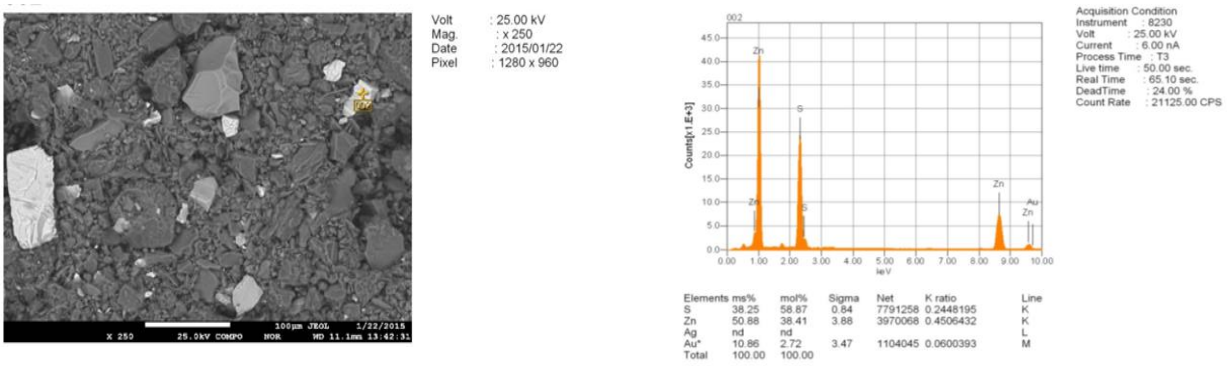
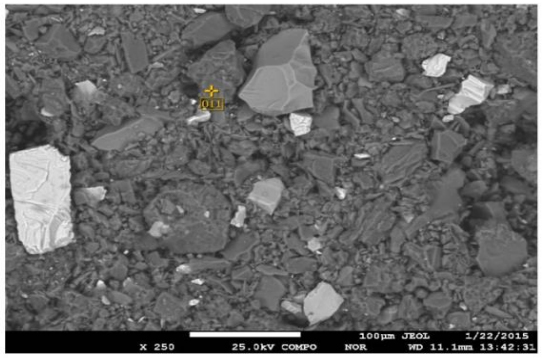
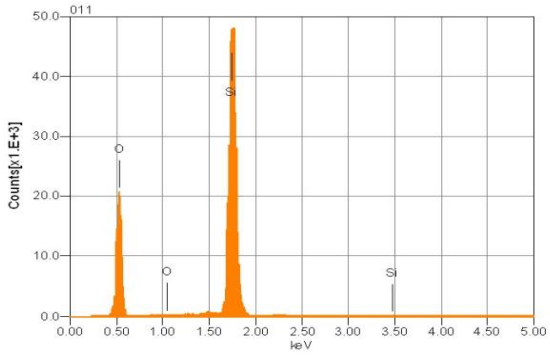


Fig. 2. Analysis of initial tailings of flotation enrichment on electron-probe microanalyzer JXA-8230 by JEOL (zinc minerals)

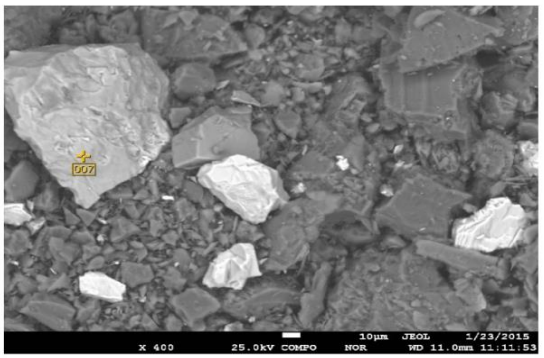


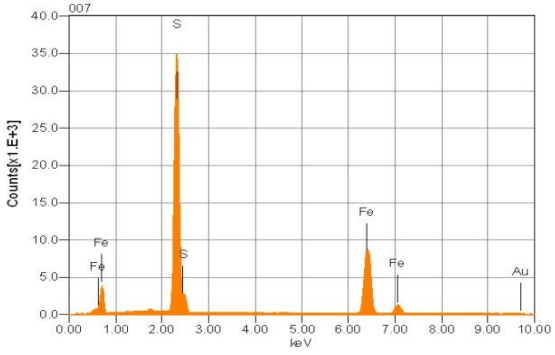


Acquisition Condition
Instrument : 8230
Volt : 25.00 kV
Current : 5.00 nA
Process Time : T3
Live time : 50.00 sec.
Real Time : 60.60 sec.
DeadTime : 18.00 %
Count Rate : 14119.00 CPS

Elements	ms%	mol%	Sigma	Net	K ratio	Line
O	65.92	77.29	1.14	3831840	0.4843100	K
Si	33.98	22.70	0.50	12232193	0.2948830	K
Ag	nd	nd				L
Au*	0.10	0.01	2.99	11350	0.0006188	M
Total	100.00	100.00				

Fig. 3. Analysis of initial tailings of flotation enrichment on electron-probe microanalyzer JXA-8230 by JEOL (silica)





Acquisition Condition
Instrument : 8230
Volt : 25.00 kV
Current : 3.00 nA
Process Time : T3
Live time : 50.00 sec.
Real Time : 61.81 sec.
DeadTime : 19.00 %
Count Rate : 14386.00 CPS

Elements	ms%	mol%	Sigma	Net	K ratio	Line
S	52.33	71.04	0.58	11688632	0.4606162	K
Fe	33.00	25.72	1.43	4169832	0.3403191	K
Ag	nd	nd				L
Au*	14.67	3.24	2.17	1803240	0.1229814	M
Total	100.00	100.00				

Fig. 4. Analysis of initial tailings of flotation enrichment on electron-probe microanalyzer JXA-8230 by JEOL (pyrite)

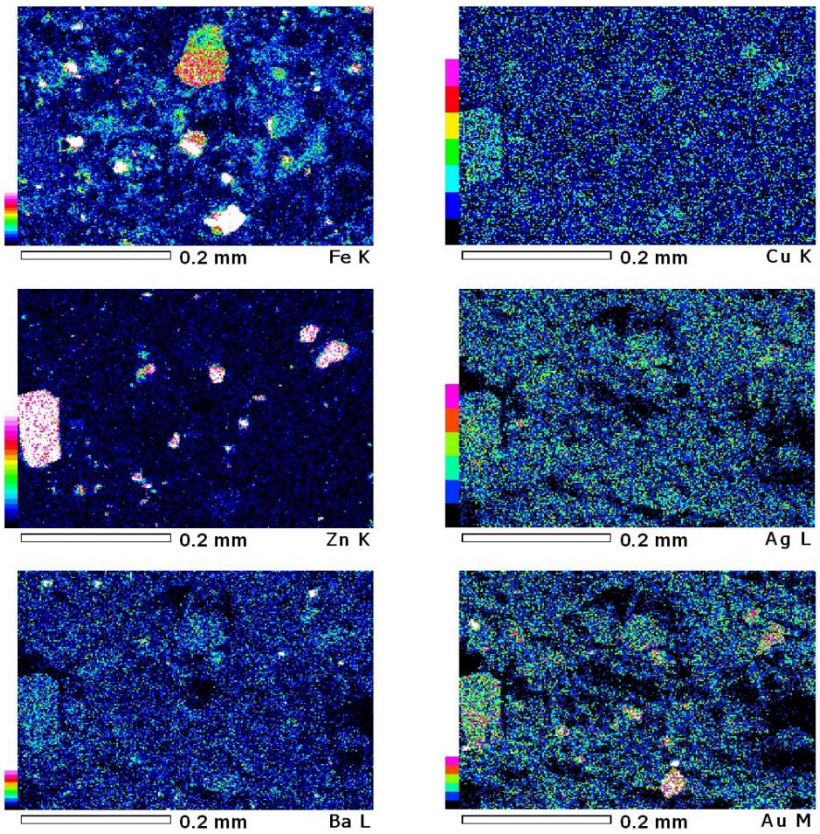


Fig. 5. Distribution of Fe, Cu, Zn, Ag and Au in a sample of flotation tailings sample

To determine the particle size distribution of the initial sample of flotation enrichment tailings, the analysis of variance was carried out, which showed that most of the useful components - copper, lead and zinc are concentrated in the fraction 0-10 microns. The reagent mode of enrichment tailings flotation with the use of basic reagents was tested. The optimum grinding mode, and costs of basic reagents - butyl xanthate and frother - were selected. The scheme of tailings flotation included tailings regrinding, main, control flotation and four recleanings of the collective copper-lead-zinc concentrate. The initial size of flotation tailings by class -0.040 mm was 71.6 %. It follows from the results of studies that additional grinding of flotation tailings up to 78 % of -0.040 mm class allows to increase the degree of extraction of copper, lead, zinc, iron and gold in the froth product by 10-15 %.

The results of studies have shown that the optimal consumption of basic reagents - collector is the consumption of 150 g/t, foaming agent T-92 80 g/t. The use of a modified collector in the flotation cycle of tailings allows to reduce the consumption of frother T-92 by 25 % and increases the recovery of copper, lead, zinc and gold in the collective concentrate. Table 3 shows the results of tailings processing with the modified collector in comparison with the basic mode.

Table 3. Table 3 shows the results of tailings processing with the modified collector in comparison with the basic mode

Name of Products	Yield, %	Content, %, g/t				Recovery, %				Note
		Cu	Pb	Zn	Au	Cu	Pb	Zn	Au	
Collective concentrate	2.0	2.0	1.6	3.2	4.1	67.1	62.0	62.0	54.45	Basic technology BKx-150 g/t T-92–80 g/t
Dump tailings	98.0	0.02	0.02	0.04	0.07	32.9	38.0	38.0	45.55	
Initial tails	100.0	0.060	0.052	0.103	0.151	100.0	100.0	100.0	100.0	
Collective concentrate	2.2	2.2	1.8	3.3	4.3	76.7	70.4	71.2	58.02	Modif. collector 100 g/t T-92–60 g/t
Dump tailings	97.8	0.015	0.017	0.03	0.07	23.3	29.6	28.8	41.98	
Initial tails	100.0	0.063	0.056	0.102	0.163	100.0	100.0	100.0	100.0	

The basic technology produced a collective copper-lead-zinc concentrate containing 2.0 % copper at 67.11 % recovery; 1.6 % lead at 62.02 % recovery; 3.2 % zinc at 62.02 % recovery; 7.0 % iron at 41.67 % recovery; and 4.1 g/t gold at 54.45 % recovery.

Flotation using a modified collector produced a collective copper-lead-zinc concentrate containing 2.2 % copper at 76.74 % recovery; 1.8 % lead at 70.43 % recovery; 3.3 % zinc at 71.22 % recovery; 7.1 % iron at 44.4 % recovery; and 4.3 g/t gold at 58.02 % recovery.

Conclusions

The paper presents the results of laboratory studies on flotation processing of copper-lead-zinc tailings using a modified collector. The modified collector is a mixture of modified butyl xanthate and aeroflot in combination with N-allyl-o-isobutylthionocarbamate. Application of the modified collector allows increasing the extraction of useful components in the collective copper-lead-zinc concentrate obtained from the tailings: copper - by 9.63 %, lead - by 8.41 %, zinc - by 9.2 %, iron - by 2.73 %, gold - by 3.57 %. At the same time the consumption of modified collector, in comparison with butyl xanthate, is reduced by 33 % (from 150 to 100 g/t), the consumption of basic frother T-92 is reduced by 25 % (from 80 to 60 g/t).

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Effect of modifier reagent on sulfite ion oxidation during selective separation of copper and lead sulfides

Abstract: Oxidation of minerals and reagents, the mechanism of interaction of components of the liquid phase of the pulp between themselves and with the surface of ore-forming minerals have the greatest impact on selective flotation. The study of redox processes occurring in sulfide ores and pulps and leading to changes in the physical and chemical surface properties of minerals is an urgent task. The influence of divalent and trivalent forms of iron on the oxidation of sulfite ions in the pH range of 6-12 at different flotation conditions has been studied. It was found that 95-98% of sulfite ions are oxidized in the pH range of 6-8.5 in the presence of a mixture of divalent and trivalent iron oxides under aeration conditions for 8-10 min.

Keywords: flotation, modifier, selection, oxidation, sulfite ions.

Introduction

Most concentrators processing polymetallic ores operate according to the following scheme: collective flotation of copper and lead minerals from the initial ore with suppression of sphalerite and pyrite, followed by separation of the copper-lead concentrate; sphalerite and sometimes pyrite are extracted from the tailings of the copper-lead cycle.

The separation of copper, lead and zinc concentrates from polymetallic ores is very challenging (Mei et al., 2012; Kenzhaliyev, 2019; Chepushtanova et al., 2022; Dihanbaev et al., 2019; Yessengaziyev et al., 2020; Gladyshev & Nurhadiyanto, 2021). The quality of the homogeneous concentrates, which can only be achieved by flotation enrichment, is very important for metallurgical processing. Currently, there are several common techniques for separating the collective copper-lead concentrate. Cyanide and sulfite technologies (Bakinov, 1962; Kosherbaev, 1975; Viduetsky et al., 2009; Turysbekov et al., 2018) have found industrial applications. Cyanide technology is not environmentally safe, and at the sulfite method of separation, there is a large consumption of sodium sulfite (3-4 kg/t) and iron sulfate (5-6 kg/t). The development of new methods of separation of collective concentrates with the use of new reagents-modifiers is an important task in the flotation enrichment of non-ferrous metal ores.

Modifiers are of great importance in the flotation process (Bocharov et al., 2022; Kong et al., 2024; Kyaw et al., 2024; Miao et al., 2024). Numerous studies with various iron-containing reagents (Turysbekov

et al., 2020) were carried out to replace sodium sulfite and iron sulfate. As a result, a new iron-containing galena modifier was found, which has a depressing effect and more actively hydrophilizes lead sulfide minerals.

Such processes as oxidation of minerals and reagents, the mechanism of interaction of components of the liquid phase of the pulp between themselves and with the surface of ore-forming minerals, sorption of the collector and sulfur-containing modifiers have the greatest influence on selective flotation (Abramov, 1984; Eliseev et al., 1992; Bocharov, 1994; Kayumov et al., 2023). In addition, in the process of oxidation of sulfides and components of ore pulps, such products as sulfide ions, iron ions, metallic iron, their oxidation products, and waste rock minerals are formed. These products most effectively affect the flotation performance.

When using sulfite technology for the separation of copper-lead concentrate, sulfite ion, being a good reducing agent, creates a redox medium in the pulp, which is intensively oxidized in water with oxygen. Both sulfite ion and iron cations, being present in the pulp, always have a certain effect on the process, given which undesirable consequences can be eliminated to a certain extent. Currently, there is no consensus on the mechanism of action of minerals of both the sulfite ion and its joint action with iron cations.

Redox processes that occur in sulfide ores and pulps and lead to a change in the physicochemical surface properties of minerals are the main cause of difficulties in the separation of selective concentrates during selective flotation (Avdokhin & Abramov, 1989; Bogdanov et al., 1983). The purpose of the work is to study the effect of the flotation modifier reagent, which is a mixture of divalent and trivalent forms of iron, on the oxidation of sulfite ions in the flotation system.

Materials and research methods

To study the effect of the reagent-modifier on the oxidizability of sulfite ions at different pH of the medium, sodium sulfite solution with an initial concentration of 400 mg/dm^3 was used. The studies were carried out at different pH of the medium, which varied from 6 to 12. The pH was monitored using a pH-meter of pH-150 type. Sulfuric acid and caustic soda were used as medium regulators. The residual concentration of sodium sulfite [($\omega_{residual}(SO_3^{2-})$)] was determined by inverse iodometric titration. The concentration of iodine solution for titration was 12.7 g/dm^3 or 0.05 n. Test experiments were carried out in the flotation chamber in agitation and agitation-aeration modes without and with the addition of a reagent-modifier. The volume of the working chamber of the flotation machine was 50 cm^3.

A mixture of divalent and trivalent forms of iron (Fe^{2+}+Fe^{3+}) was used as a reagent-modifier. The reagent was introduced into the solution in the form of powder with different dosages of 0.5-3.0 g.

The effect of Fe^{2+} divalent iron ions was investigated as a comparison. Iron sulfate solution of the concentration used in production conditions was used in the work.

Oxidation of sulfite ion was studied not only at different pH of the medium, and different modes of operation of the flotation machine but also at different agitation times with the reagent-modifier.

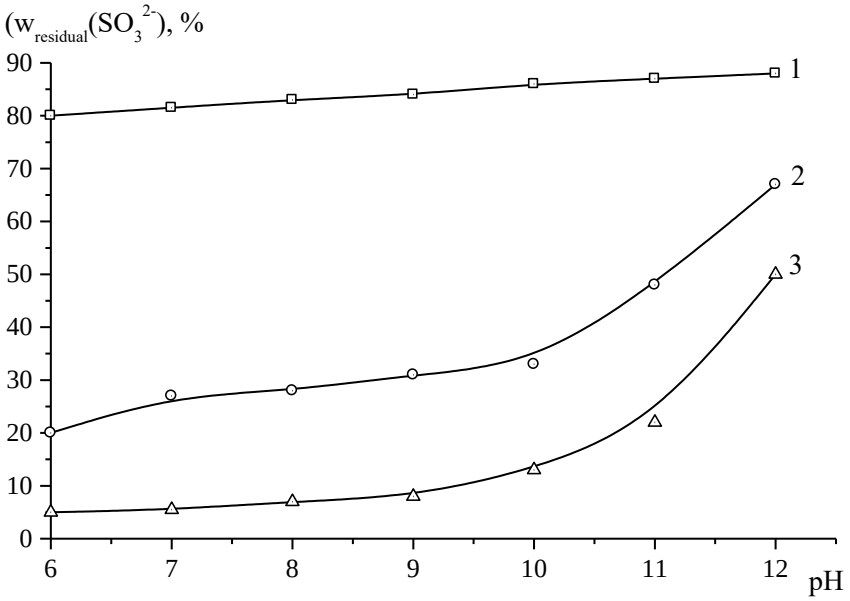
Results and Discussion

Test experiments were carried out to study the effect of solution pH on the oxidizability of sulfite ions in agitation and agitation-aeration modes without and with the addition of a reagent-modifier. The results of the experiments are presented in Figure 1.

It is known that under sulfite regime conditions the $(SO_3)^{2-}$ ion, reducing the galena surface, enhances the hydrophilic properties of the mineral. Based on the data of analysis of the residual concentration of sulfite ions ($\omega_{residual}(SO_3^{2-})$) in solution, it is shown that under agitation-aeration conditions in distilled water, the degree of its oxidation is insignificant (curve 1, Figure 1). Under the agitation-aeration regime in the absence of the modifier reagent, the oxidation of $(SO_3)^{2-}$ -ion is markedly increased compared to the agitation regime, which is due to the increased oxygen content. In the presence of the modifier reagent under the same treatment regime, the degree of sulfite ion oxidation is markedly enhanced (curve 2, Figure 1), as there is physical sorption of oxygen on the surface of the material, which promotes the oxidation of sulfite ions. At agitation-aeration mode in the region of pH above 10, the lowest degree of oxidation of $(SO_3)^{2-}$ ions is observed, which is consistent with the results of E.V. Adamov's studies on the

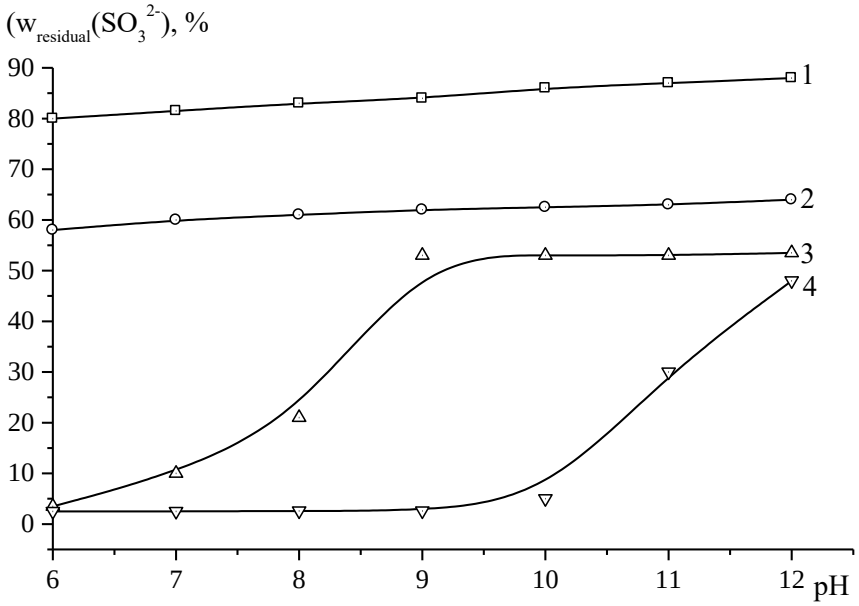
stability of sulfite ions in flotation conditions (Avdokhin, 2008). The results show that the most intensive oxidation occurs in agitation-aeration mode in the presence of a reagent-modifier (curve 3, Figure 1).

To obtain comparative data on the effect of mixture (Fe^{2+}+Fe^{3+}) and divalent iron ions on the oxidation of sulfite ions, the corresponding experiments were set up. The results are shown in Figure 2.



1 - agitation mode; 2 - agitation-aeration mode; 3 - agitation-aeration mode in the presence of reagent-modifier

Figure 1. Influence of medium pH on oxidation of sulfite ions in different flotation modes



1- in agitation mode without reagent; 2 - in agitation mode in the presence of mixture (Fe^{2+}+Fe^{3+});
3 - in aeration mode in the presence of iron sulfate; 4 - in aeration mode in the presence of a mixture (Fe^{2+}+Fe^{3+})

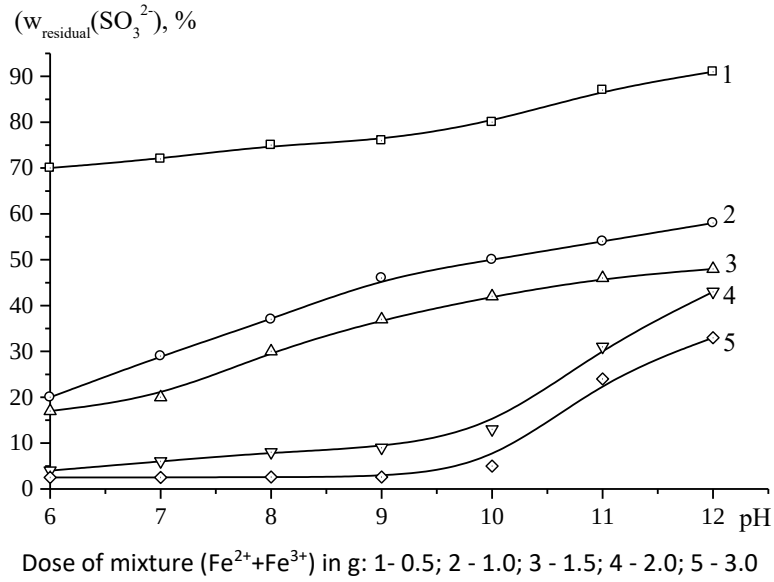
Figure 2. Influence of pH of the medium and iron-containing reagents on oxidation of sulfite ions in different flotation modes

Judging from the residual concentration of the SO_3^{2-} ions in solution (Figure 2) in the presence of a mixture of (Fe^{2+}+Fe^{3+}) under agitation conditions, the sulfite ion does not undergo appreciable transformations in the pH=6-12 range. This is apparently due to the insignificant content of oxygen activated on the surface of the material. When the process is carried out in the aeration mode, the

oxidation of sulfite ions proceeds much deeper. The influence of iron ions on the oxidation of sulfite ions in solution in the aeration mode of treatment is manifested to a much lesser extent in the considered pH range. Hence, we can conclude about the essential role of the mixture (Fe^{2+}+Fe^{3+}) in the complex redox processes occurring in the flotation system.

It is established that at aeration mode of treatment sulfite ion oxidation is intensified due to the increase of oxygen content in the solution. It is shown that sulfite ion oxidizability is intensified in the presence of a mixture (Fe^{2+}+Fe^{3+}) at the aeration mode of treatment (curve 4, Figure 3).

Test experiments were carried out to study the effect of the dosage of the mixture (Fe^{2+}+Fe^{3+}) on the oxidizability of sulfite ions. The dosage of the mixture (Fe^{2+}+Fe^{3+}) was varied from 0.5 to 3 g. The results are presented in Figure 3.

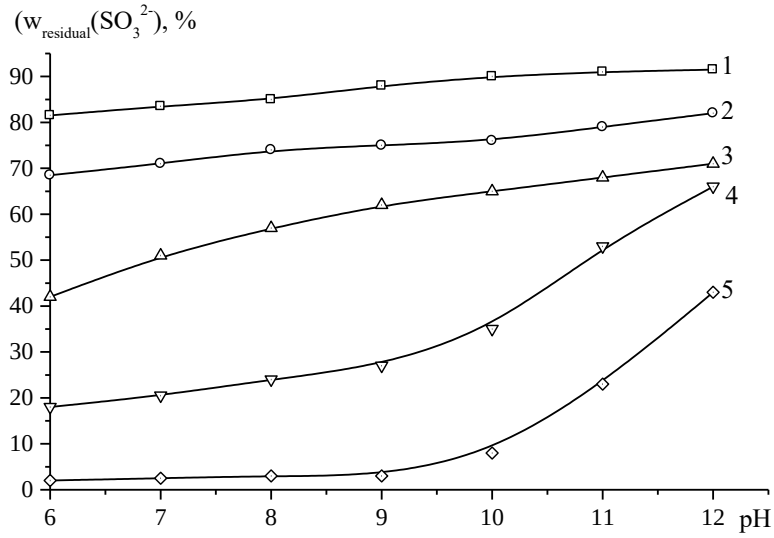


Dose of mixture (Fe^{2+}+Fe^{3+}) in g: 1- 0.5; 2 - 1.0; 3 - 1.5; 4 - 2.0; 5 - 3.0

Figure 3. Influence of pH of medium and mixture (Fe^{2+}+Fe^{3+}) on oxidation of sulfite ions at aeration flotation regime

The results of test experiments (Figure 3) show that increasing the dose of par magnetic material, i.e. ($Fe2^{+}$+Fe^{3+}) mixture, promotes the oxidizability of sodium sulfite especially in the pH range of 6-10.

Studies were also carried out to investigate the oxidizability of sulfite ions as a function of agitation duration with (Fe^{2+}+Fe^{3+}) mixture under aeration flotation regime. The results are presented in Figure 4.



Agitation time, min: 1- 2; 2 - 4; 3 - 6; 4 - 8; 5 -10

Figure 4. Influence of medium pH and agitation time with the mixture (Fe^{2+}+Fe^{3+}) on oxidation of sulfite ions at aeration flotation mode

Studies on the oxidation kinetics of sulfite ions (Figure 4) showed that within 8-10 min the residual concentration of sodium sulfite reaches 2-5 % of its initial concentration of 400 mg/dm^3 at pH 6-8.5.

Conclusions

When using sulfite technology for the separation of collective copper-lead concentrates, it is important to know the kinetics of oxidation of sulfite ions in the presence of a modifier reagent. Paramagnetic material, which is a mixture of divalent and trivalent iron, was used as a modifier. The influence of the pH of the medium on the oxidation of sulfite ions in different flotation modes was studied. The most intensive oxidation occurs in agitation-aeration mode in the presence of modifier reagent: at pH 6-9, the residual concentration of sulfite ions is 5-8%.

Comparative data on the influence of the mixture (Fe^{2+}+Fe^{3+}) and divalent iron ions on the oxidation of sulfite ions showed that divalent iron ions have an effective oxidizing effect at pH 6-8.5; and the mixture (Fe^{2+}+Fe^{3+}) - in the whole range of pH 6-12.

The study of the influence of the dosage of the mixture (Fe^{2+}+Fe^{3+}) on the oxidation of sulfite ions showed that an increase in the dosage of par magnetic material promotes the oxidizability of sodium sulfite in the pH range 6-10. In addition, it was found that for oxidation of sulfite ions in the aeration mode in the presence of paramagnetic material is sufficient for 8-10 min.

CRediT author statement: **D.Turysbekov**: Conceptualization, Methodology, Software; **L. Semushkina**: Software, Validation; **Zh. Kaldybayeva**: Reviewing and Editing; **N. Tussupbayev**: Data curation, Writing draft preparation; **S. Narbekova**: Visualization, Investigation, Supervision; **A. Mukhamedilova**: Investigation, Supervision..

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Study of acid treatment of lithium-manganese precursors

Abstract: Lithium production in Kazakhstan could be strategically important for the country as there has been a growing demand for this metal for the production of lithium-ion batteries, which are widely used in electric vehicles, portable devices and for storing energy from renewable sources. In addition, Kazakhstan is actively developing its lithium industry and is looking for ways to make the most efficient use of its lithium resources to support global energy. The use of highly selective sorbents can play a decisive role in the development of lithium-containing natural resources. The paper presents the results of research on acid treatment. X-ray phase analysis showed that the obtained manganese dioxide sorbent has a cubic crystal lattice structure.
Keywords: acid treatment, lithium-manganese precursors, hydrochloric acid, X-ray diffraction analysis, sorbent.

Introduction

Lithium is a light alkali metal with high ductility. Due to its outstanding chemical characteristics, including excellent electrical conductivity and low density, it is widely used in various industries (Tarascon, 2010; Kenzhaliyev et al., 2021; Ablakatov, et al., 2023; Abdulvaliyev et al., 2025).

Lithium is characterised by a wide variety of compounds that are required for many applications. Also, lithium has a wide range of industrial applications. It plays a key role in the production of glass and ceramics, is used in pharmaceuticals and nuclear power, and finds use in the creation of alloys for the aerospace industry. However, the most well-known use of lithium is in the production of lithium batteries, which are found in mobile phones, laptops, electric cars and other lithium-ion battery-powered devices (Bai et al., 2020; Ultarakovaet al., 2021; Ablakatov et al., 2022; Balaram et al., 2024).

Lithium-ion batteries (Li-ion) are a type of battery that uses lithium ions as the main element for storing and transferring electrical energy. As mentioned above, they are widely used in modern devices such as smartphones, laptops, electric cars and portable electronics due to their high energy capacity, and low self-discharge (Gao et al., 2023; Nandihalli, 2024).

These features make lithium-ion batteries one of the most sought-after and efficient batteries, especially for mobile devices and electric vehicles.

The growing global demand for lithium stimulates research and development of technological solutions for processing lithium-containing hydromineral raw materials, including associated formation brines (Alera et al., 2024; Xin et al., 2016).

Recently, lithium-ion sieve (LIS) technology has become one of the most promising technologies for lithium extraction from petroleum brines. LIS provide highly selective extraction of lithium from complex solutions with a high content of associated components. In general, LIS is divided into two types depending on their chemical composition: lithium-manganese oxide (LMO) and lithium-titanium oxide (LTO) (Quanmin et al., 2024; Joshua et al., 2022; Stringfellow & Dobson, 2021).

Manganese oxide-based lithium ion oxides are currently the most popular selective sorbents. In previous studies, the conditions for the preparation of lithium-manganese precursor having the composition $Li_{1.6}Mn_{1.6}O_4$ were studied. To clarify and obtain additional information, it is of great interest to study the acid treatment of lithium-manganese precursors.

Research Methods

Analysis methods: the quantitative content of basic elements in precursors were determined on an atomic emission spectrometer with inductively coupled plasma Optima 8300DV (Perkin Elmer Inc., Waltham, MA, USA). X-ray phase analysis (XRD) was carried out on a diffractometer D8 ADVANCE "BRUKER AXS GmbH", (Karlsruhe, Germany) radiation Cu-Kα, database PDF-2 International Center for Diffraction Data ICDD (Swarthmore, PA, USA).

Experimental procedure: precursors were poured with the required amount of dilute hydrochloric acid solution according to the experimental procedure for acid treatment. The process was performed at a given temperature and contact time under stirring in a 3 dm^3 sealed thermostated cell equipped with a VELP Scientifica LS F201A0151 mechanical stirrer (Usmate Velate, Italy), providing a fixed speed. Constant temperature was maintained using an Aizkraukles TW 2.02 water bath thermostat (ELMI, Riga, Latvia).

Research Results

Acid treatment was carried out to remove lithium from the lithium-manganese precursor and to obtain a sorbent. At removal of lithium from the precursor, at the same time in the structure of the resulting sorbent, there should remain free vacant cells, very small in size, which during sorption can be occupied only by lithium, or replacement of lithium by a hydrogen atom capable of exchange for a lithium atom.

The effects of temperature, precursor-to-acid weight ratio and duration on acid treatment were studied.

The influence of process temperature was studied under the following conditions: temperature 30, 40, 50, 60 °C; HCl concentration 0.5 M; duration 12 h; ratio of sorbent mass to acid solution volume (S:L) = 1:800. The results of the studies are given in Figure 1.

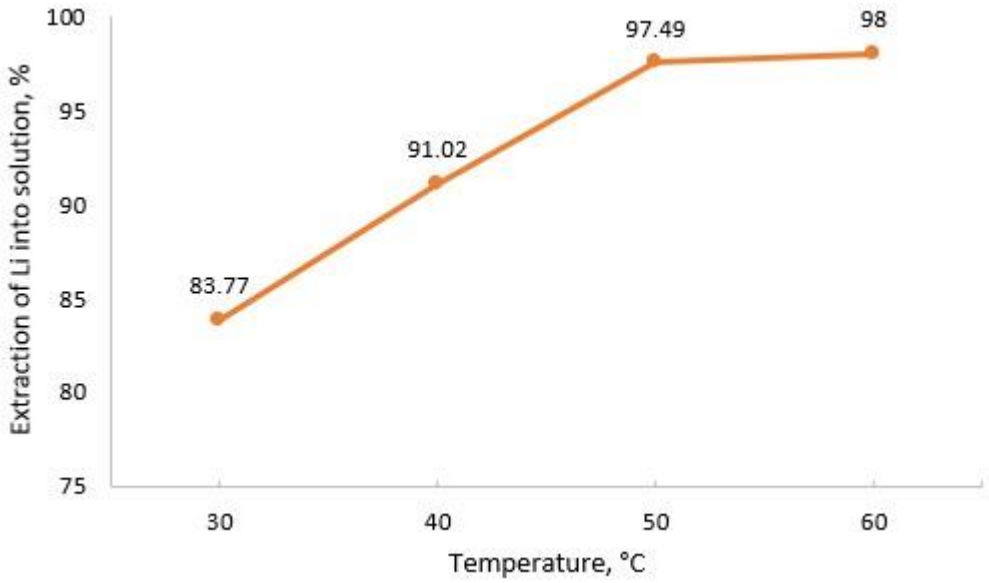

Figure 1. Effect of temperature on acid treatment of precursor

The obtained research results show that with increasing process temperature lithium extraction into solution increases, at temperature 40 °C lithium extraction reaches above 91 %. Losses of manganese in the whole temperature range under study are ~12.5-14 %. The most preferable temperatures are 40 °C, at which lithium extraction is 91 %, manganese losses are 12.95 %.

Study of the influence of precursor mass to acid volume ratio. The studies were carried out under the following conditions: temperature 40 °C; HCl concentration 0.5 M; duration 12 h; sorbent mass to acid solution volume ratio (S:L) = 1:600; 1:700; 1:800; 1:900. The results of the studies are given in Figure 2.

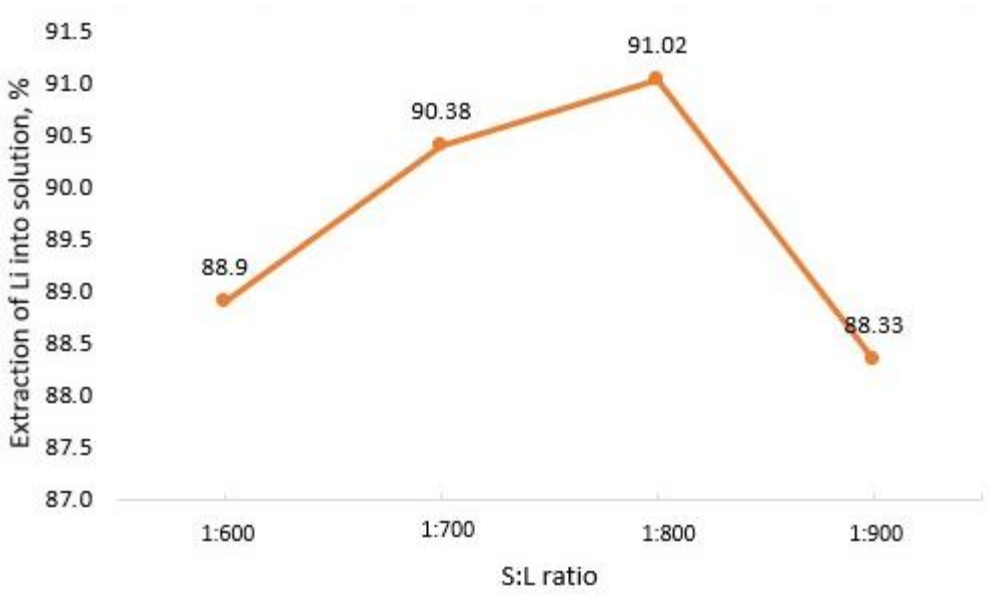

Figure 2. Effect of S:L ratio on acid treatment of precursor

The results of experiments show that at S:L ratios 1:700 and 1:800 lithium extraction becomes maximum and makes ~90-91 %, at the same time manganese losses are in the range of 12,28-12,95 %. On this basis, the most acceptable are S:L ratios of 1:700 and 1:800.

The influence of duration of acid treatment was studied under the following conditions: temperature 40 °C; HCl concentration 0.5 M; S:L ratio = 1:800; duration 2, 6, 12, 18 and 24 hours. The obtained results are given in Figure 3.

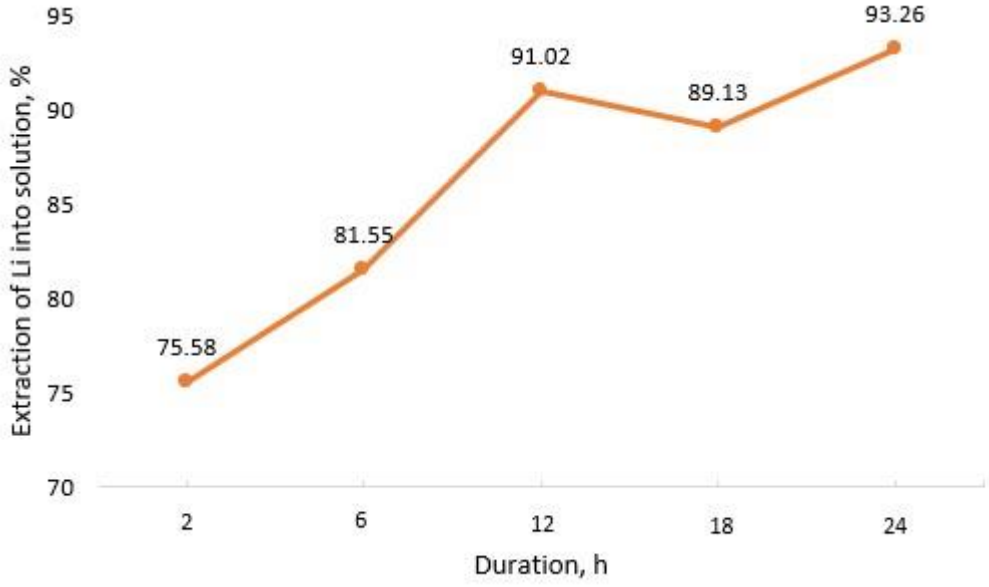

Figure 3. Effect of Process Duration on acid treatment of Precursor

Increasing the duration of acid treatment leads to an increase in the degree of lithium transfer into the solution. At 12 h and more the recovery reaches ~90 % and more, at that throughout the studied values of duration of the process manganese losses practically do not change. From the obtained data the most preferable duration of 24 h, at which the lithium recovery above 93 % is achieved.

X-ray phase analysis of the obtained sorbent presented in Figure 4. shows that it consists of manganese dioxide monophase with cubic crystal lattice structure.

Thus, the results of the conducted studies of acid treatment showed that the most acceptable conditions of the process are temperature 40 °C, HCl concentration 0.5 M; S:L ratio = 1:700 and 1:800 and

duration of 24 h. In this case, the lithium extraction into solution from the precursor can reach ~93 %, and the lithium content in the sorbent is 0.277 %.

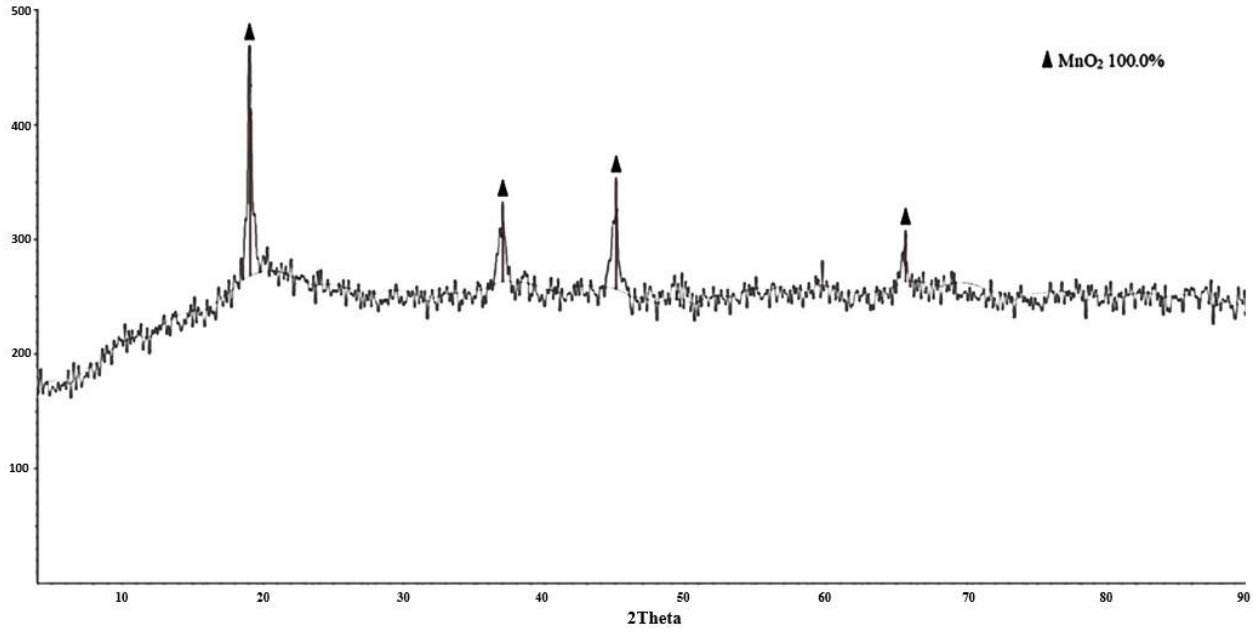

Figure 4. Diffractogram of the obtained sorbent

Thus, the results of the conducted studies of acid treatment showed that the most acceptable conditions of the process are temperature 40 °C, HCl concentration 0.5 M; S:L ratio = 1:700 and 1:800 and duration 24 h. In this case, the lithium extraction into solution from the precursor can reach ~93 %, and the lithium content in the sorbent is 0.277 %.

Conclusions

The obtained research results show that acid treatment of precursor is preferably carried out under the following conditions: temperature 40-50 °C, HCl concentration 0.5 M; S:L ratio = 1:700 and 1:800 and duration of 24 hours. In this case, the lithium extraction into solution from the precursor can reach ~93-97 %.

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Mapping Educational Technology Trends in Physical Education: A Bibliometric Analysis Based on The Scopus Database

Abstract: In recent years, digital technologies have played a key role in transforming education, including physical education. This research aims to provide an overview of the application of technology in education, as well as explore its opportunities and challenges in physical education. This study uses secondary data from the Scopus database, consisting of 350 articles published between 1980 and 2024. The selection of articles is based on inclusion criteria that include the keywords "education," "technology," and "physical education" in the title, abstract, or keyword, as well as being included in the social sciences area. The analysis was conducted using the R and VOSviewer applications. The first publication appeared in 1980, with an upward trend starting in 2012 till now. Lviv Polytechnic National University is the most relevant affiliate, while Retos is the journal with the most publications. "Sport, Education, and Society" is the most impactful journal. The most relevant author is Blavt, O., while Goodyear, V.A. is the author with the greatest impact. The keyword "multimedia system" emerged in 2019 and peaked in 2023, along with the keyword "e-learning." The VOSviewer analysis identified three research clusters, and topics such as 'teacher experience' and 'challenges' were found to be still rarely explored, thus offering future research opportunities. The results of this study are useful as a reference for academics and physical education practitioners who want to research the topic of educational technology.

Keywords: Bibliometrics, educational technology, physical education.

Introduction

In recent years, digital technology has played a key role in transforming education. Technologies such as artificial intelligence (AI) and data-driven tools allow for more effective personalization of learning. Teachers can tailor teaching to the individual needs of students, significantly improving learning outcomes (Hartman et al., 2019). The development of 5G networks accelerates the implementation of technologies in learning, such as the Internet of Things (IoT), artificial intelligence, and Augmented Reality (AR)/Virtual Reality (VR). The technology allows for a more interactive and immersive learning environment, facilitating distance learning, global collaboration, and access to a wider range of resources. This shows that education is now becoming more flexible and accessible to more students (Ammanamanchi & Domede, 2024).

Technology has had a significant impact on teaching methods, allowing teachers to create a more interactive and adaptive learning environment. The application of technology helps create a more focused learning approach to student needs, provides greater flexibility in learning methods and times, and facilitates collaboration between students and teachers in various locations. Tomar & Soni (2024) stated that the integration of technology into learning makes teaching materials more interesting. The use of multimedia and interactive tools can increase students' motivation to learn so that they are more involved in the learning process. Rabani et al., (2023) stated that technology improves students' digital skills, accelerates the learning process, and increases the efficiency of teachers' and lecturers' administrative tasks. The benefits of technological collaboration in education are felt in various aspects, such as increased access to educational resources, the effectiveness of teaching methods, and the improvement of student learning outcomes.

Technology helps overcome the limitations that exist in the traditional education system, such as time, space, and resource limitations.

Educational technology in physical education has undergone significant development in recent years, and one of the important approaches to understanding it is through bibliometric analysis. This analysis is especially important to identify challenges and opportunities in the use of technology in physical education because it can present information about the pattern of literature development effectively and efficiently. With bibliometric analysis, researchers can understand the structure, dynamics, and impact of educational technology on physical education (Oluwadele et al., 2023). Bibliometrics also allows for the measurement of scientific work mathematically and statistically (Diodato & Gellatly, 2013), helping to explore research development trends in physical education, especially those related to technology (Bornmann & Leydesdorff, 2014).

Compared to experience-based or experiment-based methods, bibliometric analysis has the advantage of collecting and processing copious amounts of technical information. The results of this method are more objective and allow for an in-depth dig into the relevant scientific literature to uncover patterns of technological change in physical education (Huang et al., 2020). According to (Julia et al., 2020), the bibliometric analysis examines seven key areas, including publication trends, leading journals, most cited articles, common keywords, author collaboration networks, institutional collaboration patterns, and overall statistical trends.

The bibliometric approach is invaluable in mapping research on the use of technologies such as augmented reality (AR) or interactive learning applications in physical education. (Mejia et al., 2021). Through this approach, decision-making regarding research priorities can be more directed, and trends in physical education science and technology can be observed more accurately. Bibliometric analysis is not a substitute for experimental methods but is a complementary approach that can provide a macro picture related to publication patterns (Ellegaard & Wallin, 2015; Öztürk et al., 2024), while the experimental method offers deeper micro-insights regarding the direct influence of technology on physical learning. Thus, educational technology in physical education can be optimized through a thorough understanding of research trends and the application of these technologies, which are identified through bibliometric analysis.

Through this study, an analysis of technology research trends in education and sports education was conducted using a bibliometric approach from the Scopus Database. The purpose of this study is to provide an overview of how technology has been applied in education, as well as to explore the opportunities and challenges that exist in sports education. Thus, it is hoped that the results of this study can provide a better understanding of integrating technology in sports education.

***Research question*:**

How are the trends of technology research in education and sports education developing based on bibliometric analysis from the Scopus Database, and what are the opportunities and challenges that arise in the application of technology in sports education?

Research procedure

This study uses the Scopus database as a source of data related to the use of educational technology in sports education. Scopus was chosen because it can update the database more effectively and efficiently so that it can assist researchers in analyzing citations, calculating research collaborations, reporting annual productivity, and exporting data into CSV and RIS formats for more in-depth tabulation and mapping purposes (Oluwadele et al., 2023). There were 350 articles found using the criteria that had been determined (see Table 1).

The data obtained through Scopus is then analyzed using VOSviewer and R Studio by utilizing the 'biblioshiny' package which can subsequently provide visualization and analysis of indicators related to research trends, such as publication productivity, active authors, and developing research trends. (Ibrahim et al., 2023; López Belmonte et al., 2020; Nurjanah et al., 2024). The data that has been obtained from the Scopus database and has met the requirements, is then exported as a . RIS and . CSV. Next, the data is processed through RStudio using the biblioshiny package (Nurjanah et al., 2024) and also processed via VOSviewer.

Table 1: Criteria of article inclusion

Search within	Search documents
Article title, abstract, keywords	"education" AND "technology" AND "physical education"
Document Type	Article
Subject area	Social sciences
Years	1980 – August 2024

Research results and discussions

Publication productivity related to the use of technology in physical education based on the Scopus Database. Based on the results of the search and selection conducted on data obtained through the Scopus database, it was found that the first research related to this topic has emerged since 1980. However, no research was found on related topics until 2007. In 2008, this topic began to be researched again and in 2012 it became the starting point for topics related to educational technology in sports education to begin to develop. Figure 2 shows the developments related to publications on this topic.

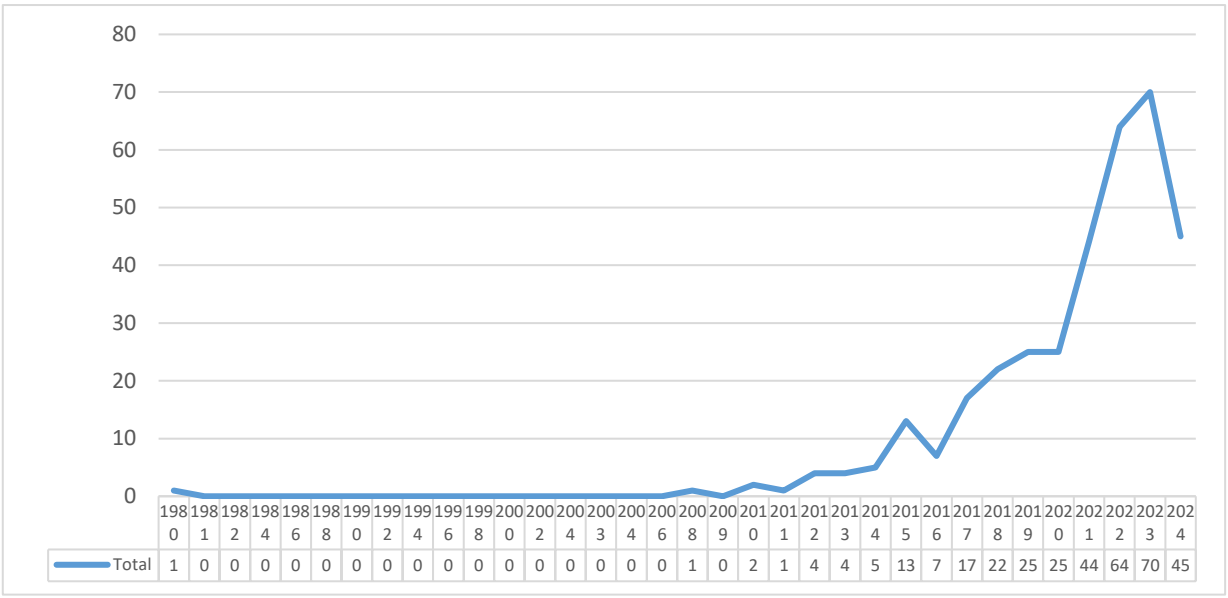

Figure 1. Number of publications in each year

The first research on this topic comes from research conducted by Allison & Ayllon in 1980. In contrast to the current definition of technology which usually focuses on technology physically, the Allison & Ayllon research (1980) The technology in question is a behavioural technology that adheres to behavioral principles to teach motor skills in sports. In his research, he uses behavioral technology in physical education to reduce errors and strengthen motor skills effectively. The method used in his research succeeded in improving the performance of athletes in skills such as blocking in football, walkover in gymnastics, and forehand hitting in tennis up to many times compared to coaching methods.

Unfortunately, after 1980, no research on educational technology in physical education was found for 28 years. The lack of research on this topic can be caused by the substantial number of educators who tend to stick to traditional methods, as well as the physical education identity crisis that makes their roles and goals less clear. (Ardiyanto, 2018). New research began to resurface in 2008, and there was an incredibly significant increase between 2020 and 2020, with a rise of 156% during that period. This is believed to be due to the Covid-19 Pandemic which forced all learning to use online methods (Gopika & Rekha, 2023; Winter et al., 2021). The development of articles in the last five years, namely 2020 (25 articles), 2021 (44 articles), 2022 (64 articles), 2023 (70 articles), and 2024 (45 articles). Based on these data, we can see that research on this topic has developed significantly, and of course, this shows considerable potential for further study.

In the affiliate category, three universities are affiliated with the highest level of publications. The three universities are Lviv Polytechnic National University from Ukraine, Universidad Rey Juan Carlos from Spain, and the University of Limerick from Ireland. In detail, in Table 2 we have summarized a list of the 10 affiliates with the highest number of publications.

Table 2. Affiliates with the most publications

Category	Top 10 Publications
Affiliations	Lviv Polytechnic National University (19), Universidad Rey Juan Carlos (16), University of Limerick (14), University of Alicante (13), Spiru Haret University (10), University of Wollongong (9), Federal University of Rio Grande Do Norte (8), Kamianets-podilskyi Ivan Ohiienko National University (8), Dublin City University (7), Universidad De Granada (7).

***The most popular publications, authors, and articles related to the use of technology in physical education*.** In topics related to educational technology in the field of physical education, the analysis conducted using the Scopus database identified as many as 350 articles published in 130 different journals. These journals certainly have a diverse impact, which is measured by the number of citations from each journal, author, and article published (Nurjanah et al., 2024). Table 3 presents a list of the 10 journals with the highest number of articles on this topic. The top three journals include "Retos" from Spain with 27 articles (7.71%), "Movimento" from Brazil with 20 articles (5.71%), and "Sustainability" from Switzerland with 17 articles (4.86%).

Table 3. Top 10 Journals related to collaboration between educational technology and physical education

Journal	Number of documents	Percentage
Retos	27	7,71%
Movimento	20	5,71%
Sustainability (Switzerland)	17	4,86%
International Journal of Emerging Technologies in Learning	16	4,57%
Sport, Education, and Society	13	3,71%
International Journal of Human Movement and Sports Sciences	12	3,43%
Physical Education and Sport Pedagogy	12	3,43%
Rehabilitation and Recreation	10	2,86%
European Physical Education Review	8	2,29%
Journal of Teaching in Physical Education	8	2,29%

Retos, which is a journal whose focus is on physical education, has made a significant contribution to topics related to educational technology in physical education. The journal has played an important role in disseminating the methods, functions, and effectiveness of the use of educational technology in physical education. In addition, the journal also encourages international collaboration among researchers, creating a global community dedicated to advancing technological collaboration in the world of education. In addition, this collaboration also promotes the development of educational technology in the world of physical education. So, this journal can be one of the goals for researchers who have an interest in this topic. In line with what said that choosing the right journal can not only help the development of science but also help promote the academics of an academic (Shamsi et al., 2023).

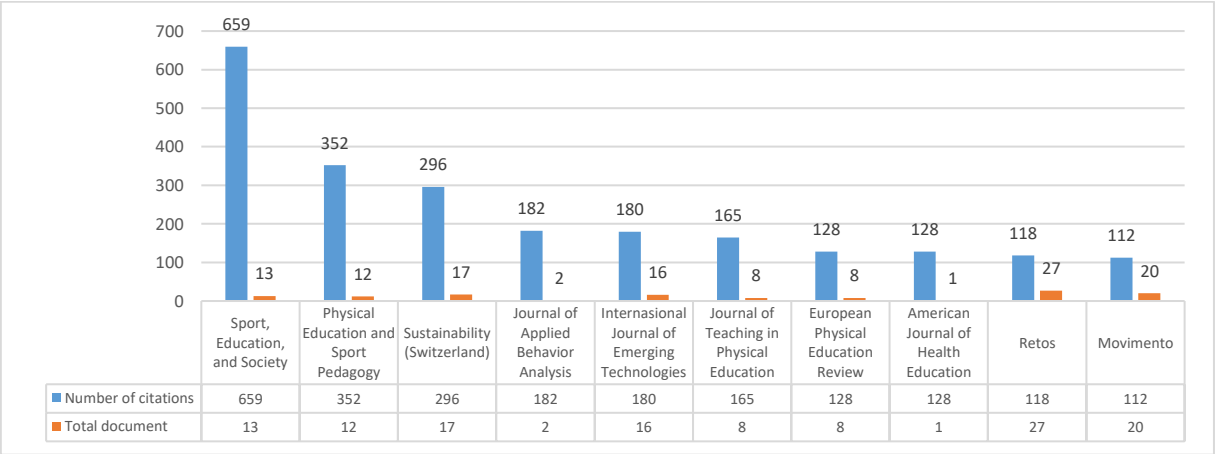

Figure 2. Top 10 most cited journals

In terms of impact based on the number of citations, it has been shown in Figure 2 a list of the 10 journals with the highest citations on this topic. The three journals with the highest citations were "Sport, Education, and Society" from the United Kingdom with 659 citations, "Physical Education and Sport Pedagogy" from the United Kingdom with 352 citations, and "Sustainability" from Switzerland with 296 citations.

Furthermore, the author is the most active and influential on the topic of educational technology in physical education. In this section, the analysis is conducted based on the number of publications and the number of citations obtained. Of the 350 articles obtained and analyzed, 1010 authors are actively involved in this topic. In the most productive category (see Table 4), the three authors with the highest number of publications are Blayt, O. from Ukraine with eight articles, Casey, A. from the United Kingdom with seven articles, and De Araújo, A. C. from Brazil and Goodyear, V. A. from the United Kingdom, who each have six articles on this topic. Then in the most cited category (see Table 5), the three highest authors in the category are all from the United Kingdom, namely Goodyear, V. A. with 707 citations, Casey, A. with 437 citations, and Kerner, C. with 275 citations.

Table 4. Top 10 most productive authors

Authors	Country	Document
Blavt, O.	Ukraine	8
Casey, A.	United Kingdom	7
De Araújo, A. C.	Brazil	6
Goodyear, V. A.	United Kingdom	6
Sargent, J.	United Kingdom	5
Østerlie, O.	Norway	5
Calderón, A.	Ireland	4
Gil-Espinosa, F. J.	Spain	4
Scanlon, D.	Australia	4
Burgueño, R.	Spain	3

Table 5. Top 10 most influential authors

Authors	Country	Quotation
Goodyear, V. A.	United Kingdom	707
Casey, A.	United Kingdom	437
Kerner, C.	United Kingdom	275
Kirk, D.	United Kingdom	204
Quennerstedt, M.	Sweden	154
Armour, K. M.	United Kingdom	133
Williamson, B.	United Kingdom	130
Marttinen, R.	United States	120
Rye, E.	United States	112
Erwin, H.	United States	112

Oksana Z. Blavt is an author with a significant contribution to the topic of educational technology in physical education through her productive research results. As one of the researchers from Lviv Polytechnic National University, his focus on the application of technology to learning in physical education highlights his dedication to exploring effective teaching methods that improve students' understanding of the concepts that exist in sports. His work, of course, has broadened the horizons for the implementation of educational technology in physical education. In addition, Dr. Victoria Goodyear, PhD., SFHEA., a researcher from the University of Birmingham who focuses on research related to pedagogies in sport, also made a great contribution to this topic. This can be seen in the number of citations he got, which is 707 citations on this topic. One of his research projects that is quite popular on this topic is research related to the use of healthy lifestyle technology that can be worn by young people. His research gives the idea that although daily goals such as 10,000 steps and calorie burn set by the Fitbit device encourage higher physical activity at first, their effectiveness decreases over time.

Based on 350 articles obtained through the Scopus database, we have identified the 10 articles with the greatest influence on the topic of educational technology in physical education (see Table 6). Article with the title "Young people's uses of wearable healthy lifestyle technologies; surveillance, self-surveillance and resistance" by Goodyear et al. (Goodyear et al., 2019) Became the most influential article on this topic with 147 citations. Then, the second position is supported by an article titled "Rethinking the Relationship between Pedagogy, technology and Learning in Health and Physical Education" by Casey et al. (Casey et al., 2017). In third place, an article titled "Algorithmic Skin: health-tracking Technologies, Personal Analytics and the Biopedagogies of Digitized Health and Physical Education" by Williamson (Williamson, 2015). These three articles come from the same journal, namely the Sport, Education and Society journal managed by Routledge, United Kingdom.

The top ten most cited articles mainly discuss how the use of technology in physical education can increase engagement and physical activity in learners. These articles are widely cited because they can provide a strong empirical picture and evidence that shows how the application of technology when integrated into physical education is compared to traditional teaching approaches in physical education.

Table 6. Top 10 most influential articles (number of citations)

Title	Reference	Journal	Citation
Young people's uses of wearable healthy lifestyle technologies; surveillance, self-surveillance, and resistance	(Goodyear et al., 2019)	Sport, Education, and Society	147
Rethinking the relationship between pedagogy, technology and learning in health and physical education	(Casey et al., 2017)	Sport, Education, and Society	133
Algorithmic skin: health-tracking technologies, personal analytics and the pedagogies of digitized health and physical education	(Williamson, 2015)	Sport, Education, and Society	130
The Motivational Impact of Wearable Healthy Lifestyle Technologies: A Self-determination Perspective on Fitbits With Adolescents	(Kerner & Goodyear, 2017)	American Journal of Health Education	128
Tweet me, message me, like me: using social media to facilitate pedagogical change within an emerging community of practice.	(Goodyear et al., 2014b)	Sport, Education, and Society	120
The effects of exergaming on physical activity among inactive children in a physical education classroom	(Fogel et al., 2010)	Journal of Applied Behavior Analysis	109
Barriers and facilitators to using digital technologies in the Cooperative Learning model in physical education	(Bodsworth & Goodyear, 2017)	Physical Education and Sport Pedagogy	95
Exploring the changes in physical education in the age of Covid-19	(Varea et al., 2022)	Physical Education and Sport Pedagogy	86
Hiding behind the camera: social learning within the Cooperative Learning Model to engage girls in physical education	(Goodyear et al., 2014a)	Sport, Education, and Society	84
How can video feedback be used in physical education to support novice learning in gymnastics? Effects on motor learning, self-assessment, and motivation	(Potdevin et al., 2018)	Physical Education and Sport Pedagogy	79

The most popular keywords and trends in research related to the use of technology in physical education are in the Scopus database. In this section, we have identified the research areas that are the

main focus of research related to educational technology in physical education. Through this analysis, the development of this topic can be observed. By utilizing the keyword plus setting from the 350 articles collected as many as 50 keywords were generated. The keywords are then analyzed to assess the frequency of their use and identify keyword trends over time. Figure 3 shows the frequency of use of this topic word. The five most widely used keywords were physical education (31), teaching (21), human (16), education (15), student (15), and learning (14).

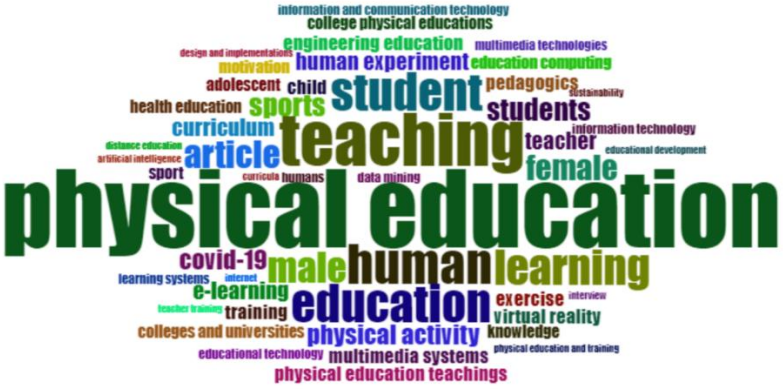

Figure 3. Trending words that appear most often

The finding of the most frequently emerged keywords from the 350 articles analyzed described the development of research related to the topic of educational technology in physical education. Keywords such as teaching, education, student, and learning reflect the application of technology to student-centered physical education, which is in line with the theory of constructivist learning. The application of educational technology to physical education has improved the quality of learning (AL-Sinani & Al Taher, 2023; Lai, 2024; Lobo et al., 2024; Narciso, 2023; Qian, 2024), increase student engagement and participation (Asogwa et al., 2020; Gil-Espinosa et al., 2023; Lai, 2024; Luo, 2023; Moreno-Guerrero et al., 2021), and motivation and fun learning (Moreno-Guerrero et al., 2021; Ponce et al., 2022; Quintas-Hijós et al., 2020).

Furthermore, the trend of word use over time on the topic of educational technology in physical education (see Figure 4). From the results of the analysis, the topic trend began in 2016 and the first topic that emerged was "sport". However, it started to become a trend in 2018 along with "physical education". After that, the trend of "physical education" has been consistently used with 31 frequencies. For 2024, the keyword "motivation" (since 2020) and the keyword "college physical education" (since 2019) are the most commonly used keywords with a total frequency of five for these two keywords.

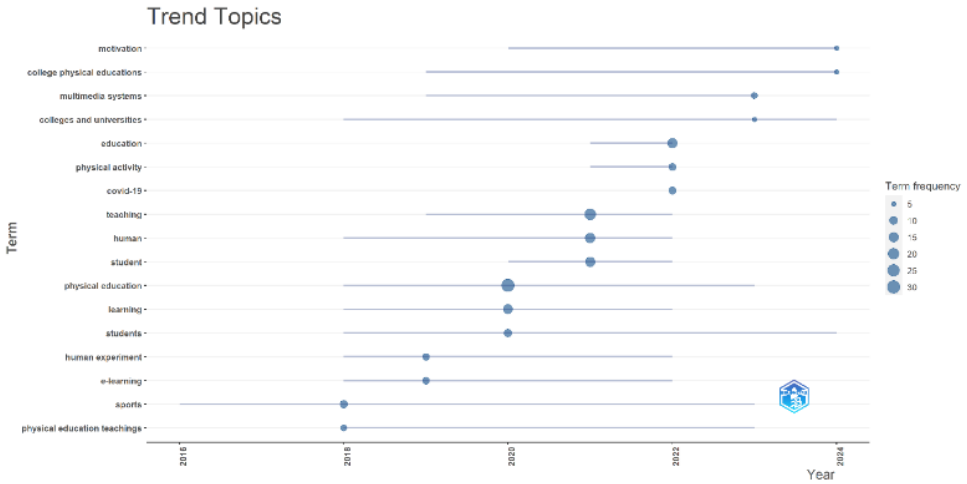

Figure 4. Trends in word usage over time

The keyword trend section in the article discusses the topic of educational technology in physical education has consistently started to develop since 2016. In the development of the keyword trend, the keyword sports is the keyword that appears for the first time on this topic. This shows that the roots of this

topic start from the application of educational technology to sports. Furthermore, in 2019, multimedia system keywords began to appear alongside e-learning keywords and peaked in 2023 as seen in Figure 4.

VOSViewer analysis result. The relationship between keywords can be seen from the grouping or grouping of several keywords related to physical education. Figure 5 shows a concept map or visualization of the linkage of keywords related to education, sports, technology, and challenges in the context of physical education learning and the application of digital technology, which are grouped into three clusters or groups. The blue color group includes keywords such as communication technology, information, questionnaires, online, and motivation. This cluster shows the relationship between communication technology, information collection through online questionnaires, and student motivation. This shows that communication technology plays an important role in supporting physical education learning through online methods, including collecting data on student participation or motivation more efficiently (Lumbantobing et al., 2024). This technology can also help teachers better understand the needs of their students and provide a more personalized learning experience.

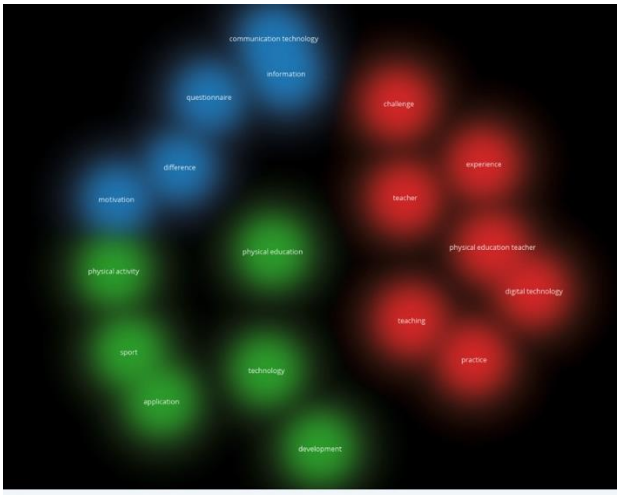

Figure 5. Density visualization (cluster density)

The green cluster focuses on words like sports, physical activity, education, technology, apps, and development. It shows the link between physical education, sports, and the application of technology. The green color describes how technology can be integrated into physical activities and sports, which involves the application of technology in the form of applications or digital devices to support the development of students' skills. It can also involve the use of sports-specific apps or technological tools that aid in the measurement of students' performance and physical activity.

The red color group consists of words such as challenge, experience, teacher, physical education teacher, digital technology, teaching, and practice. This color represents the challenges faced by physical education teachers in implementing digital technology into teaching. These challenges may be related to a lack of experience or training in the use of technology, adaptation to digital change, and how teachers must adapt their teaching practices to incorporate digital tools. The group highlighted the need to overcome these barriers for technology to truly improve the physical education teaching process.

The three-color clusters show the close relationship between technology and physical education and the challenges faced in integrating technology into such learning. These colors help group keywords based on thematic areas that are interconnected between technology and communication (blue), physical education and sports (green), and teaching challenges and teacher experience (red).

***Visualization analysis of topics related and contribution*.** Based on Figure 6, the visualization analysis of topics related to physical education shows that concepts such as 'technology', 'development', 'experience', 'physical education teacher', and 'student' are related to physical education. The lines connecting these elements illustrate the close relationship between technology, development, experience, and the role of teachers in supporting physical education learning. The different colors in these visualizations can be used to group specific categories or themes, such as technology, pedagogy, or physical activity. For example, the terms 'digital technology' and 'application' are connected to 'technology', which indicates the importance of the application of technology in the teaching of physical education. In addition, these aspects are interrelated

in advancing physical education through a modern and interdisciplinary approach. For example, the use of fitness apps or wearables (e.g., smart watches) in physical education classes to track students' physical activity (Filiz et al., 2024). This technology allows for more scalable and interactive teaching.

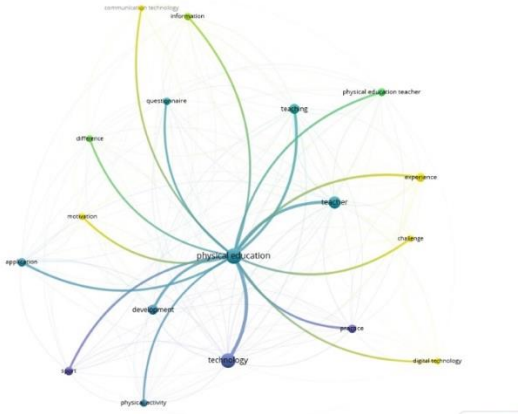

Figure 6. Topics related to physical education

Based on Figure 6, the visualization analysis of topics related to physical education shows that concepts such as 'technology', 'development', 'experience', 'physical education teacher', and 'student' are related to physical education. The lines connecting these elements illustrate the close relationship between technology, development, experience, and the role of teachers in supporting physical education learning. The different colors in these visualizations can be used to group specific categories or themes, such as technology, pedagogy, or physical activity. For example, the terms 'digital technology' and 'application' are connected to 'technology', which indicates the importance of the application of technology in the teaching of physical education. In addition, these aspects are interrelated in advancing physical education through a modern and interdisciplinary approach. For example, the use of fitness apps or wearables (e.g., smart watches) in physical education classes to track students' physical activity (Filiz et al., 2024). This technology allows for more scalable and interactive teaching.

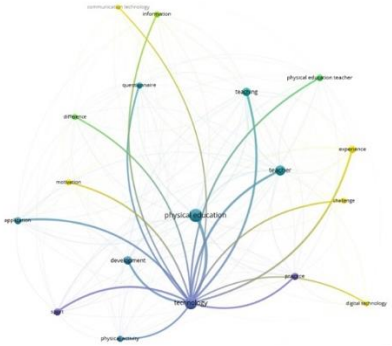

Figure 7. Topics related to technology

Furthermore, the analysis of Figure 7 shows the complex relationships between various concepts in the context of physical education, involving aspects of technology, teaching, development, and student experience. This relationship confirms that physical education not only includes physical activity but is also closely related to the application of modern technology and pedagogical approaches. For example, the link between physical education and technology suggests that technology can be applied to improve the learning experience, such as the use of wearables and fitness apps to monitor students' physical activity. In addition, the relationship between physical education and development highlights the importance of curriculum development programs that focus on improving students' motor skills through innovative and technology-based learning methods (Bangun et al., 2023).

In addition, the relationship with physical education teachers suggests that the role of teachers is crucial in facilitating the student learning experience, where technology such as interactive boards or video tutorials can help teachers explain exercise techniques more effectively (Ospankulov et al., 2023). It also

supports the relationship between experience and teaching, where the student learning experience can be enhanced through teaching methods that focus on interactive and collaborative physical activity, such as team sports games that enhance social skills (Johnson, 2018). In addition, the importance of digital technology in physical education reinforces the idea that the integration of digital technology helps students to be more engaged and motivated in physical activities (Bogdanovskaya & Andreichenko, 2024). In addition, examples of the application of technology in sports learning are technological tools such as smartwatches and sensors used to measure athletes' performance, monitor physical activity, and improve training methods in sports, as discussed in the research paper (Cristina NAE, 2024).

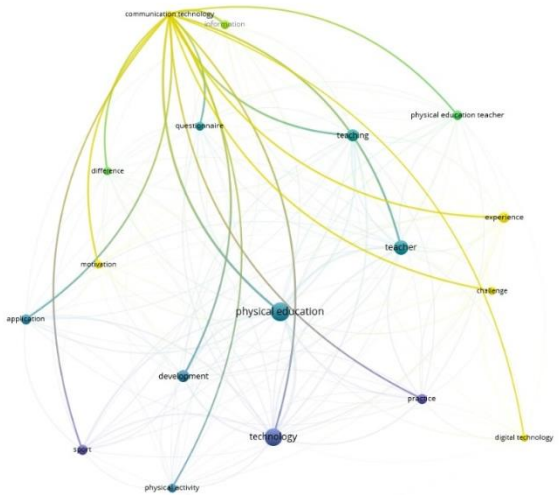

Figure 8. Topics related to communication technology

Figure 8 shows how technology is increasingly playing an important role in improving the quality of physical education learning. For example, the relationship between physical education and communication technology shows the role of communication technology in facilitating the interaction and distribution of information in physical education classes, such as using online learning applications or student-teacher communication platforms (Vampugani et al., 2020). In addition, the relationship between the keywords experience and teachers emphasizes the important role of teachers in creating meaningful learning experiences for students. Teachers can use digital technology to enrich teaching with demonstration videos or interactive sports apps that increase student engagement (Bores-García et al., 2024).

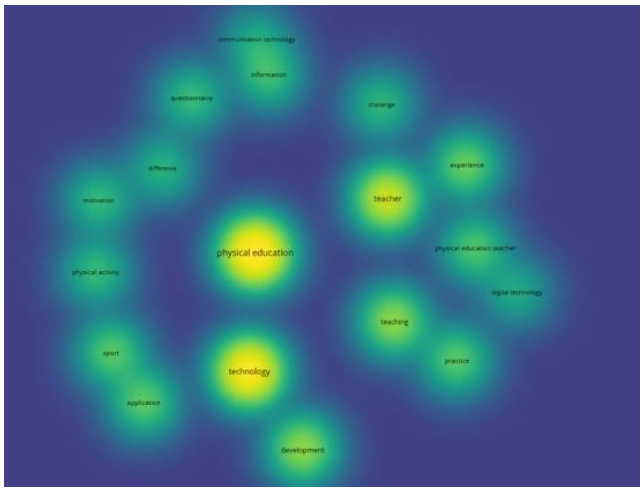

Figure 10. Destiny visualization (item density)

Other relationships such as between physical education and development keywords highlight the importance of development programs that integrate technology to improve students' physical skills, such as app-based exercise programs that track students' fitness progress individually (Brown & Zhang, 2024). Meanwhile, the link between motivation and students shows that the right use of technology can increase students' motivation to participate in physical activities in the classroom (Johnson, 2018). Therefore, the

integration of digital technology in physical education is an important strategy to increase the effectiveness of teaching, both in physical and cognitive aspects.

***Future research opportunities*.** Based on Figure 10, explains future research opportunities, especially those related to the integration of digital technology in physical education. From the visualization of the density of the images, the keywords that appear in lighter colors, such as 'physical education' and 'digital technology', indicate a topic that has been extensively researched. In contrast, darker-colored keywords, such as 'teacher experience' and 'challenge', indicate topics that are still rarely explored. This could be an opportunity for future research, especially on how physical education teachers face the challenge of integrating digital technology into their teaching practices. Research in this area can provide new insights into practical challenges and possible solutions.

Conclusions

Publications related to educational technology in physical education began to appear in 1980 but only developed significantly after 2012. The surge in the number of research developments occurred in the 2020-2024 range, indicated by the Covid-19 pandemic which accelerated the adoption of technology in learning. Retos is the most relevant journal with the most sources of article documents, while "Sport, Education, and Society" is the most impactful journal with the most citations. Authors such as Oksana Blavt and Victoria Goodyear became the most active and influential contributors. In addition, the keywords that are often used in this study, such as "physical education", "teaching", and "learning", reflect a trend that focuses on the integration of technology in physical activity and student-based learning. The results of the VOSViewer analysis identified three main clusters that show the relationship between technology, physical education, and pedagogical challenges. This cluster describes how communication technology, sports applications, and digital devices can support learning, although implementation challenges for teachers are still an obstacle. The visualization further highlights the importance of digital technologies such as fitness apps and implementable devices to enhance student engagement and support more interactive teaching methods. This research also opens up opportunities for future research exploration, especially in overcoming the challenges faced by teachers in integrating digital technology into physical education teaching practices.

Research recommendation. This research has limitations because it only uses data from the Scopus database, so further research can expand its scope by using other databases such as Web of Science or Google Scholar. The main benefit of this research is to provide an evaluation of technological research trends in physical education, as well as provide a valuable reference for future researchers to determine the direction of research, select a target journal, and find opportunities for collaboration with relevant authors or institutions on this topic.

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Solubility of Alkali Metals in Natural Resources and Industrial Wastes: A Study of Dead Sea Salts and Titanium-Magnesium Byproducts

Abstract: This study investigates the solubility of alkali metal chlorides (KCl, NaCl) and magnesium chloride in a KCl–NaCl–$MgCl_2$–H_2O system under varying temperatures. Experimental results show a 4% increase in the solubility of potassium and sodium chlorides and a 15% increase in magnesium chloride solubility between 25°C and 65°C. The study also explores the partial separation of magnesium at lower temperatures, contributing to advancements in waste processing technologies in chemical and metallurgical industries.

Keywords: Solubility, alkali metal chlorides, magnesium separation, technogenic waste, KCl–NaCl–$MgCl_2$ system.

Introduction

The extraction and processing of titanium and magnesium production waste have garnered increasing attention due to the potential recovery of valuable metals, particularly rare and rare earth elements. Mamutova et al. (2018) highlighted the pressing need for innovative solutions to manage chloride waste generated during titanium-magnesium production, suggesting various processing techniques to mitigate environmental impacts and recover useful materials. Building on this foundation, Toishybek et al. (2023) conducted a comprehensive review of recovery technologies for rare and rare earth metals derived from the same industrial waste. Their findings emphasized the importance of developing efficient recovery methods to enhance resource sustainability and reduce the ecological footprint of titanium and magnesium production. Moreover, Kenzhaliyev (2019) explored innovative technologies aimed at improving the extraction processes for non-ferrous, precious, and rare metals, underlining that advancements in technology are crucial for maximizing resource recovery. The evolution of these techniques is vital, especially as industries face increasing pressure to minimize waste and enhance the circular economy. In the context of specific metal recovery, Baigenzhenov et al. (2024) focused on scandium extraction from secondary raw materials, providing insights into the methodologies employed and their efficiency. Their overview of extraction technologies reveals the potential for reclaiming valuable materials from waste streams, further supporting the idea that waste can be transformed into a resource. Collectively, these studies underscore the critical need for continued research and development in waste processing and metal recovery

technologies, particularly in the titanium and magnesium sectors. By implementing innovative approaches, industries can not only reduce environmental impact but also contribute to a more sustainable future.

In modern industry, a wide range of mineral salts of alkali metals and pure metals, particularly lithium, sodium, and potassium, are extensively utilized, each playing a critically important role in various sectors, including nuclear energy, chemical production, and renewable energy technologies. Lithium, in particular, occupies a central position in nuclear technologies due to its isotope ^{6}Li, which is employed in neutron reactions for tritium production—a key component in thermonuclear reactions:

$$^{6}_{3}Li + ^{1}_{0}n = ^{3}_{1}H + ^{4}_{2}He \quad (1)$$

This process not only facilitates tritium generation but also underscores lithium's importance in regulating neutron flux and as a coolant in uranium reactors. Beyond the nuclear domain, lithium finds broad application in the production of lithium-ion batteries for electronics and electric vehicles, as well as in the aerospace industry and medicine as a mood stabilizer (Yoo et al., 2023). Sodium is used as a highly efficient coolant in nuclear reactors, both in its pure form and in alloys with potassium. In the chemical industry, sodium is essential for rubber synthesis and is a crucial component in the production of glass, paper, textiles, and cleaning agents. Sodium vapour lamps, employed in street lighting, demonstrate their importance in energy technologies (Sujit et al., 2022) Potassium, as an element, is indispensable in geochemistry for fertilizer production (Ahmed et al., 2023) Industrially, it is used to obtain potassium peroxide (K_2O_2) by Anil et al. (2022), which is applied for oxygen regeneration in closed systems such as submarines and space stations (John et al.,2008). Potassium also serves as an important catalyst in synthetic rubber production and is used in soap manufacturing and as a coolant in nuclear reactors (Jianwei et al., 2022).

Thus, the role of alkali metals in modern industry is undeniably significant, as they serve as key elements in numerous critically important technological processes, ranging from energy production to the manufacture of everyday consumer goods. Research continues in contemporary industry, focusing on the effects of sodium and potassium hydroxides on the properties and technological processes associated with the use of chemical compounds. Special attention is given to the impact of these alkali metals on the technological parameters of mineral extraction and their application in the creation of geopolymer backfills, which facilitate processes in the mining industry by optimizing the properties of the materials used (Noureddine et al., 2020).

Studies demonstrate that alkali metals enhance the catalytic properties of Fe-Co compounds by increasing the dispersion of active sites, thus promoting the transition from disordered carbon to more ordered forms and removing oxygen-containing functional groups such as O-H. This leads to increased CO_2 output and effectively aids in methane splitting and dehydrogenation of organic compounds, thereby boosting hydrogen yield. In this context, the activity of Na surpasses that of K (Deng et al., 2023).

It was also found that the treatment of cellulose with sodium and potassium hydroxides significantly affects its crystallinity, opening new opportunities for its use in fields such as emulsion stabilization (Wang et al., 2023).

The main part of the research

Materials. The studied samples were provided by Ust-Kamenogorsk Titanium and Magnesium Plant JSC (Ultarakova et al., 2013). The above analysis data confirm the content of controlled components in significant concentrations (Table 1).

Table 1. The content of controlled components, %

Products	*Rb	*Li	Na	K	Mg	Cl
Carnallite	н.о	20	1.13	7.86	8.07	35.62
Spent melt of titanium chlorinators (SMTC)	270	48	0.75	11.09	4.38	41.67
Smelter sludge	90	16	0.82	4.18	18.51	21.40

*The contents of Rb and Li are given in ppm

Methods of Analysis. X-ray diffraction (XRD) analysis of the sludge was performed using a D8 Advance diffractometer (BRUKER) with Cu-Kα radiation. The processing of the obtained diffractograms and the calculation of interplanar spacings were conducted using EVA software. Sample interpretation and phase identification were carried out through the Search/Match program, utilizing the ASTM card database. X-ray fluorescence (XRF) analysis was performed on a Venus 200 wavelength-dispersive spectrometer (PANalytical B.V., Netherlands).

Chemical analysis of the samples was conducted using an Optima 2000 DV inductively coupled plasma optical emission spectrometer (USA, Perkin Elmer). Mineralogical analysis was carried out using an OLYMPUS BX51 microscope (Japan).

Results and discussions

According to the mineralogical analysis of samples 114, 117, and 119, the carnallite supplied to JSC "UKTMK" in an anhydrous state gradually transitions into a crystalline hydrate during prolonged storage. The examined sample contains the mineral carnallite, with the chemical formula $KMgCl_3 \cdot 6H_2O$ (Fig. 1). Carnallite is characterized by an orthorhombic crystal system, which defines its crystalline structure.

The crystals of carnallite take the form of hexagonal pyramids, a typical morphological feature of this mineral. Carnallite ($KMgCl_3 \cdot 6H_2O$) crystallizes in the orthorhombic system, indicating its three-axis symmetry with orthogonal axes of varying lengths. This crystal system defines the specific form of the crystals, which, in this case, are represented by hexagonal pyramids. The absence of well-defined cleavage indicates high structural integrity of the carnallite crystals, reducing the likelihood of fracture along certain planes under mechanical stress.

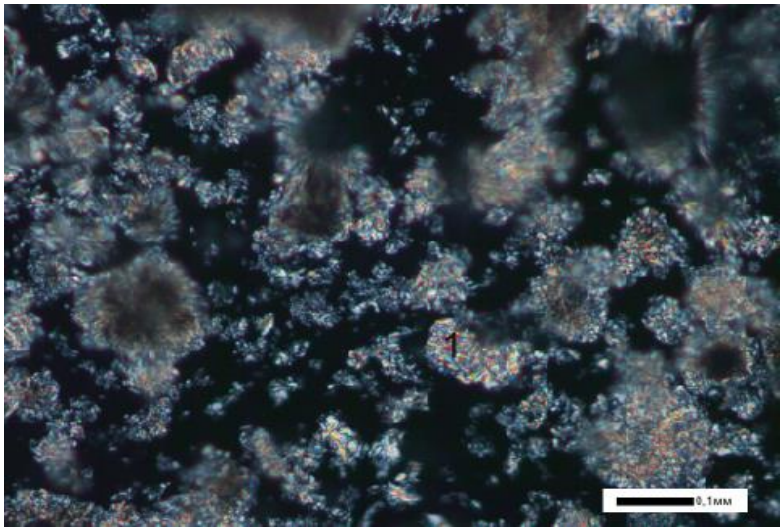

Figure 1. Micrograph of a mineralogical sample of carnallite. Uv.100, nick+

In the analysis of the smelter sludge, two main phases were identified: periclase (MgO) and sylvite (KCl) (Fig. 2). Below are detailed characteristics of these phases, illustrating their crystalline and optical properties.

MgO (Periclase) – Cubic crystal system. Isotropic, colorless. Refractive indices: n=1.7335C, 1.7366D, 1.7475F. Periclase is a mineral with a cubic crystal system and isotropic properties, meaning its optical properties are uniform in all directions, as indicated by its constant refractive index across various wavelengths of light. Periclase is notable for its high refractive indices and absolute isotropy, making it an important material in various technological processes.

KCl (Sylvite) – Cubic crystal system. Cubic crystals with perfect cleavage along the cube. Isotropic, colorless or tinted. Refractive indices: n=1.4872C, 1.4904D, 1.4984F. Sylvite is also characterized by a cubic crystal system and isotropic properties. The cubic crystalline structure provides perfect cleavage along the cube, a key feature for identifying and practically applying this mineral. The refractive indices of sylvite are slightly lower than those of periclase, which is also important to consider in its study and use. Sylvite, with its perfect cleavage and characteristic optical properties, plays a crucial role in industry.

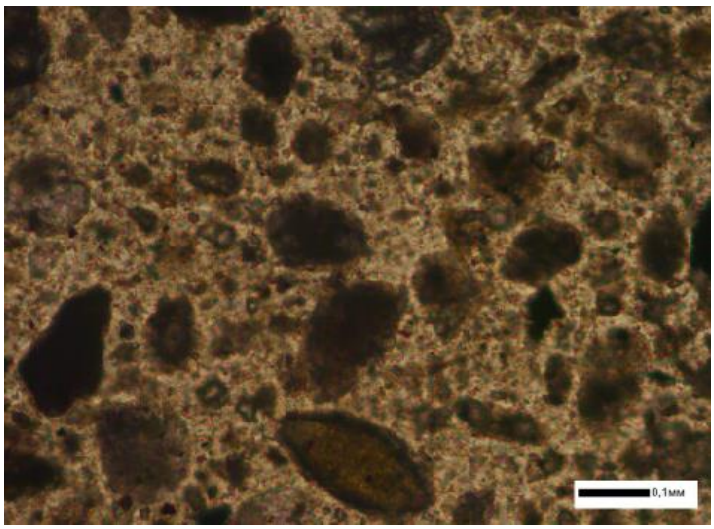

Figure 2. Micrography of a mineralogical sample of the smelter sludge. Uv.100, without analyzer

In the examined sample of (SMTC), two main phases were identified: halite (NaCl) and erythrosiderite ($K_2FeCl_5 \cdot H_2O$) (Fig. 3). These phases differ in their crystalline structure and optical properties, which play an important role in their identification and understanding of their behavior under various conditions.

NaCl (Halite) – Cubic crystal system. Cubic crystals with perfect cleavage along the cube. Isotropic, colorless, or tinted. Refractive indices: n=1.5407C, 1.5443 D, 1.5534F. Halite, also known as rock salt, has a cubic crystal system and isotropic properties, meaning its optical characteristics are the same in all directions. Halite crystals are typically colorless but may be tinted depending on the presence of impurities. The perfect cleavage along the cube is a distinctive feature of halite, making it easily identifiable in both fieldwork and laboratory studies.

$K_2FeCl_5 \cdot H_2O$ (Erythrosiderite) – Orthorhombic crystal system. Perfect cleavage. Refractive indices: Np=1.715, Nm=1.75, Ng=1.8. Color ranges from ruby red to brownish-red. Erythrosiderite is characterized by an orthorhombic crystal system and perfect cleavage. Its optical properties are anisotropic, meaning its refractive indices vary depending on the direction (Np, Nm, Ng). The color of erythrosiderite ranges from ruby red to brownish-red, which is one of the key features for its visual identification.

The phase composition analysis of (SMTC) revealed the presence of halite and erythrosiderite, each possessing unique crystalline and optical properties. Halite is distinguished by its isotropy and perfect cubic cleavage, making it an easily recognizable mineral. Erythrosiderite, with its orthorhombic system and anisotropic optical properties, requires more detailed analysis for precise identification.

These findings are important for understanding the chemical and mineralogical composition of ORTH and can be valuable for further research and application in various technological processes.

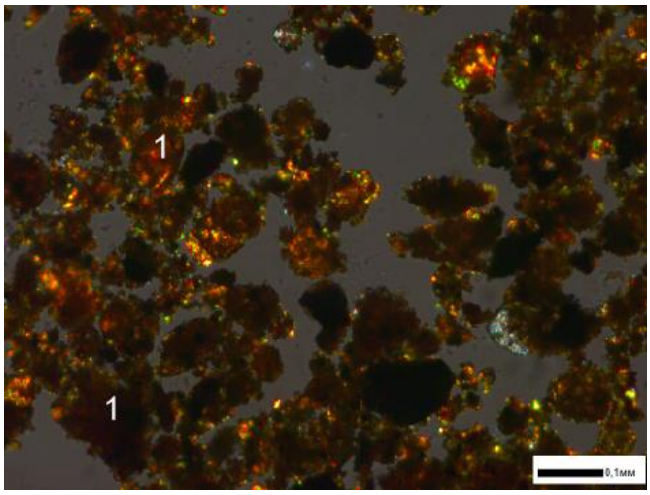

Figure 3. Micrography of a mineralogical sample (SMTC). Erythrosiderite. Uv.100, nick$^+$

To clarify the composition of the studied products, their X-ray phase analysis was carried out (Fig. 4,5,6)

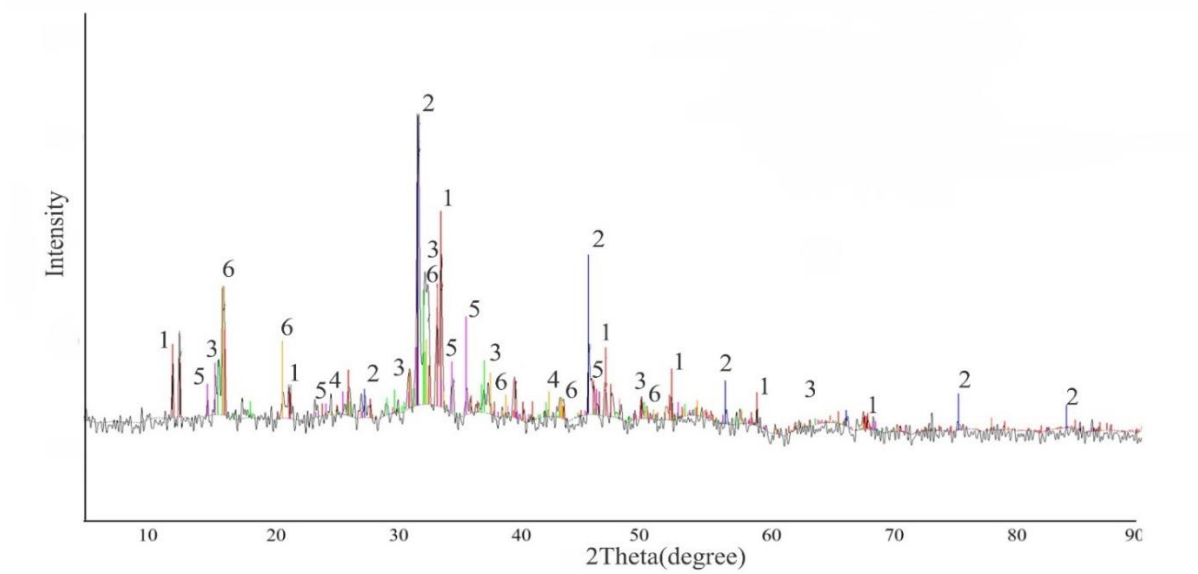

Figure 4. Diffractogram of the carnallite sample

Table 2. Results of X-ray phase analysis of carnallite

Number	Name of the compound	Formula	Content, rel. %
1	Carnallite	$KMgCl_3 \cdot 6H_2O$	45.9
2	Halite, syn	NaCl	21.2
3	Sylvite, syn	KCl	19.6
4	Magnesium Oxide	MgO	5.8
5	Magnesium Peroxide	MgO_2	4.1
6	Chlorartinite, syn	$(Mg_2(CO_3)(H_2O)(OH))Cl(H_2O)_2$	3.4

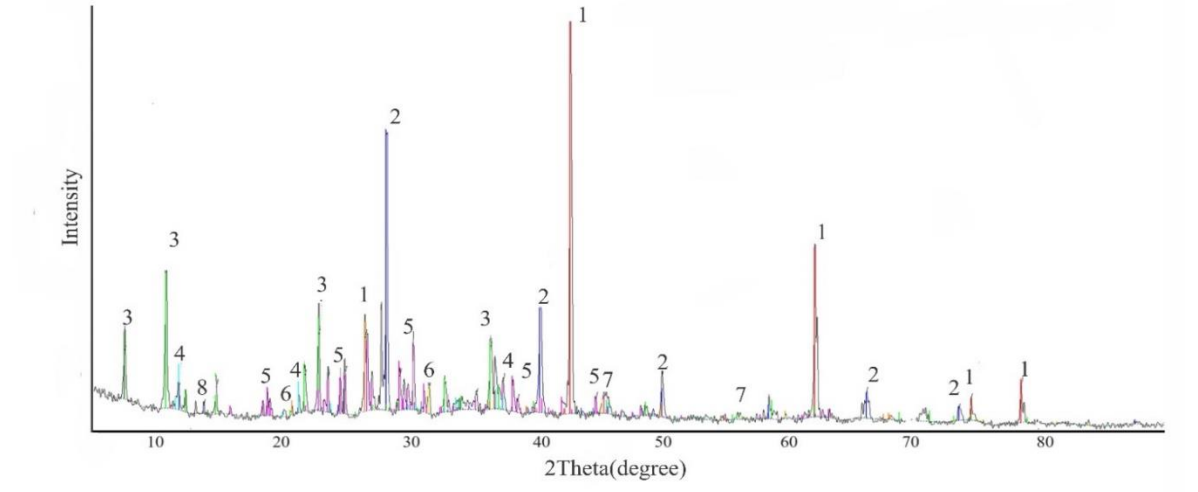

Figure 5. Diffractogram of the smelter sludge sample

Table 3. Results of X-ray phase analysis of the smelter sludge

Phase number	Compound name	Formula	Content, rel. %
1	Periclase, syn	MgO	41.6
2	Sylvite, syn	KCl	27.0
3	Korshunovskite, syn	$Mg_2(OH)_3Cl{\cdot}4H_2O$	12.9
4	Carnallite	$KMgCl_3{\cdot}6H_2O$	6.7
5	Magnesium Aqua Chloride Hydroxide Hydrate	$(Mg_3(OH)_5(H_2O)_3Cl)H_2O$	4.3
6	Quartz, syn	SiO_2	2.6
7	Titanium Oxide	TiO_2	2.2
8	Halite, syn	NaCl	2.6

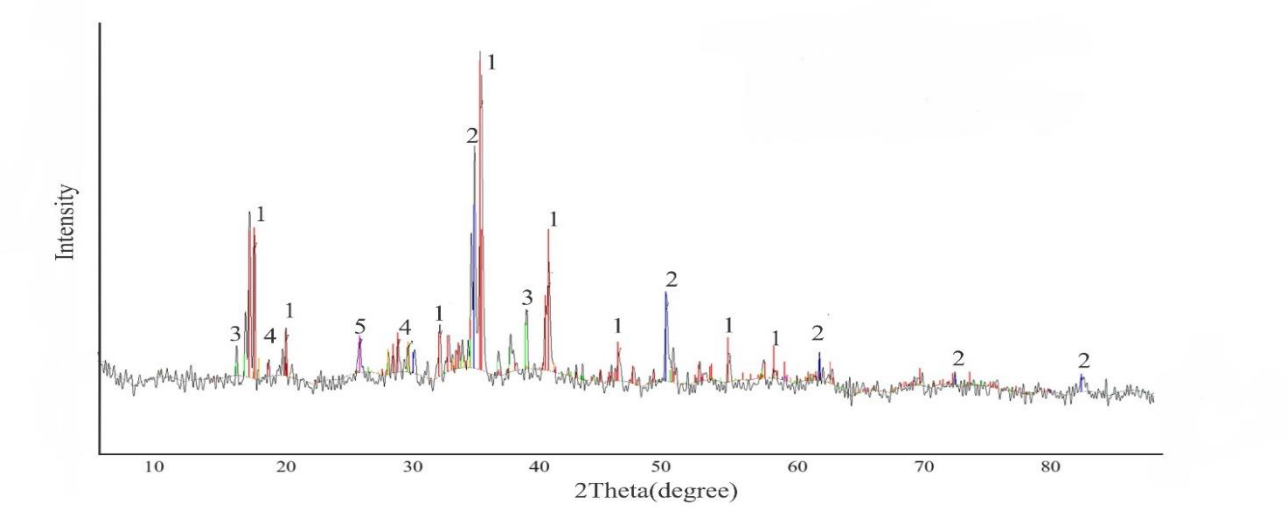

Figure 6. Diffractogram of the (SMTC) sample

According to X-ray phase analysis, the sludge of the smelter includes potassium and sodium chlorides, and potassium is partially bound into carnallite.

The NUT contains highly soluble potassium and sodium chlorides in comparable amounts.

It should be noted that when SMTC is dissolved in water, a certain amount of iron and magnesium will enter the solution.

Table 4. Results of SMTC X-ray phase analysis

Phase number	Compound name	Formula	Content, rel. %
1	Erythrosiderite, syn	$K_2(FeCl_5(H_2O))$	60.0
2	Halite, syn	NaCl	15.8
3	Saltonseaite	$K_3NaMnCl_6$	8.9
4	Potassium Iron Silicate	$K(FeSi_2O_6)$	8.1
5	Bernalite	$Fe^{+3}(OH)_3$	7.2

Conclusions

This study on the solubility of chloride salts of alkali metals and magnesium in the KCl – NaCl – $MgCl_2$ – H_2O system under varying temperatures has revealed key findings. The solubility of potassium and sodium chlorides increased by only 4% between 25°C and 65°C, while magnesium chloride's solubility rose by 15%, highlighting differing behaviours. A novel method for partial separation of magnesium from potassium and sodium chlorides at lower temperatures was developed, which could optimize industrial processes in the chemical and metallurgical sectors. The phase analysis identified crucial minerals like carnallite, halite, and erythrosiderite, contributing to the understanding of these compounds during processing. The research offers practical solutions for improving resource extraction from industrial waste, aligning with sustainable practices, and lays a foundation for further technological advancements.

***CRediT author statement*: R.Abdulvaliyev:** Conceptualization, Methodology, Software. **A. Ultarakova:** Data curation, Writing draft preparation. **A. Mukangaliyeva:** Visualization, Investigation. **A. Yessengaziyev:** Supervision. **N. Lokhova:** Software, Validation. **K. Kassymzhanov**: Reviewing and Editing

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Physical and chemical studies of substandard ilmenite concentrate from the deposit of Obukhovskoye

Abstract: The results of physical and chemical studies of a representative sample of substandard titanium concentrate from the Obukhovskoye deposit are presented. According to the results of X-ray phase analysis, the main components of the concentrate are ilmenite and synthetic rutile, titanium chromium oxide iron chromate, etc. Mineralogical analysis data indicate that the concentrate consists of rutile and ilmenite. The conducted electron probe studies have established that rare and rare earth elements in ilmenite concentrate are found in various minerals in the form of monazite inclusion. The results obtained will be taken into account when developing methods for the complex extraction of valuable components from this raw material.

Keywords: ilmenite concentrate, titanium, chromium, rare earth elements, physical and chemical study.

Introduction

Titanium-bearing placer deposits of the Republic of Kazakhstan contain mainly ilmenite. There is a shortage of titanium raw materials in Kazakhstan, so it has become urgent to process chromium-containing ilmenite concentrates from deposits such as Obukhovskoye and Shokash. The high chromium content in these concentrates makes it difficult to further process them into titanium-containing slag, titanium tetrachloride, and spongy titanium. This poses challenges with the transition of chromium into production waste, requiring extensive purification of the raw material (Akhmetova et al., 2020; Krysenko et al., 2020; Khursanov, Hasanov, Tolibov, 2023)).

The primary types of chromium impurities found in ilmenite concentrates are chromium-containing spinel minerals, specifically spinels that are rich in chromium, such as chromite ($FeCr_2O_4$) and magnesiochromite ($MgCr_2O_4$). In current industrial processes, chromium impurities are removed from ilmenite concentrates through a magnetization firing procedure (Ahmad et al., 2016; Lv et al., 2016).

The current Obukhovskoye deposit which located in the North Kazakhstan region produces industrial products such as zircon-rutile and ilmenite concentrate. The ilmenite concentrate meets the requirements of consumers in terms of titanium dioxide content, but its high chromium content (7.5-8%) prevents its sale (Kenzhaliyev et al., 2024). The developed technology will allow the production of marketable products: REE concentrate and titanium dioxide, thus diversifying the market of titanium products in the Republic of Kazakhstan.

The Ust-Kamenogorsk Titanium and Magnesium Plant, operating in Kazakhstan (UKTMP JSC), receives ilmenite concentrate from the Satpaevskoye field, which accounts for about 30% of its raw materials (the rest is imported from Ukraine). The plant produces titanium metal in the form of ingots and slabs. Ilmenite concentrates from the Obukhovskoye deposit are currently not processed at titanium-magnesium plants due to their high chromium content, despite having sufficient titanium content (Tuleutay et al., 2018).

In world practice, ilmenite concentrates with a high chromium content are practically not processed. In the Republic of Kazakhstan, technologies for processing titanium-containing raw materials with the formation of titanium slags from conditioned ilmenites have been developed, and the titanium-magnesium combine of JSC UKTMKP operates on their basis (Ultarakova et al., 2021).

There are still no implemented technologies for processing chromium-containing ilmenite concentrates. Thus, the purpose of the research is to study to process of substandard ilmenite concentrate and it is necessary to obtain objective data on the composition of the initial ore for the further complex processing of this raw material with the extraction of all valuable components.

Research Methods

The following methods of analysis were used to investigate the composition of the ilmenite concentrate: chemical, X-ray phase, X-ray fluorescence, and electron scanning microscopy. Also, the following types of equipment were used for the study: atomic emission spectrometer Optima 2000 DV (PerkinElmer, Inc., Waltham, MA, USA); X-ray diffractometer D8 Advance BRUKER, Cu α-radiation (BRUKER AXS GmbH, Karlsruhe, Germany); X-ray fluorescence spectrometer Venus 200 PANalytical B.V. (Malvern Panalytical, Almelo, The Netherlands); LEICA DM 2500 P (Leica Microsystems GmbH, Wetzlar, Germany) and JEOL JXA 8230 Electron Probe Microanalyses (JEOL Ltd., Tokyo, Japan).

Research Results

The physical and chemical properties of a batch of substandard ilmenite concentrate from the Obukhov deposit have been studied.

Chemical composition, weight. %: 39,8 Ti; 31,4 Fe; 2,8 Cr; 0,6 Al; 0,4 Si; 0,004 Sr; 0,018 Y; 0,013 Th. The results of the X-ray phase analysis are shown in Table 1. XRD of ilmenite concentrate is shown in Fig. 1.

Table 1-The results of the X-ray phase analysis of the ilmenite concentrate

№	Compound	Content
1	Ilmenite $Fe_{1.04}Ti_{0.96}O_3$	28.4 %
2	Iron chromate $FeCrO_3$	14.4 %
3	Rutile syn. $Ti_{0.912}O_2$	11.7 %
4	Titanium chromium oxide $(Ti_{0.97}Cr_{0.03})O_2$	10.5 %
5	Pseudorutile $Fe_2Ti_3O_9$	10.3 %
6	Titanium iron oxide $Fe_2Ti_3O_9$	10.2 %
7	Panguite $Ti_{1.67}O_3$	8.1 %
8	Iron oxide (III) Fe_2O_3	6.4 %

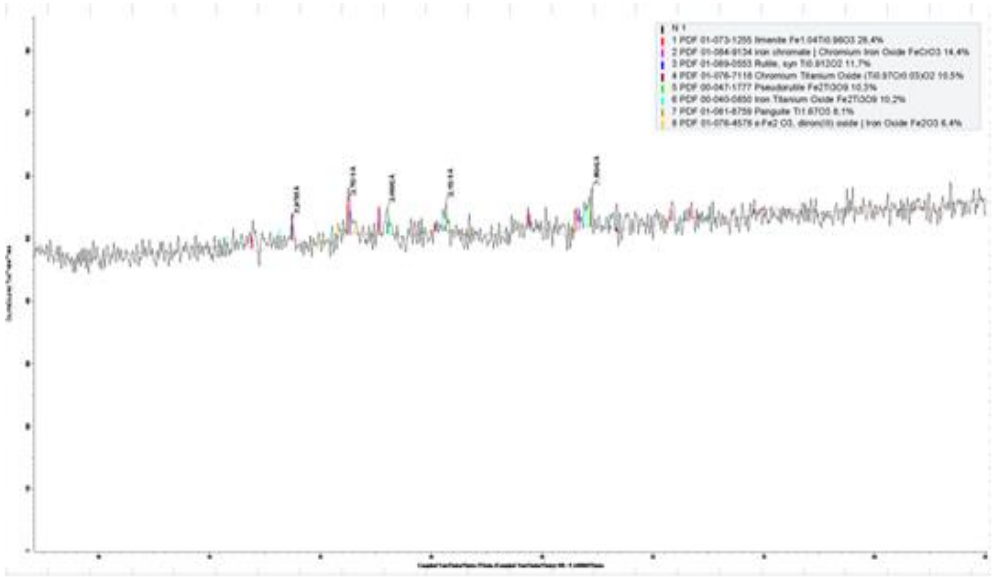

Figure 1 – XRD of ilmenite concentrate

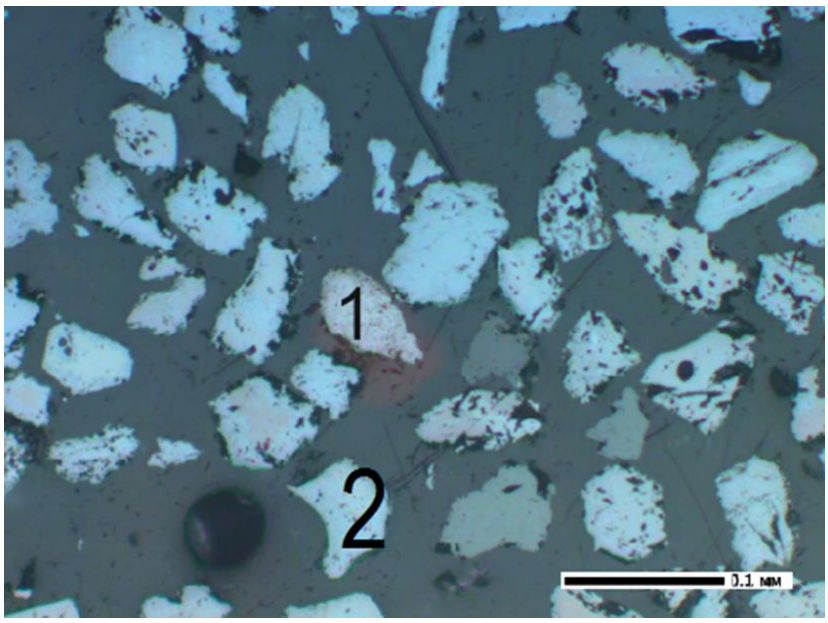

Figure 2 - Rutile (1) and ilmenite (2). Sample №1, ×200

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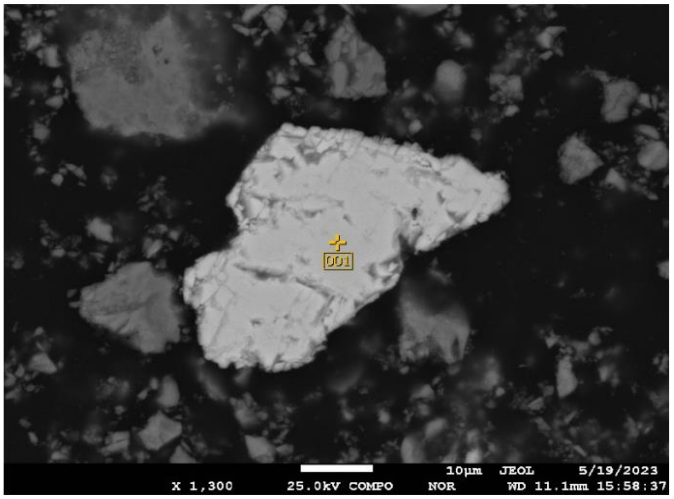

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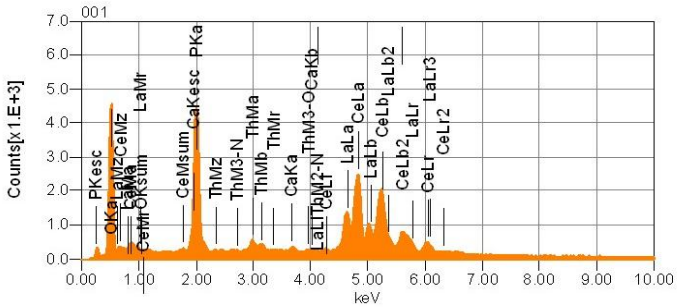

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Live time : 60.00 sec.
Real Time : 71.32 sec.
DeadTime : 16.00 %
Count Rate : 7331.00 CPS

Chemical formula	ms%	mol%	Sigma	Net	K ratio	Line
O	40.23	76.18	0.21	923960	0.1946111	K
P	14.28	13.97	0.12	1479674	0.0982318	K
Ca	0.55	0.41	0.13	72735	0.0045679	K
La	11.47	2.50	0.41	724505	0.0830271	L
Ce	29.92	6.47	0.40	2061241	0.2291432	L
Th*	3.56	0.46	0.43	204496	0.0205343	M
Total	100.00	100.00				

Figure 3 - The results of the EDS analysis of REE containing particles of ilmenite concentrate

According to the results of X-ray fluorescence and chemical analysis, chromium is present in the sample. According to the results of X-ray phase analysis, chromium is represented in the concentrate by minerals of the spinel group, namely spinel (aluminochromite), and chromite (chrompicotite).

The study involved analyzing the material composition of ilmenite concentrate samples from the titanium-zirconium placers of the Obukhovskoye deposit. The samples were crushed for X-ray phase and X-ray fluorescence analyses. Polished artificial plates (briquettes) were made from the samples for further study.

Rutile (TiO_2) is a light gray mineral with low reflectivity. It has thick brown internal reflexes with a reddish tinge and is anisotropic (Sun et al., 2011). It is marked in the form of an anhedral shape (Fig. 2).

Ilmenite ($FeO{\cdot}TiO_2$) is a gray mineral with high hardness, clear reflection, and strong anisotropy. It has an irregular shape with sinuous borders (Fig. 2).

With the magnification of x1300 (Fig. 3), the phases of the rare earth elements monazite (Ce, La, Nd, Th) were detected in the studied sample [PO_4]. Monazite is a mineral belonging to the lanthanide phosphate class, mainly cerium (Ce), lanthanum (La), neodymium (Nd), praseodymium (Pr), thulium (Tm), gadolinium (Gd), samarium (Sm), as well as scandium (Sc), yttrium (Y), along with lanthanides, they are classified as rare earth elements and impurities of actinides — thorium (Th), uranium (U) with the general chemical formula M(III)PO_4 (Naumov, 2008). Due to the content of thorium and uranium, it is weakly radioactive. It is an ore of rare earth elements and thorium.

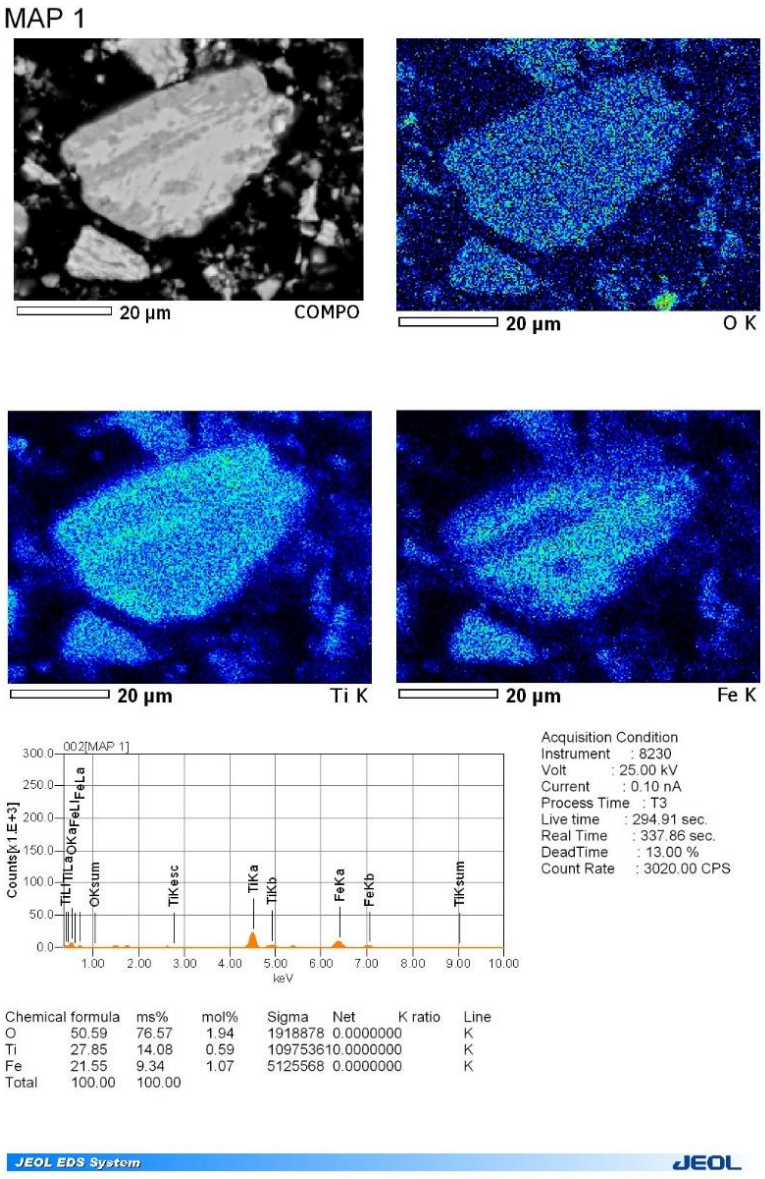

Figure 4 - SEM-EDS elemental mapping of ilmenite concentrate

The elemental mapping using SEM-EDS was performed to obtain information on the distribution of Fe, Ti and O elements between phases in the samples. Furthermore, this supported the findings of the chemical analysis and EDS analysis.

Conclusion

Ilmenite concentrates from the Obukhovskoye deposit are currently not processed at titanium-magnesium plants due to their high chromium content, their processing is relevant in terms of expanding titanium raw materials. Thus, in the process of physical and chemical studies, objective data were obtained on the material composition of substandard ilmenite concentrate from Obukhovskoye deposit. It also identifies the features of the minerals present in the composition. The results of the electron probe analysis showed the activation of the REE phosphate lattice using the example of monazite. These results are crucial for developing methods to extract valuable components from this raw material effectively. The obtained results should be taken into account when developing methods for the complex extraction of valuable components from this raw material.

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Sorption of rare earth metals under static conditions from solutions after leaching of phosphogypsum

Abstract: Processing of apatite raw materials is associated with the formation of multi-tonnage waste - phosphogypsum. The content of rare-earth metals in such waste reaches 1 %, which allows us to consider it a man-made source of rare-earth metals and their compounds. Until now there are neither processing enterprises nor effective technological processes for phosphogypsum processing. It is rational to use a method involving the extraction of valuable components and the overall reduction of phosphogypsum volumes. One such method can be the sorption extraction of REM after leaching of phosphogypsum with hydrochloric acid. In this work the results of sorption by sulphocationites are presented: Purosorb SAC 140 (in H- and Na-forms); Purolite C150 (in H- and Na-forms) and Puromet MTC 1600 (in H- and Na-forms).

Keywords: Rare earth metals (REM), sorption, hydrochloric acid, phosphogypsum, sorbent.

Introduction

Rare earth metals (REM) are one of the most important raw materials that ensure the development of modern knowledge-intensive industries. REMs are essential for such high-tech industries as space, aviation nuclear, and radioelectronics. In connection with the increasing demand for rare earths in various industrial fields and with the growth of REM prices on the world market, the problem of developing new raw material sources is now becoming increasingly necessary. One of the most promising sources of technogenic raw materials for REM extraction is phosphogypsum - the main by-product of phosphoric acid production by sulphuric acid decomposition of phosphate raw materials. Being a product of the chemical process, phosphogypsum, unlike natural gypsum, contains several residual components such as phosphorus, fluorine, and REM. The direct use of phosphogypsum in industrial production, in agriculture can negatively affect its consumption due to the presence of harmful components. In addition, valuable components present in phosphogypsum are lost. Depending on the process conditions, about 70-85 % of the rare earth elements (REE) initially present in the phosphate rock are transferred to the phosphogypsum (Najmanbaev et al., 2015; Koopman & Witkamp, 2000; Kenzhaliyev, 2019; Litvinova & Oleynik, 2021; Kulczycka, et al., 2021).

The process of sorption on organic ions is one of the most promising ways to concentrate REM from highly dilute solutions. This method has several advantages: simplicity of apparatus design, economy and environmental friendliness.

The work aims to study the process of sorption of rare-earth metals from the prepared solution after hydrochloric acid leaching of phosphogypsum under static conditions with the use of the above-mentioned sorbents at different ratios of the amount of sorbent to a given volume of solution.

Research Methods

Cation exchange resins are produced by industry in sodium form. Cationic resins in sodium and hydrogen forms were used for research. Ionites were purified from synthesis products and converted to H-form by hydrochloric acid solution (GOST, 1964). A certain volume of each ionite pre-swollen in distilled water was loaded into glass columns. Then 5% hydrochloric acid solution was passed through each column at a rate of 3 wpm until the acid concentration was equalised at the inlet and outlet. Ionites from acid were washed with distilled water to pH = 6 - 7. The prepared ionites were dried at 50 °C to constant weight.

To investigate the process of sorption of rare earth metals, solutions containing REM were preliminarily produced by leaching of phosphogypsum, a waste product of sulfuric acid processing of apatite concentrate. 20 litres of solution containing, g/dm^3: 0,04475 ΣREM; 3,12 Ca; 0,486 Al; 0,45 Fe; 0,13 Mg. The elemental content of rare earth metals in solution is, mg/dm^3: 9.87 Ce; 0.86 Dy; 6.21 Er; 0.25 Eu; 1.5 Gd; 0.14 Ho; 8.68 La; 0.05 Lu; 5.23 Nd; 1.54 Pr; 0.06 Sc; 0.89 Sm; 0 Tb; 0.3 Tm; 8.97 Y; 0.2 Yb.

The following macroporous sulphocationites were used as sorbents for REM sorption: Purosorb SAC 140 (in H- and Na-forms); Purolite C150 (in H- and Na-forms) and Puromet MTC 1600 (in H- and Na-forms).

The quantitative content of basic elements in solutions was determined on an atomic emission spectrometer with inductively coupled plasma Optima 8300DV, on an atomic absorption spectrometer SHIMADZU type AA-7000 (Japan).

Research Results

Sorption was carried out under static conditions at a temperature of 25 ± 5 °C on an orbital shaker with a rotation speed of 160 rpm. To perform sorption, a certain amount of cationites in H- and/or Na-form was placed in dry flasks of 0.25 dm^3 volume, poured a given volume of solution containing REM, and set on a stirring device. Contact of cationites with the solution was carried out for 5 days with stirring on three working days, then the solution was separated from the ionite by filtration.

The stock solution and sorption filtrates were analysed for the content of rare earth metals and associated impurity components.

As shown in Figure 1, that at 0.1 g of sorbent per 100 ml of solution the best performance on recovery of 45.2 % of REM has sorbent Puromet MTC 1600 in Na-form, when increasing the amount of sorbent from 0.1 to 0.4 g per 100 ml of solution sorbent Purosorb SAC 140 in Na-form showed almost the same recovery of 43.7 % of REM. Purolite C150 sorbent showed lower recovery of REM. Further increasing the amount of sorbent to 0.6 g per 100 ml of solution did not show higher REM recovery results on the sorbents. Compared to H-form, Na-form is more effective for all studied sorbents.

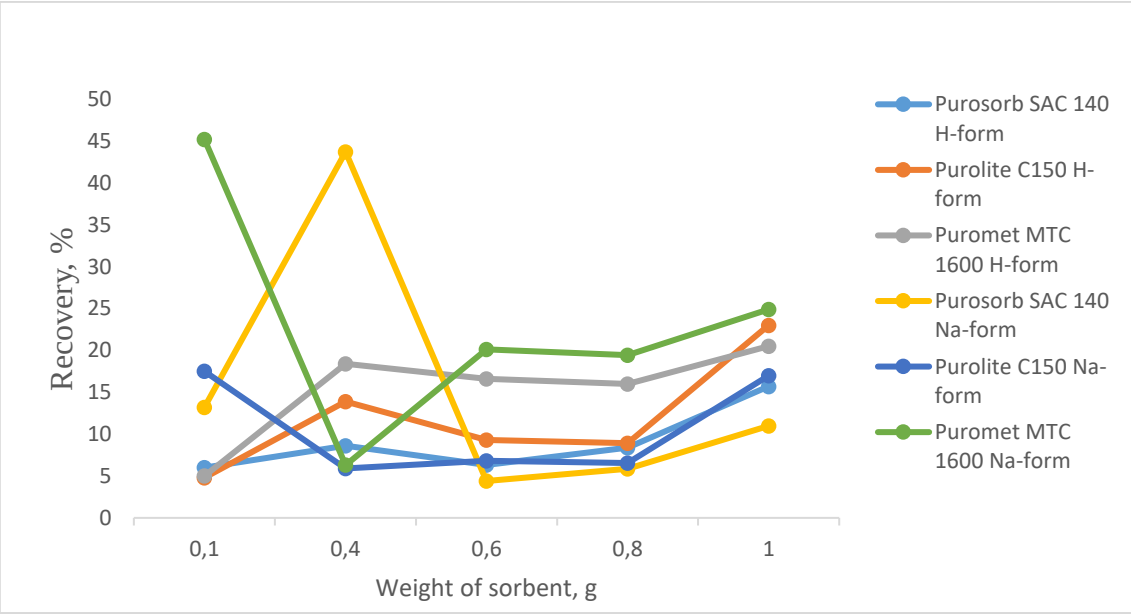

Figure 1. Sorption of REM from solution after phosphogypsum leaching on strongly acidic cationites

We were also interested in the behaviour of calcium, magnesium, aluminium and iron impurities during the sorption of rare-earth metals from hydrochloric acid solutions on the studied macroporous sulphocationites. Tables 1-4 present data on the behaviour of the listed impurity components during sorption of rare-earth metals from solution.

Table 1 - Calcium sorption from solution after phosphogypsum leaching on strongly acidic cationites

Quantity of sorbent per 100 ml of solution, g,	Calcium recovery per sorbent, %					
	H-form			Na-form		
	Purosorb SAC 140	Purolite C150	Puromet MTC 1600	Purosorb SAC 140	Purolite C150	Puromet MTC 1600
0.1	0	0	0	13.1	0	45.8
0.4	-	-	6.29	4.0	-	37.1
0.6	0.18	0.8	5.3	2.4	19.2	3.4

The most interfering impurity in sorption, taking into account its content in solution, is calcium.

Table 2 - Magnesium sorption from solution after phosphogypsum leaching on strongly acidic cationites

Quantity of sorbent per 100 ml of solution, g	Magnesium recovery per sorbent, %					
	H-form			Na-form		
	Purosorb SAC 140	Purolite C150	Puromet MTC 1600	Purosorb SAC 140	Purolite C150	Puromet MTC 1600
0.1	0	1.5	0	0	3.1	0
0.4	2.3	0	0	0	0	0

Table 3 - Sorption of aluminium from solution after phosphogypsum leaching on strongly acidic cationites

Quantity of sorbent per 100 ml of solution, g	Aluminium recovery per sorbent, %					
	H-form			Na-form		
	Purosorb SAC 140	Purolite C150	Puromet MTC 1600	Purosorb SAC 140	Purolite C150	Puromet MTC 1600
0.1	0	7.2	7.4	17.0	19.0	9.0
0.4	11.1	14.5	19.2	22.3	23.2	14.0
0.6	2.3	0.8	1.7	1.0	4.8	5.4

Table 4 - Sorption of iron from solution after phosphogypsum leaching on strongly acidic cationites

Quantity of sorbent per 100 ml of solution, g	Iron recovery per sorbent, %					
	H-form			Na-form		
	Purosorb SAC 140	Purolite C150	Puromet MTC 1600	Purosorb SAC 140	Purolite C150	Puromet MTC 1600
0.1	0	7.3	8.7	14.5	15.3	5.9
0.4	13.1	10.0	22.8	20.1	23.4	15.0
0.6	7.9	5.5	11.1	16.8	17.6	5.2

According to the analysis of sorption filtrates calcium is sorbed by sorbents Purosorb SAC 140 and Puromet MTC 1600 in Na-forms at all ratios of sorbent mass to solution volume. When the amount of sorbent is increased to 0.6 g per 10 ml of solution, calcium is sorbed by all resins in hydrogen and sodium forms. At further processing of saturated resins, it is necessary to take into account the presence of calcium impurity in them.

As the results of analyses of sorption filtrates at all studied cationites from the considered impurities magnesium is practically not sorbed on sorbents, except for single cases.

Aluminium and iron impurities are sorbed with an average degree, practically in all cases. At the same time in studies at sorption of rare-earth metals on sulfocationite KU-2, it was found that aluminium and iron are weakly retained by the resin and do not interfere with the extraction of REM concentrate (Lokhova et al., 2018; Mihajlichenk et al., 2015; Papkova et al., 2016).

Conclusions

Thus, the obtained results of REM sorption studies on different sulfocationites showed that the most acceptable for further studies on sorption under dynamic conditions to extract REM from hydrochloric acid solutions after phosphogypsum leaching are Purosorb SAC 140 and Puromet MTC 1600 in Na-forms, which showed the best REM recovery rates, 43.7 and 45.2 %, respectively.

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Analytical review of the theoretical prerequisites for developing flotation reagents based on sulfur-containing compounds and their compositions

Abstract: Innovative strategies for developing straightforward and efficient technologies are necessary due to the depletion of conditioned ore sources and the rising proportion of low-grade and technogenic raw materials utilized in production. Special emphasis is placed on flotation agents, as flotation is a primary method for processing low-grade, challenging thin scattered ores. An analytical evaluation of the evolutionary progression of theoretical foundations for formulating fundamental flotation agents and their combinations derived from sulfur-containing compounds utilized and suggested for application in the mining sector is offered. Collective flotation reagents, both traditional and contemporary, are crucial for effective processing, particularly in froth flotation and solid-liquid separation. The pursuit of novel and enhanced reagents is both technological and ecological, mirroring the dynamic difficulties faced by the business. This work aims to summarize and analyze the existing theory and practice of using collector mixes in sulfide flotation, encompassing both practical applications and research, to offer insights and recommendations for developing a predictive technique.

Keywords: sulfur-containing, flotation agent, composite collector, flotation.

Introduction

Reagents play a pivotal part in the flotation process. A defining aspect of the chemicals employed in the flotation process is their selective activity concerning various phase boundaries and, specifically, different mineral surfaces, contingent upon the conditions established in the aqueous medium of the pulp. This selectivity is invariably linked to a marked specificity of adsorption, adsorption-chemical, electrochemical action, or chemical reaction within the liquid phase of the pulp (Shubov, Ivannov & Shcheglova, 1990; Kenzhaliyev, 2019; Zhapbasbayev et al., 2021; Semushkina et al., 2023; Abikak et al., 2023; Argyn, Zoldasbay & Dosmukhamedov, 2024). These mechanisms alter the wetting conditions of individual mineral grains' surfaces, hence affecting their adherence to bubbles.

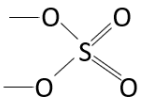
Flotation reagents can be classified based on their chemical composition into organic and inorganic groups, based on physical and chemical characteristics into soluble and insoluble in water, and based on their application across various industries such as chemical, petrochemical, oil refining, and metallurgy. Currently, the classification of reagents proposed by A.M. Gaudin (1957) is utilized and has been admitted. Gaudin classifies flotation reagents into the following categories:

- collectors - organic compounds that adhere to the surfaces of specific minerals, facilitating the formation of hydrophobic films;
- foaming agents - substances that concentrate at the water-air interface, aiding in the stabilization of air bubbles in a dispersed state;
- depressors - agents that diminish the flotability of minerals, inhibiting the attachment of collectors to mineral surfaces;

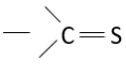
- activators - compounds that enhance the attachment of collectors to mineral surfaces, counteracting the effects of depressors;

- medium regulators - substances that influence the interaction of collectors by modulating the ionic composition of the pulp.

The primary agents for the flotation of non-ferrous minerals are collectors, which in the polar group possess a reduced sulfur atom (= S), in contrast to an oxidized sulfur atom, as seen in sulfuric acid derivatives.



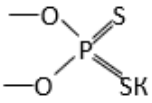
Based on the atom to which the sulfur atom is attached, the entire category of collectors can be divided into two classifications: 1) xanthates, where the sulfur atom is bound to a carbon atom.



or 2) Aeroflot's, wherein the sulfur atom is connected to a phosphorus atom.

Xanthates were initially identified by Zeiss in 1822 and remained unutilized in beneficiation for nearly a century, serving solely in the production of fake liquor and the vulcanization of rubber. Keller introduced its application as a flotation reagent. The primary rationale for the collecting action of xanthates is the presence of xanthogenic acid ions, while alkali metal ions exert no influence on flotation. Butyl and ethyl xanthates are predominantly utilized in flotation practices.

Di-alkyl di-thiophosphates, or aeroflots, are thionic derivatives of di-alkyl phosphoric acid esters in which oxygen atoms are substituted with sulfur. Aeroflot is produced through the interaction of pentasulfuric phosphorus with alcohols at temperatures ranging from 50 to 80˚C. Potash, soda, or ammonium carbonate is included in the resultant di-thio-phosphoric acid for neutralization.



The polar group of di-thiophosphates resembles that of xanthates, differing only in the inclusion of phosphorus in place of carbon.

In flotation, many chemicals are typically employed concurrently, with their effects being interdependent and contingent upon their respective concentrations.

One principle in the formulation of selective reagent systems is the utilization of combinations of strong and weak collectors. Three approaches exist for the implementation of this principle concerning sulfide minerals: the utilization of ionogenic sulfhydryl collectors with varying hydrocarbon radical lengths and distinct solidophilic groups; the application of ionogenic sulfhydryl compounds (such as di-thiophosphates and xanthates) as potent collectors, alongside non-ionogenic compounds (including low-polarity thiono-carbamates, xanthogenic acid esters, and disulfides) and polar compounds as weaker collectors.

Research conducted by the Institute of Mining Engineering of the USSR Academy of Sciences since 1952 has empirically demonstrated the potential for enhancing the flotation process through the simultaneous application of xanthates with varying hydrocarbon radical lengths, alongside the amalgamation of long-chain xanthates with diethyl dithiophosphates. Experimental evidence demonstrates the establishment of a denser adsorption layer when utilizing combinations of collectors (ethyl xanthate, amyl xanthate, diethyl dithiophosphate) on arsenopyrite and galena. The optimal flotation outcomes are attained with the combination of amyl xanthate and di-ethyl di-thiophosphate at a mass ratio of 1:1, and with the compound of ethyl xanthate and amyl xanthate at a molecular ratio of 2:1. The concurrent use of multiple

collectors is proposed to enhance the formation rate of the adsorption layer due to the mineral surface's heterogeneity and the presence of sorption centers with varying affinities for different collectors, resulting in improved flotation kinetics (Ignatkina, 2009).

The findings of laboratory investigations on established sulfhydryl collectors and novel modified di-thiophosphates from the Beraflot series for the flotation of monomineral fractions of pyrite, chalcopyrite, galena, and sphalerite are reported.

The enhancement of selectivity in flotation reagent modes for sulfide ores containing copper, zinc, lead, iron, and gold minerals relies on the utilization of a combination of weak and strong collectors from the same class, such as the simultaneous application of xanthates with varying hydrocarbon chain lengths and the integration of xanthates with di-thiophosphates. Combinations of weak and powerful collectors of various types—ionogenic and non-ionogenic—such as xanthates and thiono-carbamates; di-thiophosphates and thiono-carbamates; esters of xanthogenic acids; xanthates and apolar oils, among others.

The mechanics of thiol collector adsorption on sulfide minerals have been extensively studied over the years. Consequent to these investigations, several theories have emerged, specifically:

- the chemical theory proposed by (Taggart et al. 1934);
- the ion exchange theory articulated by Sutherland, Wark (1955), and Gaudin (1957);
- the neutral molecule theory posited by Cook and Nixon (1950);
- and an electrochemical model developed by several researchers (Plaksin and Shafeev,1963; Tolun and Kitchener,1964; Majima and Takeda, 1968; Allison et al.,1972; Woods,1976; Richardson et al., 1984; and Chander, 1988; Fuerstenau, Natalie & Rowe, 1990).

The chemical theory posits that "all dissolved reagents operate through established chemical reactions between the reagent and the affected particle." This theory presupposes that the mineral or its oxidation product present at the surface is more soluble than the product resulting from the interaction between the mineral surface and the collector ions. Wark (1955) formulated the ion exchange theory based on the premise that sulfides are typically floated with coverage below a monolayer. Sutherland and Wark (1955) established that merely one per cent coverage is necessary for floating. The authors assert, "When the collector exists as a monolayer or less, no direct correlation with the solubility product is necessary." The ion exchange theory posits that xanthates adsorb onto sulfide surfaces through exchange with adsorbed ions, including carbonate, hydroxyl, and sulfur oxide.

The neutral molecule idea proposed by Cook and Nixon (1950) is founded on the hydrolysis of xanthate to xanthic acid in solution. This idea posits that xanthic acid is essential for the formation and release of water through the interaction of hydrogen ions from xanthic acid with adsorbed hydroxyl ions.

In the context of the electrochemical model, when a sulfide mineral is immersed in an aqueous solution, it generates a potential known as the resting potential. When the resting potential exceeds the reversible potential for xanthate oxidation, xanthate undergoes electrochemical oxidation to di-xanthogen on the mineral surface, while oxygen is released as hydroxyl. Pyrite, arsenopyrite, and pyrrhotite are classified within this category when ethyl xanthate is present (McFadzean, Castelyn & O'Connor, 2012).

A micro flotation investigation was conducted utilizing various ratios of ethyl and isobutyl chain lengths of xanthates, dithiocarbonates, and dithiophosphates as collectors, by these stipulations. Flotation recoveries and galena rate constants were analyzed about particle size to see whether the combinations of collectors yielded any advantageous effects relative to the employment of individual collectors. Combinations of ethyl xanthate and ethyl thiocarbamate showed a considerable enhancement in the rate and recovery of galena flotation relative to the use of individual collectors. The recovery rates diminish when employing a combination of ethyl xanthate and ethyl di thiophosphate. Nonetheless, isobutyl xanthate, when utilized as a sole collector, outperformed mixes in every instance.

Russian researchers examined the impact of collector mixes on the flotation process. Microradiography was employed to ascertain the galena surface coverage of xanthate mixes with varying alkyl chain lengths (Ignatkina, 2010; Bacharov et.al., 2005) . It was established that enhanced galena recovery resulted from a denser and more uniform surface coverage achieved through the application of a mixture of ethyl and butyl xanthate.

Adkins and Pearse (1992) saw enhancements in copper recovery rates from a mixed sulfide/oxide copper ore utilizing xanthate–di-thiophosphate combinations. Bradshaw and O'Connor (1994) discovered that combinations of cyclohexyl di-thiocarbamate with an additional di-thiocarbamate enhanced recovery,

grade, flotation rate, and coarse particle recovery, and decreased the necessary concentration for the batch flotation of pyrite ore.

Consequently, substantial experimental evidence indicates enhanced flotation performance when employing collector mixtures. Nevertheless, a comprehensive fundamental comprehension of the mechanics behind this phenomenon has not yet been attained.

Several explanations have been proposed to elucidate the improved flotation observed with mixes. Plaskin and Zaitseva (1960) ascribed improved performance to the concept of "collector-specific" locations on the mineral surface. Various sorption centers will exhibit distinct actions about the different collectors. They hypothesized that this led to increased adsorption kinetics, which consequently resulted in an enhanced flotation rate.

Hanson et al. (1985) posited that, in a binary xanthate-glycine system, glycine facilitated enhanced adsorption of xanthate by the creation of metal glycinate complexes, which subsequently react with the xanthate and ultimately adsorb onto the mineral surface. It is recognized that xanthate adsorbs in several layers on a mineral surface and requires minimal assistance from a co-collector. Bradshaw and co-authors have proposed a method that suggests either selective adsorption of collectors onto certain spots or the precise orientation of molecules, leading to enhanced surface coverage. Subsequently, the elevated reaction heat observed with mixes indicated that the presence of di-thiocarbamate enhanced the oxidation of xanthate to di-xanthate or that a more robust link was established when utilizing combinations of collectors. The di-thiocarbamate was also suggested to function as an anchor for the secondary adsorption of di-xanthogen molecules.

The hypothesis of strong and weak sites, akin to that proposed by Plaskin and Zaitseva (1960), was introduced for a xanthate-di-thiophosphate mixture, wherein the stronger collector occupies the weaker, more oxidized sites, while the weaker collector occupies the stronger, less oxidized sites. This would yield a denser and more uniform surface coverage. Alternative recommendations have been suggested concerning the mechanisms involved in the use of collector mixes. This encompasses alterations in froth behavior, heightened collector adsorption, and enhanced particle hydrophobicity.

The advantageous effects of collector mixes diminish with increasing dosages and the predominance of a more potent collector.

Consequently, the evidence indicates that the theory about the interaction of flotation agents with minerals is continually evolving, thereby establishing the foundation for the formulation of novel, more effective flotation reagent compositions.

A series of studies examined the influence of the ratio of sulfhydryl ionogenic collectors, specifically butyl xanthate or isobutyl di-thiophosphate, in conjunction with thiocarbamates; the ratio of butyl xanthate combined with the sulfhydryl collector M-TP (a mixture of thionocarbamate and di-thiophosphate) on the flotation rate of non-ferrous minerals. It was determined that augmenting the amount of butyl xanthate in any mixture enhances the flotation rate of all monominerals (Ignatkina et al., 2015; Ignatkina, 2016). The application of reagent M-TF in conjunction with butyl xanthate on a copper-coal ore sample resulted in the selective separation of copper sulfides in the initial fractions, surpassing the efficacy of the usual reagent protocol utilizing butyl xanthate. The optimal flotation rate constant is achieved with a 4:1 and 3:1 ratio of M-TF to butyl xanthate, contingent upon the ore's material composition.

It is noteworthy that several enhanced modifications of Aeroflot, produced at the Institute "Mekhanobr" and CJSC "Mekhanobr-Orgsintez-Reagent," are currently being utilized effectively in industry.

The reagent IMA-1012A, an aqueous solution of sodium or ammonium salts of di-alkyl-di-thio-phosphoric acids derived from fatty alcohols with a broad range of C9 - C12, is utilized at ALROSA's beneficiation facilities. This reagent enhances diamond recovery in the foam separation process, using 10 to 15 times less than butyl Aeroflot.

A variation of Aeroflot is endorsed and has been effectively utilized for several years at "Primorsky GOK." This reagent significantly enhances the selectivity of flotation for copper ores containing arsenic, yielding a copper concentrate with arsenic level below 1.0%. The introduction of Aeroflot decreased collector consumption by 4-5 times, with Aeroflot usage at 30-40 g/t compared to 150 g/t of butyl xanthate.

Currently, in light of the prevailing conditions in the non-ferrous metals market, research is being conducted on the broader application of reagents from the class of di-alkyl di-thiophosphates at Russian firms. A prototype batch of FRIM-9 reagent was manufactured and sent for industrial evaluation at the Erdenet facility.

Aeroflot, as an auxiliary collector to butyl xanthate, enhances the recovery of fine sulfide minerals and those containing precious metals (gold, silver), while also improving the selectivity in the separation of non-ferrous metal sulfides and pyrite.

Thus far, such tests have been conducted at "Urupsky GOK" CJSC, "Salairsky GOK" OJSC, and the facilities of "Kazakhmys Corporation." The utilization of a combination of xanthate with butyl Aeroflot (BTF) or xanthate with Aeroflot FRIM-9 enhances the efficiency of copper and zinc beneficiation by 3.0 - 4.0%, attributed to an increase in metal content within the concentrate (Ryaboy, 2011; Zhang, Nguyen & Zhou, 2018; Kenzhaliyev et al., 2021).

A substantial amount of laboratory research was conducted on ores processed at Kazakhmys Corporation facilities. Research indicates that copper recovery in rough concentrate can increase by up to 5.0% when employing a combination of xanthates and Aeroflot FRIM-9, and in certain instances, Aeroflot BTF.

Conclusions

Consequently, the aforementioned succinct review indicates that the theoretical foundations for the development of novel flotation reagents, particularly those comprising sulfur-containing compounds, are continually advancing. However, the challenge of a scientifically grounded selection of initial collectors and their formulations in establishing selective reagent protocols for the flotation of refractory ores persists, as their application is directly influenced by the qualitative and quantitative characteristics of the feedstock and its structure, necessitating a tailored approach in each instance.

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Study of the influence of hydrophobic polymers on the wettability of minerals: chalcopyrite, galena and pyrite

Abstract: This study investigates the impact of hydrophobic polymers on the wettability and flotation efficiency of key minerals, including chalcopyrite, galena, pyrite, and quartz. Copolymers based on [[2-(methacryloyloxy) ethyl] trimethylammonium chloride] and styrene were synthesized using radiation copolymerization in various ratios. The chemical structures of the copolymers were confirmed through IR spectroscopy, highlighting the key functional groups that contribute to their effectiveness in modifying mineral surfaces. Contact angle measurements were used to assess the changes in wettability of mineral surfaces treated with these hydrophobic polymers. Results showed that the application of the copolymers significantly reduced the contact angles of chalcopyrite, galena, and pyrite, indicating an increase in their surface hydrophobicity. The study also explored the combined use of the polymers with traditional flotation reagents, such as sodium butyl xanthate, demonstrating a synergistic effect that enhanced the flotation process by further reducing contact angles and improving selectivity. The findings suggest that hydrophobic polymers can optimize flotation efficiency by altering the surface properties of minerals, leading to higher recovery rates and improved separation of valuable minerals from waste materials. Additionally, the use of polymers has the potential to reduce the environmental impact of flotation processes by lowering the consumption of toxic reagents.

Keywords: hydrophobic polymers, mineral wettability, copolymers, chalcopyrite, galena, pyrite.

Introduction

The ore beneficiation process plays a key role in the mining industry, as it enables the separation of valuable minerals from waste rock, thus increasing the overall efficiency of resource extraction. Among the various techniques used in mineral processing, flotation remains one of the most widely applied and effective methods. It operates by exploiting differences in the surface properties of minerals, allowing for the selective separation of valuable components from gangue.

In recent years, considerable attention has been directed toward the use of hydrophobic polymers in flotation processes, due to their ability to modify the surface properties of minerals such as chalcopyrite ($CuFeS_2$), galena (PbS), pyrite (FeS_2), and quartz (SiO_2). These minerals are often found together in polymetallic ores, and their selective separation remains a critical challenge in mineral processing. The ability to enhance the separation of valuable minerals from waste through selective modifications of surface properties is of great importance for optimizing the flotation process (Song et al., 2000; 2001; Kenzhaliyev et al., 2018; Kenzhaliyev, 2019; Wang et al., 2021; Kvon et al., 2023).

One of the key factors influencing flotation efficiency is the wettability of mineral surfaces. The degree of hydrophobicity or hydrophilicity of these surfaces plays a decisive role in determining the attachment of air bubbles to mineral particles, which is essential for successful flotation. Researchers have identified the contact angle, measured on the surface of minerals, as the primary parameter used to quantify

hydrophobicity. A larger contact angle typically indicates higher hydrophobicity, which improves the flotation performance of the mineral (HUANG et al., 2018).

This study focuses on the interaction between hydrophobic polymers and the minerals chalcopyrite, galena, pyrite, and quartz. Specifically, it examines how these polymers influence the wettability of the mineral surfaces and how this modification can improve flotation efficiency. The primary objective of this research is to identify opportunities for increasing the selectivity and recovery of valuable minerals by altering their surface characteristics with hydrophobic polymers. Understanding these interactions at the molecular level could lead to more effective separation techniques and overall process optimization in the mineral beneficiation industry.

Research methods

The research was conducted using a combination of advanced experimental techniques and analytical methods to investigate the influence of hydrophobic polymers on the wettability of mineral surfaces. The following methods were employed:

Synthesis of Copolymers

Copolymers based on [[2-(methacryloyloxy) ethyl] trimethylammonium chloride] and styrene in various molar ratios were synthesized through radiation copolymerization. The copolymerization was performed using γ-radiation to initiate the polymerization process, ensuring a controlled reaction environment. Different copolymer compositions (e.g., 90:10, 60:40) were prepared by adjusting the monomer feed ratios to examine the impact of varying polymer structures on mineral surface modification.

Infrared (IR) Spectroscopy

To confirm the chemical structure of the synthesized copolymers and ensure the success of polymerization, infrared (IR) spectroscopy was used. The IR spectra of both the original monomers and synthesized copolymers were recorded. This allowed for the identification of key functional groups in the polymer chains, including characteristic absorption bands for $–CH_2$, C=O, and C–O–C groups. The analysis also helped assess the influence of different monomer ratios on the structural features of the copolymers.

Contact Angle Measurements

The wettability of mineral surfaces (chalcopyrite, galena, pyrite, and quartz) was evaluated through contact angle measurements. A goniometer was used to measure the contact angle of distilled water droplets placed on the mineral surfaces. The contact angle is a key parameter that reflects the hydrophobicity or hydrophilicity of the mineral surface. Higher contact angles indicate increased hydrophobicity, which is favorable for flotation processes. Contact angles were measured both in the absence of polymers (as a baseline) and after treating the mineral surfaces with different concentrations of synthesized hydrophobic polymers (e.g., 4 ppm). Additional tests were conducted using combinations of copolymers with traditional flotation reagents such as sodium butyl xanthate (Bx Na) to observe the synergistic effects.

These research methods provided a comprehensive framework to study the influence of hydrophobic polymers on the flotation efficiency of minerals, focusing on their ability to modify surface properties and enhance the recovery of valuable components from ore. The combination of contact angle measurements, flotation tests, and structural analysis enabled a detailed understanding of the mechanisms behind polymer-mineral interactions.

Results and discussions

Copolymers based on [[2-(methacryloyloxy) ethyl] trimethylammonium chloride] and styrene in different ratios were synthesized via radiation copolymerization. The chemical structures of the original monomers and synthesized copolymers were confirmed by IR spectroscopy, as shown in Figure 1. In the IR spectrum of [[2-(methacryloyloxy) ethyl] trimethylammonium chloride], absorption bands appeared at 2922 cm^{-1} and 1206 cm^{-1}, corresponding to the stretching vibrations of aliphatic $–CH_2$ and C–O groups, respectively. A broad peak at 3356 cm^{-1} indicates intermolecular hydrogen bonding, while a weak absorption band at 1436 cm^{-1} corresponds to the amine group –CH-O–.

In the IR spectrum of styrene, strong absorption bands at 1428 cm^{-1} and 1654 cm^{-1} were attributed to the stretching vibrations of the methylene group -HRC=CH_2-. The spectra of the copolymers displayed prominent carbonyl stretching vibrations from [[2-(methacryloyloxy) ethyl] trimethylammonium chloride] at 1323 cm^{-1} and 1298 cm^{-1}. Furthermore, the hydroxyethyl ether group from [[2-(methacryloyloxy) ethyl]

trimethylammonium chloride] was confirmed by the presence of double peaks in the C–O–C stretching vibrations at 1143 cm^{-1} and 1088 cm^{-1}. The intensity and position of these peaks varied with the composition of the monomer mixture, showing that lower styrene content increased the relative intensity of the hydroxyethyl ether group's vibration peaks.

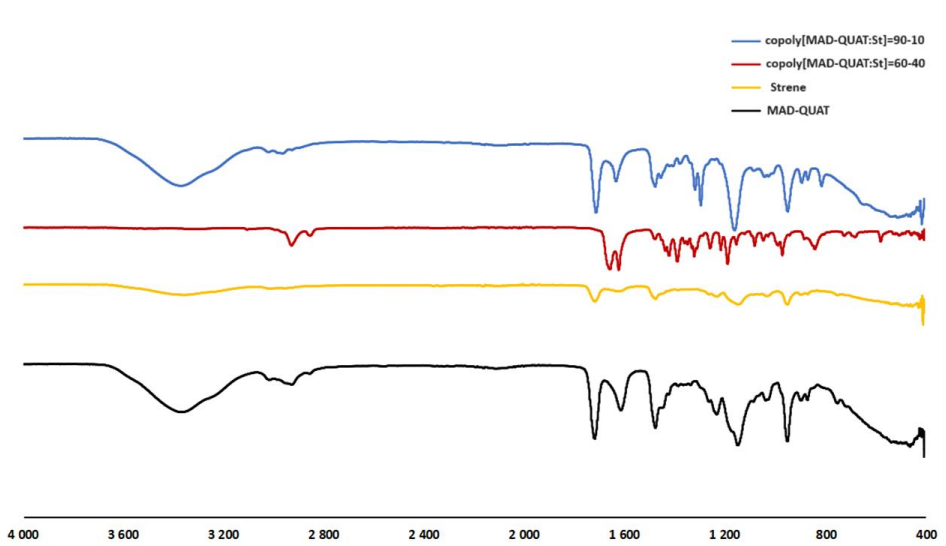

Figure 1. IR spectra of copolymers based on [MAD-QUAT-styrene]

Contact angle measurements were performed to evaluate the influence of hydrophobic polymers on the wettability of mineral surfaces in Figure 2. Without polymer treatment, the contact angle of chalcopyrite in distilled water averaged 80.25°, indicating moderate hydrophobicity. Upon adding a [MAD-QUAT]-[St] copolymer with a 90:10 ratio at 4 ppm concentration, the contact angle decreased to 74.99°, revealing enhanced hydrophobicity.

Galena, with an initial high contact angle of 101.03°, was highly hydrophobic in distilled water. Treatment with the same [MAD-QUAT]-[St] copolymer reduced the contact angle to 68.17°, demonstrating a significant change in wettability and an improved interaction with air bubbles. This result indicates a strong adsorption of the copolymer on the galena surface, likely due to its affinity for the sulfide groups present in the galena.

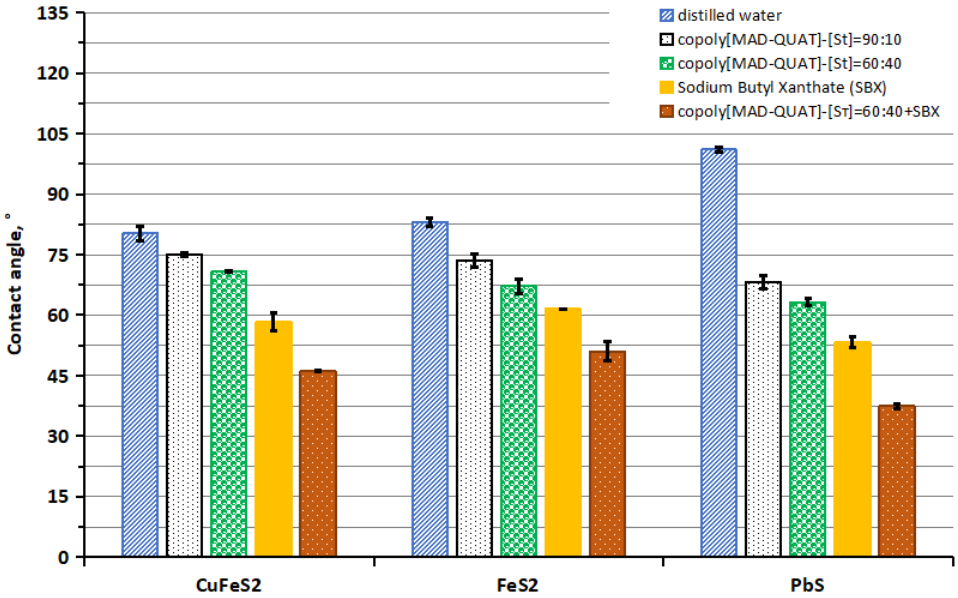

Figure 2. The influence of various reagents on the contact angles of a drop on the surface of minerals (Chalcopyrite, pyrite, galena)

Pyrite, another key mineral, had an initial contact angle of 83.00°, showing a natural hydrophobic character. After treatment with the [MAD-QUAT]-[St] copolymer, the contact angle dropped to 73.53°, further improving its hydrophobic properties, which suggests a potential enhancement in flotation performance.

A comparative analysis indicated that variations in the composition of copolymers affected their effectiveness. For example, when using the [MAD-QUAT]-[St] copolymer in a 60:40 ratio, the contact angle of chalcopyrite decreased to 70.78°, representing a less significant increase in hydrophobicity compared to the 90:10 ratio copolymer. A similar trend was observed in Galena, where the contact angle decreased to 63.15°.

The combination of copolymers with sodium butyl xanthate (Bx Na) produced the most significant reductions in contact angles. For instance, the contact angle of chalcopyrite treated with this combination averaged 46.12°, suggesting a high degree of hydrophobicity. Galena and pyrite exhibited similar behavior, with their contact angles decreasing to 37.41° and 51.06°, respectively, indicating the synergistic effect of combining polymers with traditional flotation reagents.

The mechanism of adsorption of hydrophobic polymers on mineral surfaces is largely governed by the physicochemical interactions between the functional groups of the polymers and the active sites on the mineral surfaces. For chalcopyrite and galena, the high contact angles can be attributed to the strong adsorption of the polymers, facilitated by the presence of sulfide groups that interact effectively with the hydrophobic portions of the polymer chains. This results in the formation of a hydrophobic film on the mineral surface, enhancing their flotation behavior through improved attachment to air bubbles (Scharnberg et al., 2023).

Despite the presence of sulfide groups, pyrite has a denser crystal structure, which can hinder the adsorption of polymers on its surface. However, the introduction of specific functional groups into the polymer structure may improve the polymer's interaction with pyrite, thereby altering its wettability.

The use of hydrophobic polymers in conjunction with traditional flotation reagents offers a promising route for reducing reagent consumption and enhancing the efficiency of mineral beneficiation. This approach not only improves process efficiency but also reduces the volume of flotation waste, thereby mitigating the environmental impact. For example, reducing the use of conventional reagents like sodium butyl xanthate can decrease the toxicity of flotation tailings, making the process more environmentally friendly (Zhang et al., 2023).

The results of this study indicate that modifying the wettability of minerals using hydrophobic polymers presents new opportunities for optimizing flotation processes. Enhancing the hydrophobicity of valuable minerals such as chalcopyrite and galena through polymer treatment can lead to improved concentrate recovery and quality. Future research will focus on exploring the effects of various hydrophobic polymers and their combinations on a broader range of minerals, to develop more efficient and eco-friendly mineral beneficiation techniques (Li et al., 2024).

In conclusion, the use of hydrophobic polymers to modify the surface properties of minerals is a promising strategy for advancing flotation technology, which could significantly enhance the efficiency of mineral processing (Li et al., 2021).

Conclusions

The copolymers based on [[2-(methacryloyloxy) ethyl] trimethylammonium chloride] and styrene were successfully synthesized using radiation copolymerization, and their chemical structures were confirmed through IR spectroscopy. The composition of the copolymers played a crucial role in determining their effectiveness in modifying mineral surfaces. Specifically, a higher content of [[2-(methacryloyloxy) ethyl] trimethylammonium chloride] increased the hydrophobic properties of the polymers, making them more effective in enhancing mineral flotation performance.

The study demonstrated that hydrophobic polymers significantly influence the wettability of minerals, which is a critical factor in flotation. Contact angle measurements showed that the application of copolymers reduced the contact angles of chalcopyrite, galena, and pyrite, indicating an increase in surface hydrophobicity. The degree of hydrophobicity was dependent on both the polymer composition and concentration, with the 90:10 ratio of [MAD-QUAT]-[St] copolymer exhibiting the most pronounced effect.

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The combination of hydrophobic polymers with traditional flotation reagents, such as sodium butyl xanthate, produced a synergistic effect, further reducing the contact angles and enhancing the flotation efficiency of the minerals. This combination allowed for more selective separation of valuable minerals (e.g., chalcopyrite and galena) from waste materials (e.g., quartz and pyrite), resulting in higher recovery rates and improved concentrate quality. These findings suggest that hydrophobic polymers can be used to optimize flotation processes, reducing the need for higher amounts of conventional reagents.

The use of hydrophobic polymers offers a potential reduction in the consumption of traditional flotation reagents, such as xanthates, which are known for their environmental toxicity. By improving the selectivity and efficiency of the flotation process, the polymers contribute to reducing the volume of waste generated, leading to a lower environmental footprint in mineral processing operations. This opens the possibility for more environmentally sustainable beneficiation methods.

The study highlights the potential of using hydrophobic polymers to develop more efficient and eco-friendly flotation technologies. Future work could expand on this research by exploring other types of hydrophobic polymers and their interactions with a wider range of minerals. Moreover, investigating the long-term stability of the hydrophobic films formed on mineral surfaces and their behavior under varying flotation conditions will be crucial for further optimization.

In conclusion, the use of hydrophobic polymers represents a promising approach to improving the selectivity and efficiency of flotation processes in mineral beneficiation. The results of this study provide a foundation for future advancements in the development of innovative and environmentally friendly flotation techniques.

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Comparative Analysis of Sorbents on Chromate Ion (VI) Sorption and Desorption: Influence of Composition and pH from Ilmenite Processing Solutions

Abstract. In this work, the processes of sorption and desorption of chromate ions from the solution obtained as a result of the processing of high-chromium ilmenite concentrate were studied using sorbents: Amberlite IR120 (Na), Amberlite IRA-35, PuroliteA-100, LewatitMono Plus M-500. The influence of pH factor and sorption system composition on the sorption process of chromate ions (VI) was investigated. Different polymers were tested to evaluate their combined effect on the recovery of chromate ions. A correlation was found between the increase in the efficiency of the sorption process of chromate ions (98%) and a decrease in pH from pH 13.5 to pH 2.5. In addition, the sorption process was improved at higher sorbent concentrations and the desorption efficiency increased at higher molar concentrations of sodium hydroxide (NaOH). The study's results will serve for the optimization of sorption processes for the extraction of chromate ions (VI) with the participation of various polymeric sorbents in the industry.

Keywords: adsorption, desorption, sorbents, chromium, Amberlite IR120 (Na), Amberlite IRA-35, PuroliteA-100, LewatitMonoPlus M-500.

Introduction

The study by Kenzhaliyev (2019) explores innovative technologies aimed at improving the extraction of non-ferrous, precious, rare, and rare earth metals. It discusses various advancements and methods that enhance recovery rates and efficiency in metal extraction processes. The study emphasizes the significance of these technologies for optimizing resource utilization and advancing sustainable practices in the mining and mineral processing industries. The increasing pollution of aquatic ecosystems with heavy metals seriously threatens the environment and human health. Among these pollutants, chromium (VI) ions attract special attention due to their widespread use in various industrial processes and their toxic effects on the biosphere (Briffa, Sinagra, & Blundell, 2020). Chromium (VI) water contamination is a serious environmental problem due to its toxicity and persistence (Xie, 2024). Effective removal of chromate ions from aqueous solutions is a key factor in reducing environmental and sanitary risks (Hammadi et al., 2024). Solutions obtained from the processing of ilmenite concentrate containing chromium (VI) are a potential source for extracting chromate ions. This study focuses on the sorption and desorption processes of chromate ions (VI) from ilmenite concentrate processing solutions, with special attention to the critical role of pH and sorbent concentration. Various sorbents, from natural to synthetic, are studied to determine the optimum conditions for the efficient removal of chromate -ions (VI). Understanding the relationship between pH levels and sorbent characteristics not only expands our understanding of sorption mechanisms but also provides a basis for developing sustainable sorbent recovery strategies.

The studies by Ultarakova et al. (2021), Mamutova et al. (2018), and Kenzhaliyev et al. (2024) collectively address critical aspects of resource recovery and waste management in the processing of ilmenite concentrate and titanium-magnesium production. Ultarakova et al. (2021) focus on optimizing methods to remove silica from pyrometallurgical wastes, aiming to enhance resource recovery and reduce environmental impact. Mamutova et al. (2018) examine the challenges of processing chloride waste from titanium-magnesium production, proposing solutions for effective management and improved industry practices. Kenzhaliyev et al. (2024) investigate the sorption of chromate ions from ilmenite processing solutions using various sorbents, analyzing the effects of pH and sorbent concentration on extraction efficiency. Together, these studies emphasize the importance of optimizing waste treatment processes to maximize resource recovery and minimize environmental harm in mineral processing industries.The main purpose of this study was to investigate the effect of solution pH and sorbent concentration on the extraction efficiency of chromate ions and to evaluate the effectiveness of sorbents under different experimental conditions.

Research material

Table 1 delineates the materials employed in the experimental procedure, along with their respective properties and characteristics. The sorbents utilized in this research include Amberlite IR120 Na, Anionite AMR, Purolite A-100, and Lewatit MonoPlus M-500 (refer to Table 1). In the course of the experiments, a solution comprising chromate ions, derived from the processing of high chromium ilmenite concentrate, henceforth designated as "the chromate ion solution," was systematically introduced into the measuring beakers.

Table-1. Materials used

Sorbentsused	**Characteristics**
Amberlite IR120 Na	Base - styrene-divinylbenzene copolymer Functional groups-Sulfonates Physical form-Amber granules Ionic form at delivery-Na+ Total static exchange capacity, Pe=2 mmol/cm^3 Moisture content - 50% Coefficient of homogeneity-1.9 Manufacturer: ROHM &HASS
Anionite AMR	A weakly basic macroporous resin with a styrene-divinylbenzene matrix. Appearance: Spherical-shaped grains of white to beige color. Total static exchange capacity, Pe=1.25 mmol/cm^3 Dynamic exchange capacity with a given re-generant flow rate, 538 mol/m^3, Mass fractionofmoisture, 45%
PuroliteA-100	Structure of polymer matrix Polystyrene cross-linked with divinylbenzene. Appearance- opaque spherical particles of white color. Functional groups- Tertiary amine Total exchange capacity1 .3 g-eq/L Residual humidity-62 % Homogeneitycoefficient-1.7 Manufacturer: Purolite (England)
LewatitMonoPlusM-500	LewatitMonoPlus M 500 is a strongly basic gel anionite based on styrene-divinylbenzene copolymer, with a monodisperse size. Ionic form at delivery: CI- Functional group: quaternary amine type I Coefficient of homogeneity- 1.1 Average granule size*: 0.62 ± 0.05 mm Residual humidity: 55%. Manufacturer: LANXESS (Germany)

Methodology of experiments

The study of sorption processes was carried out under static conditions with periodic stirring until the equilibrium state in the studied systems was reached. After specified time intervals the solutions were analyzed for the content of chromium ions, after which the sorbent was separated from the solution by vacuum filtration. Solutions based on ilmenite concentrate with chromate ions were prepared in the range of pH values from 1.5 to 13.5. Sorbent concentrations were varied to determine their effect on chromium sorption efficiency.

The desorption processes were studied in the same way as in the case of sorption, under static conditions with periodic stirring until the equilibrium state was established. Chromium-saturated sorbents were treated with solutions of sodium hydroxide (NaOH) at pH 1.5 and sulfuric acid (H_2SO_4) at pH 13.5 with different molar concentrations (0.05 M, 1 M, 2 M). The desorption efficiency was evaluated by the amount of chromium ions released back into the solution.

Discussion of results

The efficiency of the sorption process was evaluated by analyzing aliquots sampled from 10 ml of solution at intervals over 24 hours from the start of sorption. The experiments were carried out at an initial pH value of 13.5, corresponding to the solution obtained during the processing of ilmenite concentrate. For each experiment, 0.1 g sorbent suspensions and 100 ml of ilmenite concentrate solution were used. The obtained filtrates were studied by methods of chemical analysis, the results of which are presented in Table 2.

Table 2. Results of chemical analysis.

№	Name ofobject	Abbreviations	C, g/dm^3
1	Initialsolution		1.66
2	MMA	MMA	1.48
3	PuroliteA-100	A-100	1.47
4	LewatitMonoPlusM-500	M-500	1.36
6	Amberlite IR120 Na	Amberlite	1.40

Based on the data presented in Figure 1, it can be seen that the best results for the sorption of chromate ions from the solution obtained during the processing of ilmenite concentrate at pH 13.5 demonstrated sorbents LewatitMonoPlusM-500 and Amberlite.IR120 Na. Thus, these sorbents were chosen for further experiments to study the influence of various parameters on the achievement of optimal conditions for sorption and desorption.

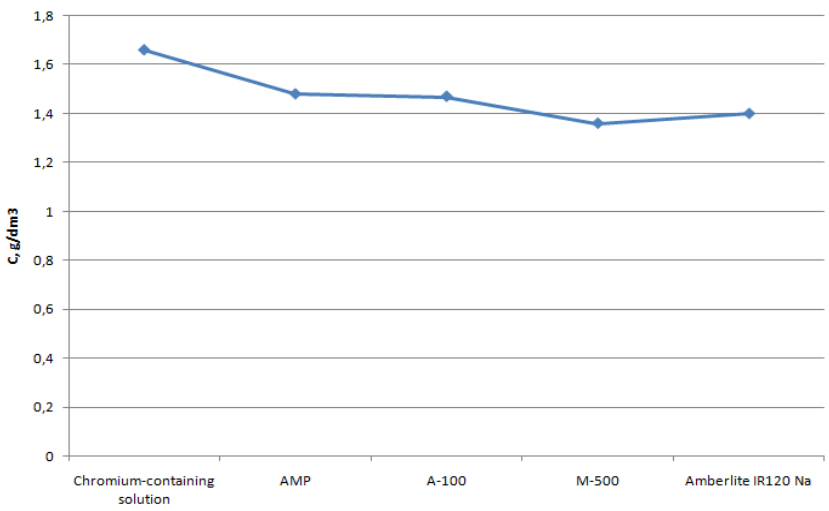

Figure 1. Sorption of chromate ions by different sorbents from the solution obtained during the processing of ilmenite concentrate

In the next series of experiments, the sorbents were suspended: Lewatit Mono Plus M-500 and Amberlite IR120 Na were taken in amounts of 5 g and 0.5 g at constant volume of chromate-containing solution (V = 50 ml) and sorption studies were carried out while varying the pH of the medium. After 24 hours, chemical analysis was carried out to determine the content of chromate ions in the solution. The results of the analysis are presented in Table 3.

Table 3. Results of sorption study.

sampleno.	Name ofobjects	Weight of sorbent m, g	mediumpH	C,g/dm^3
1	Chromium-containingsolution	50 ml	13.55	6.935
2	Amberlite IR120 Na	0.5	13.55	5.34
3	Lewatit Mono Plus M500	0.5	13.55	4.76
4	Amberlite IR120 Na	5	13.55	4.42
5	Amberlite IR120 Na	0.5	2.5	0.76
6	Lewatit Mono Plus M500	0.5	2.5	0.74
7	Amberlite IR120 Na	5	2.5	0.4

When the pH was reduced to 2.5, a significant increase in sorption efficiency was observed, which is reflected in Figure 2. At this low pH level, all the studied sorbents provided removal of chromate ions at the level of more than 90%. Increasing the concentration of the sorbent in turn also had a positive effect on the sorption process, it should be noted that increasing the concentration of the sorbent contributed to a more efficient removal of chromium ions.

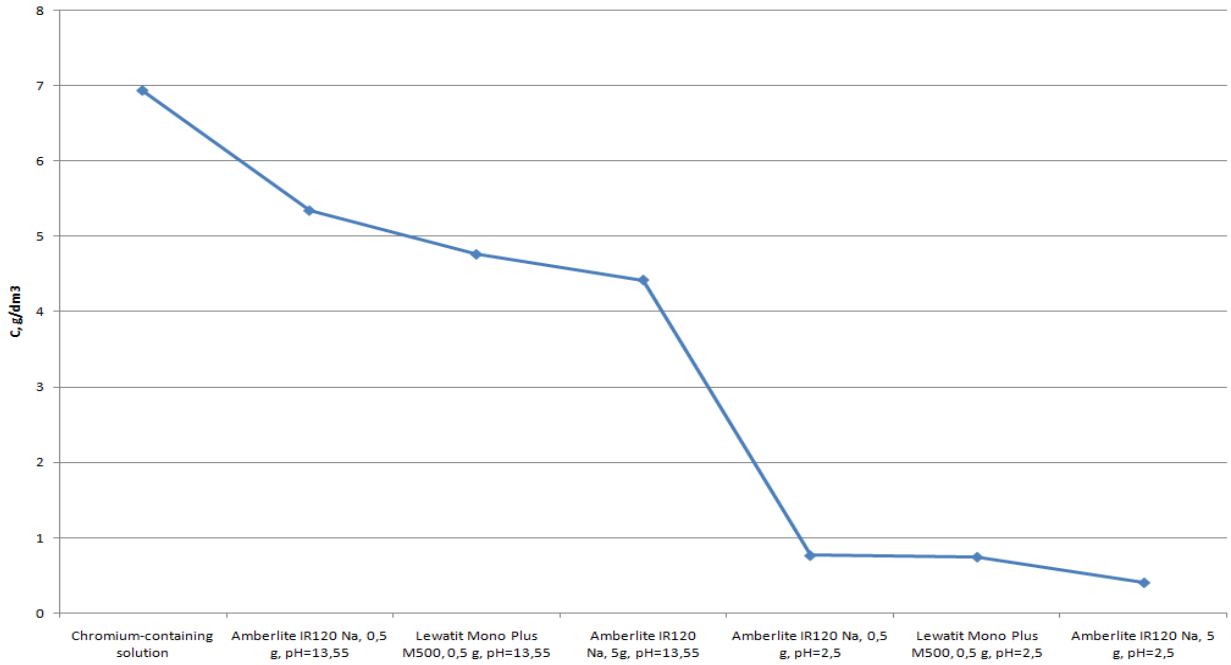

Figure 2. Effect of pH on the process of sorption of chromium from the solution obtained in the process of processing of ilmenite concentrate

Desorption was successfully carried out using 2M NaOH solutions. Increasing the molar concentration of NaOH led to an increase in desorption efficiency. The desorption efficiency was found to correlate with the alkali concentration, indicating that stronger alkaline conditions favor the release of chromate ions from the sorbent. The desorption efficiency was determined based on the chemical analysis data presented in Table 4.

Table 4. Results of chemical analysis

sampleno	Name ofobjects	Weight of sorbent m, g	mediumpH	C, g/dm^3
1	Initialchromium-containingsolution	50 r	13.55	5.838
2	Amberlite IR120 Na	5	13.55	0.31
3	Amberlite IR120 Na	0.5	13.55	0.13
4	LewatitMonoPlusM500	0.5	13.55	0.29
5	Amberlite IR120 Na	5	2.5	4.81
6	Amberlite IR120 Na	0.5	2.5	4.08
7	LewatitMonoPlusM500	0.5	2.5	4.79

Analysis of experimental data and their comparative review showed that pH has a significant effect on the process of sorption of chromium from the solution obtained from the processing of ilmenite concentrate. At high pH values, chromium sorption decreases, which is due to the formation of insoluble hydroxides or reduced availability of ions. On the contrary, at lower pH, the solubility of chromate ions and their ability to interact with sorbents increase, which contributes to the increase in sorption efficiency.

Figure 3 shows the graph demonstrating the effect of pH on the desorption process of chromate ions sorbed from the solution obtained during the processing of ilmenite concentrate.

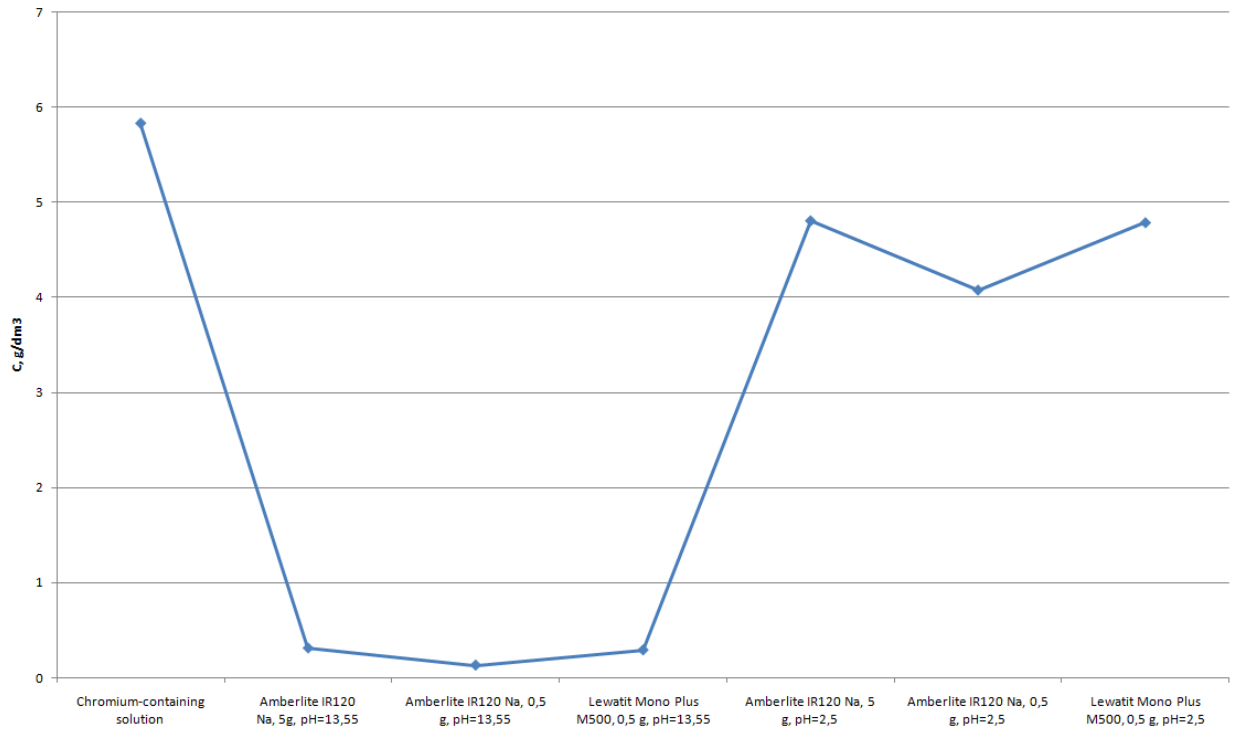

Figure 3. Effect of pH on the desorption process of chromate ions (VI)

The efficiency of ionite sorption is also determined by their amount in the sorbent:solution system. Increasing the ionite content in the solution obtained from the processing of ilmenite concentrate contributes to an increase in the available surface area for ion binding, which leads to an acceleration of the process and an increase in chromium sorption performance. The study confirms that optimization of the amount of sorbent plays a key role in improving the efficiency of the sorption process.

Desorption experiments showed that NaOH solutions are highly effective for sorbent regeneration. The desorption efficiency increases when more concentrated NaOH solutions are used because a more alkaline medium breaks the bonds between chromate ionomers and sorbent, which promotes their release.

Conclusion

The study results emphasize the key importance of pH and sorbent concentration in the processes of sorption and desorption of chromate ions from solutions of ilmenite concentrate. Lower pH values significantly improve the removal of chromate ions (VI), while increasing the sorbent concentration contributes to the efficiency of the sorption process. For the desorption process, higher molar concentrations of NaOH were found to provide better sorbent regeneration. These findings provide important data for the optimization of chromate ion purification methods and sorbent applications in industry. In the future, research should focus on a detailed study of the mechanisms of these processes and evaluation of the performance of different sorbents under different operating conditions.

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Adsorption of chromate ions (VI) from solutions formed during processing of high-chromium ilmenite concentrate using interpolymer systems

Abstract: The paper presents the results of the sorption of chromium (VI) ions from solutions, obtained during the processing of high-chromium ilmenite concentrate using the simultaneous co-presence of anionite (AB-17-8(Na)) and cationite (KU-2-8(Na)). Under static conditions, the sorption behavior of two polymer hydrogels was studied at different molar ratios of polymers to determine their sorption capacity towards chromium (VI) ions. The investigated polymer systems were formed at molar ratios of KU-2-8(Na) and AB-17-8(Na), respectively: 6:0, 4:2, 3:3, 2:4 и0:6. The sorption efficiency of interpolymer hydrogel systems towards chromate ions (VI) in solutions obtained during the processing of ilmenite concentrate has been studied. An interpolymer system with two types of hydrogels: anionic (AB-17-8(Na)) and cationic (KU-2-8(Na)) was studied. Different molar ratios of these polymers were tested to evaluate their combined effect on the sorption of chromate ions. A Shimadzu atomic absorption spectrometer was used to analyze the samples. The results showed that the simultaneous presence of the two polymers in the system enhanced the efficiency of the sorption process compared to using either of them individually. It was also demonstrated that the best sorption occurred when both polymers were present, with optimum performance at a ratio of 2:4. The combined presence of anionic and cationic polymers enhances the sorption process of chromium compared to the use of either polymer alone.

Keywords: interpolymer systems, hydrogels, chromium, adsorption, desorption.

Introduction.

The studies by Mamutova et al. (2018) and Kenzhaliyev (2019) address critical issues in the processing and extraction of metals from mineral resources. Mamutova et al. focus on the modern conditions surrounding the management of chloride waste generated by titanium-magnesium production, proposing solutions to mitigate environmental impacts and enhance resource recovery. In contrast, Kenzhaliyev examines innovative technologies designed to improve the extraction of non-ferrous, precious, rare, and rare earth metals. Together, these studies highlight the importance of advancing processing techniques and adopting innovative solutions to optimize resource utilization while addressing environmental challenges in the mining industry. Panichkin and Kshibekova (2023) assess how different flux compositions affect the efficiency of removing non-metallic inclusions in high-chromium cast iron. It likely explores the relationship between flux materials and the quality of cast iron, aiming to improve manufacturing processes and product performance by optimizing inclusion removal.

Chromium is a heavy metal widely used in industries including metallurgy, electroplating and leather tanning (Monga et al., 2023). Chromium exists in several degrees of oxidation, but the most toxic and carcinogenic is Cr (VI) (Prasad et al., 2023). It is often found in industrial wastes and can cause serious environmental and human health problems if improperly handled (Sharma et al.,2021). Effective removal and recovery of chromium from contaminated solutions is critical to reduce its impact on the ecosystem

and the health of living beings (Hussain et al., 2020; Islam et al., 2023). Conventional purification methods are usually expensive and consume large amounts of energy, they produce harmful by-products and can cause secondary contamination. The main indicators of adsorption that enhance its advantages over other methods are their efficiency, speed, simplicity and safety, and economic feasibility. However, modern science is faced with the challenge of developing new materials that could potentially improve existing sorption methods.

Extraction of chromate ions (Cr (VI)) from solutions using interpolymer systems represents a promising direction in the field of sorption technologies, providing a more efficient and environmentally friendly alternative to existing methods of water treatment. Traditional physical and chemical methods are aimed at the treatment of industrial effluents and are often accompanied by high costs, significant energy consumption (Grzegorzek et al., 2023) also the formation of harmful by-products, which can cause repeated pollution of nature. In light of these problems, there is a need to develop new and more efficient approaches to water treatment, especially for the removal of toxic metal ions such as hexavalent chromate ions.

One such approach is adsorption (Amosa et al., 2021), which offers several advantages including high efficiency, speed of sorption processes, ease of implementation and safety of use. Adsorption methods are also cost-effective as they can achieve high degrees of purification with minimal operating costs. At the same time, current research in materials science is focused on the development of new sorbents (Aarab et al., 2020) and adsorption systems that could significantly improve the efficiency of water treatment and reduce the environmental burden on nature.

Interpolymer systems, including the use of polymeric sorbents of different natures, allow flexible control of sorption characteristics, including selectivity to certain ions, sorption capacity and resistance to aggressive media (Jumadilov et al., 2023). Such systems can efficiently adsorb chromate ions from solutions obtained during the processing of high-chromium ilmenite concentrate (Kenzhaliyev et al., 2024). This makes interpolymer systems not only economically feasible but also environmentally friendly for the extraction of hexavalent chromium from solutions.

Materials used.

Two hydrogels were used in this study**:** anionic polymer AB-17-8(Cl) (styrene and divinylbenzene copolymers with benzyltrimethylammonium functional groups) and cationic polymer KU-2-8(Na) (styrene and divinylbenzene copolymers).

Results and discussion.

Two sorbents were used for the conducted research: cationite KU-2-8(Na) and AB-17-8(Na) in salt forms, both separately and in different ratios from 6:0 (in case of 6:0 ratio, six parts of this ratio represent KU-2-8(Na) sorbent) to 0:6 (in case of 0:6 ratio, six parts of this ratio represents AB-17-8(Na) sorbent) (Table-1). During the experiments, a solution containing chromate ion obtained during the processing of high chromium ilmenite concentrate, hereinafter referred to as "Solution containing chromate ion", was introduced into measuring beakers. We used 0.1 g of sorbent suspensions per 200 ml of solution.

Table-1. Materials used

Sorbents used	**Solutions used**
6-0 (net KU-2-8(Na).	Solution containingchromateions
4:2 (4 moles of KU-2-8(Na) vs. 2 moles of AB-17-8(Cl))	Solution containingchromateions
3:3 (equal number of moles of KU-2-8(Na) and AB-17-8(Cl))	Solution containingchromateions
2:4 (from 2 moles of KU-2-8(Na) to 4 moles of AB-17-8(Cl))	Solution containingchromateions
0:6 (net AB-17-8(Cl))	Solution containingchromateions

Aliquots were taken at a certain time interval from the beginning of the sorption process for 24 hours. The filtrates were investigated by chemical methods of analysis. The data are summarized in Table 2.

Table-2. Results of chemical analysis

№	Name	C, g/dm^3
1	Initial solution	1.66
2	6:0(Ku-2-8(Na))	1.61
3	4:2(Ky-2-8(Na):AB-17-8(Cl))	1.33
4	3:3(Ky-2-8(Na):AB-17-8(Cl))	1.41
5	2:4(Ky-2-8(Na):AB-17-8(Cl))	1.29
6	0:6(AB-17-8(Cl))	1.58

The effect of different ratios of sorbents KU-2-8(Na) and AB-17-8(Cl) on the process of sorption of chromate ions (VI) from the solution containing chromate ions (VI) obtained during the processing of ilmenite concentrate is presented in Figure 1.

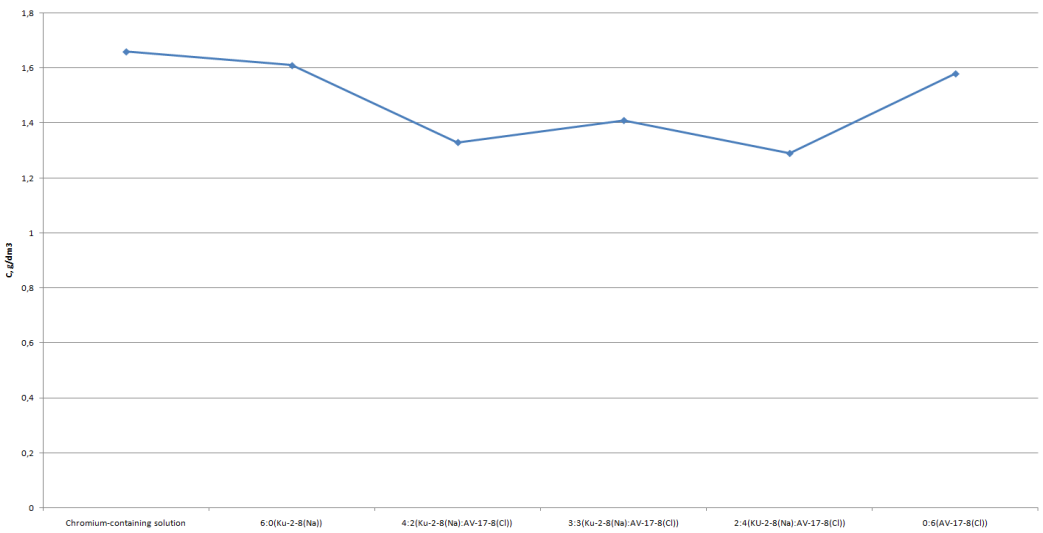

Figure 1. Effect of different ratios of sorbents KU-2-8(Na) and AB-17-8(Cl) on the process of chromium sorption from a solution containing chromate ions (VI)

Experimental data showed that chromium (VI) is sorbed more efficiently in the presence of both polymers (Figure 1). In particular, at a molar ratio of KU-2-8(Na) and AB-17-8(Cl) of 2:4, the highest sorption capacity was achieved. This improved performance is attributed to the synergistic effect of the anionic and cationic polymers, which interact with chromium ions more effectively than the individual polymers. The dual presence of both types of polymers probably provides a more complete ion exchange environment in which chromium from the solution is well sorbed.

We also studied the desorption process at different pH. Since the initial environment of the solution obtained during the processing of ilmenite concentrate was alkaline (pH-13.5), the desorption was carried out with sulfuric acid (H_2 SO_4 0.05M), in the presence of sorbents at a ratio of 2:4 and 4:2, as these ratios showed the highest efficiency of sorption of chromium from solutions obtained during the processing of ilmenite concentrate (Table-3).

Table-3. Results of chemical analysis

№	Name of research objects	C, g/dm^3
1	Initial solution	2.152
2	2:4(Cu-2-8(Na): AB-17-8(Cl)) desorption	0.167
3	4:2(Cu-2-8(Na): AB-17-8(Cl)) desorption	0.228

Figure 2 shows the effect of different ratios of sorbents KU-2-8(Na) and AB-17-8(Cl) on the process of desorption of chromium(VI) from the solution obtained during the processing of ilmenite concentrate.

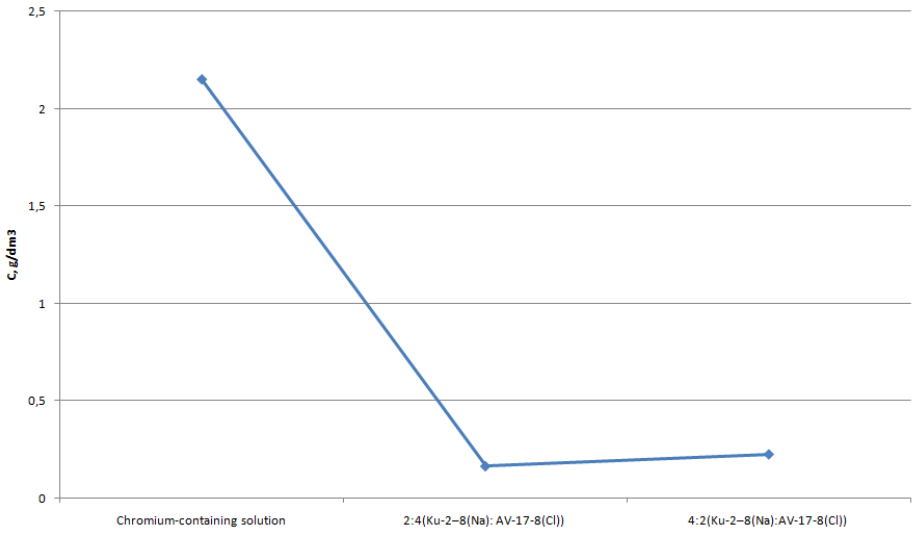

Figure 2. Effect of different ratios of sorbents KU-2-8(Na) and AB-17-8(Cl) on the desorption process of chromium(VI) from solution, obtained in the process of processing ilmenite concentrate

Studies of desorption processes have shown that chromate ions (VI) can be effectively released from hydrogels, indicating that the materials can be reused for multiple cycles of sorption and desorption. The reusability is an important factor in evaluating the cost-effectiveness of hydrogels for industrial-scale applications.

The obtained results of the study are not only the practical nature of the application of two-polymer systems in the extraction of chromate ions, but the purpose of this study is to demonstrate the possibilities of sorption and desorption of chromium from the solution obtained during the processing of ilmenite concentrate, to show that the system of two polymers in one container, due to the forces of van der Waals and other interactions adsorbs chromium(VI) ions better than these sorbents separately. We have to study the influence of various parameters such as concentration, pH, temperature, etc. on the sorption and desorption processes. In this way, we will achieve the ideal sorption and desorption of chromate ion (VI) from the ilmenite concentrate solution.

Conclusion

Experimental data were obtained indicating the effectiveness of using a combination of anionic and cationic hydrogels for the sorption of chromium ions. The results demonstrated that a balanced molar ratio of both polymers improves the sorption of chromium from industrial wastewater and is an acceptable application. Further research and optimization of the use of these polymeric materials may lead to more efficient and cost-effective solutions for the disposal of chromium (VI) contaminants.

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AI in the Classroom: A Boon or a Threat to Pedagogical Practices?

Abstract: The integration of Artificial Intelligence (AI) in education offers significant potential to enhance learning experiences through personalized feedback, automated support, and efficient content creation tools. However, this study reveals both the benefits and potential drawbacks of AI's role in pedagogy, particularly about over-reliance among secondary school students. Through a literature review, teacher surveys, and an experiment with sixth-grade students, the research explores how AI tools impact student engagement, critical thinking, and retention. Survey responses from teachers indicate mixed views on AI's effect on student independence, with some perceiving it as supportive for engagement and others noting a risk of dependency. The experiment further suggests that while AI tools can spark initial interest, the retention of AI-generated content may be moderate, and student customization of content remains minimal. These findings underscore the need for a balanced approach, where AI tools are utilized as supplements rather than replacements for traditional educational practices, fostering a supportive yet critical engagement with technology.

Keywords: Artificial Intelligence, student engagement, critical thinking, learning retention, pedagogical tools, personalized learning, secondary education.

Introduction

The rapid integration of Artificial Intelligence (AI) into the educational sphere has sparked significant debate regarding its impact on pedagogical practices. While AI promises to revolutionize classrooms with personalized learning experiences, automated grading systems, and intelligent tutoring tools, it also raises questions about the long-term effects on both teaching methodologies and student outcomes. As educators grapple with the opportunities and risks presented by AI, a pressing question arises: is AI in the classroom a boon or a threat to traditional pedagogical values? This article seeks to explore the dual-edged nature of AI's influence on education, focusing on how its integration might enhance or erode essential teaching practices. AI's presence in education has evolved beyond mere theoretical discussion to tangible implementation. From intelligent tutoring systems that provide students with instant feedback to AI-driven personalized learning platforms, these technologies have become integral to modern classrooms. Teachers can now leverage AI better to understand each student's learning style and progress, allowing for more targeted instruction. Adaptive Learning Platforms use AI algorithms to analyze student performance data and tailor lesson plans to each individual's needs. This kind of personalization, although efficient, runs the risk of diluting traditional methods of problem-solving and critical thinking. However, this reliance on machine-generated feedback may overlook the nuances that human educators bring to assessing students' work, particularly in subjects requiring deep analysis, like literature or history.

Students have also found AI to be a convenient tool for completing homework, with AI-driven applications like ChatGPT and math-solving tools helping them tackle difficult assignments more easily. While these technologies offer immediate help and save time, they risk creating a reliance on AI that might hinder

students' ability to think critically or develop problem-solving skills. For instance, students can now input complex mathematical equations into AI programs and receive solutions in seconds, bypassing the process of understanding and solving the problem independently. Similarly, AI-powered writing assistants can help generate essays or improve grammar, but they may also lead students to skip essential stages of writing development, such as brainstorming and editing. The growing use of AI by students to complete their homework raises concerns about whether these tools foster deeper understanding or simply provide a shortcut, undermining the educational process. If overused or misused, AI could impair students' capacity to engage with material creatively and independently, weakening key cognitive skills.

A parallel can be drawn between the rise of AI in education and the introduction of the printing press in the 15th century. Just as AI is reshaping today's classrooms, the printing press once revolutionized how knowledge was disseminated. The availability of printed materials made information more accessible and widespread, a transformative development that undoubtedly enhanced learning. However, it also led to unintended consequences: the decline of handwriting and spelling skills among students. With printed texts readily available, the need for students to practice handwriting diminished significantly. This decline, coupled with the rise of spell-checking tools in the digital age, has deteriorated spelling abilities. Research shows that students today rely more on digital tools to correct their writing errors, and many struggle with basic spelling and handwriting tasks when these tools are unavailable. Similarly, AI in education may enhance access to information but risks undermining foundational skills if students overly rely on it.

Literature review

The integration of AI into educational systems, particularly through e-learning platforms, promises to provide more personalized and adaptive learning experiences. Research by Kassymova et al. (2021) highlights the role of e-learning systems in improving the quality of learning by facilitating individualized approaches that cater to the unique needs of each learner. In their study, they argue that the use of AI can address educational challenges by enabling smarter systems that adjust content delivery, pace, and complexity based on real-time assessments of student performance. Similarly, Rohde et al. (2023) explore the theoretical underpinnings of AI in educational settings, focusing on how AI can further individualize e-learning programs. By leveraging AI algorithms, educational systems can create adaptive learning pathways that help students progress at their own pace, offering instant feedback and tailored recommendations. Moreover, Sheriyev et al. (2016) touch upon the importance of designing systems that are transparent, ethical, and inclusive, ensuring that AI technologies support equitable learning for all students, regardless of their background. Additionally, the development of mobile applications powered by AI, such as the one described by Mutarah et al. (2024) for the teaching of design and technology, highlights the growing trend of interactive learning tools. These AI-based applications can offer students hands-on experiences that go beyond the limitations of traditional classroom settings, making learning more dynamic and accessible.

The increasing integration of Artificial Intelligence (AI) into education has brought about concerns regarding students' over-reliance on these tools, especially in homework assignments. Basha (2023) argues that AI tools, while beneficial in assisting students with difficult tasks, may inadvertently erode essential skills such as critical thinking and independent problem-solving. Students increasingly rely on AI-generated solutions instead of engaging deeply with the material, leading to a superficial understanding of core concepts. This reliance can have long-term negative effects on academic performance and the development of critical thinking, which are foundational in education (Basha, 2023). Similarly, Karan and Angadi (2023) highlight the dangers of students using AI tools to complete assignments with minimal effort, warning that this may result in decreased retention of knowledge and reduced intellectual engagement. Their review points to the necessity for educators to carefully balance the use of AI tools, ensuring that they complement rather than replace traditional learning methods (Karan & Angadi, 2023).

The decline in handwriting and spelling skills, exacerbated by the growing use of digital tools, has been a particular point of concern. Yılmaz (2023) discusses how the rise of AI-based educational platforms has reduced the emphasis on handwriting practice, which was once a core part of the learning process. Osman (2023) adds that the cognitive benefits associated with manual writing, such as improved memory and comprehension, are being lost as students increasingly rely on digital tools to complete their work. These tools, while convenient, risk depriving students of the tactile and cognitive engagement that handwriting offers (Osman, 2023).

The increasing integration of AI tools in education presents significant threats to the cognitive competence of students. Students who frequently resort to AI-generated answers may fail to engage with the material at a meaningful level, leading to a superficial understanding of core concepts.

Furthermore, the ease of access to AI-driven solutions can negatively affect memory retention. When students rely on AI to provide quick information, they are less likely to actively engage in memorizing key facts and concepts, a process that is crucial for long-term learning. This reliance on AI as an external memory aid may result in deficits in information retention, as students outsource cognitive functions rather than exercising their brain's natural capacity for recall. This has long-term implications for their ability to retain and retrieve knowledge independently. Another area of concern is the potential weakening of metacognitive skills, which involve the ability to reflect on and regulate one's own learning processes. Metacognition is essential for effective learning, as it enables students to plan, monitor, and assess their cognitive strategies. However, when AI tools provide step-by-step solutions, students may miss opportunities to engage in this reflective process. The constant availability of ready-made answers can diminish the need for students to evaluate their thinking and problem-solving approaches, thereby limiting the development of these higher-order cognitive skills. Additionally, the use of AI tools may contribute to a shortening of students' attention spans. In an educational environment increasingly driven by instant gratification, the rapid delivery of information through AI can erode students' ability to focus on complex tasks for extended periods. Deep, sustained learning is essential for mastering difficult concepts, but if students become accustomed to receiving quick answers, they may struggle with the cognitive discipline required for long-term engagement with challenging material.

The threat to creativity and innovation is another critical issue. AI-generated responses often provide efficient but predetermined answers, potentially stifling opportunities for students to engage in original thinking. Creativity frequently arises from the process of grappling with complex problems and developing novel solutions. However, if AI shortcuts this process, students may become passive recipients of information rather than active participants in the creative and innovative aspects of learning. Finally, AI tools may narrow the scope of students' knowledge by encouraging a surface-level engagement with content. The efficiency of AI-driven solutions can dissuade students from exploring topics in greater depth, leading to a limited understanding of subjects. Exploratory learning, where students actively connect ideas across different domains, is vital for developing a broad and nuanced understanding of the world. However, AI's tendency to offer quick, predefined answers may restrict students' cognitive horizons, preventing them from engaging in the kind of deep learning that fosters intellectual growth.

Research Methods

A comprehensive literature review was conducted to explore the current academic discourse on the integration of Artificial Intelligence (AI) in education. Key studies were identified using databases such as Google Scholar, PubMed, and Web of Science, focusing on peer-reviewed articles published between 2023 and 2024. The primary focus of the review was on how AI influences students' cognitive skills, critical thinking, and engagement with learning materials. Sources that specifically discussed AI's impact on problem-solving, creativity, and traditional skills like handwriting and memory retention were prioritized, including works by Karan & Angadi (2023), Basha (2023), Yılmaz (2023), Osman (2023), Hernández (2024), and others.

Survey of Teachers - A survey was administered to a sample of teachers from schools in Almaty to gather insights into their perceptions of students' motivation and academic progress when using AI tools. The survey included both quantitative and qualitative questions designed to explore:

- Teachers' observations of students' engagement with assignments completed with the help of AI tools.
- The perceived impact of AI on students' critical thinking, creativity, and problem-solving abilities.
- Teachers' views on how AI tools influence traditional learning methods. The survey responses were collected and analyzed qualitatively to identify common themes and patterns regarding AI's influence on student motivation and progress.

An experiment was conducted with 6th-grade students to assess their comprehension and retention of AI-generated content. Students were tasked with writing a short story using AI tools, with the requirement to customize the setting, characters, and plot. The experiment aimed to evaluate two key factors:

Comprehension and Retention: After writing the AI-assisted story, students were asked to read and familiarize themselves with it. One week later, they were asked to retell the story to measure how well they retained the AI-generated content.

Engagement with AI-generated Content: Following the retelling exercise, brief interviews were conducted to assess whether students had engaged with the AI-generated story, including whether they had made efforts to understand or modify the content.

Research Results

Survey results

Teachers' Observations of Students' Engagement with Assignments Using AI Tools (Figure 1): When asked how often students appeared more engaged with assignments using AI tools as opposed to traditional methods, teachers' responses were varied. The largest portion of respondents (41.7%) rated students' engagement at level 3, indicating moderate engagement. Meanwhile, 33.3% rated it at level 4, and 16.7% rated it at level 2. Only a small percentage (8.3%) observed consistently high engagement (level 5). These results suggest that, while AI tools generally increase student engagement to some extent, not all teachers perceive a significant difference compared to traditional methods.

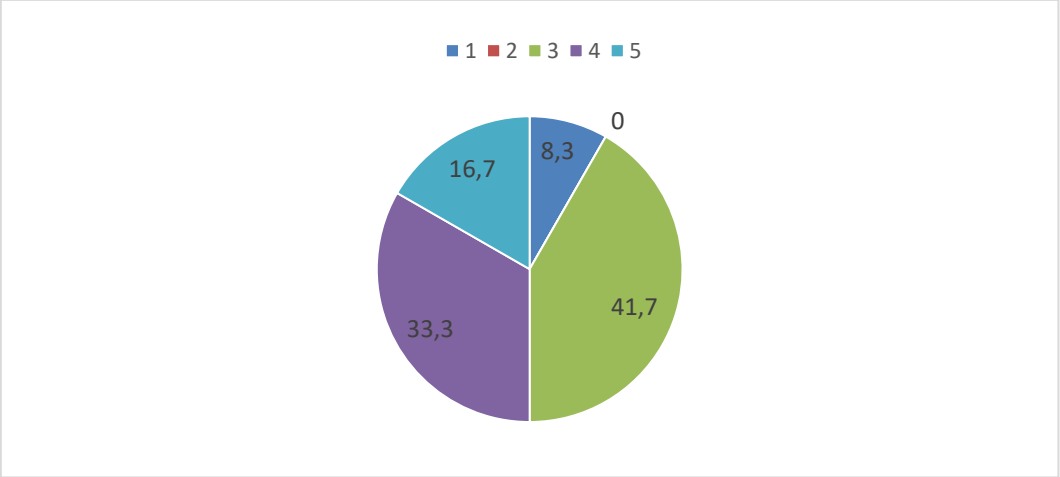

Figure 1. On a scale of 1 to 5, how often do you observe students engaging more with assignments when they use AI tools compared to traditional methods? (1=never, 5= always)

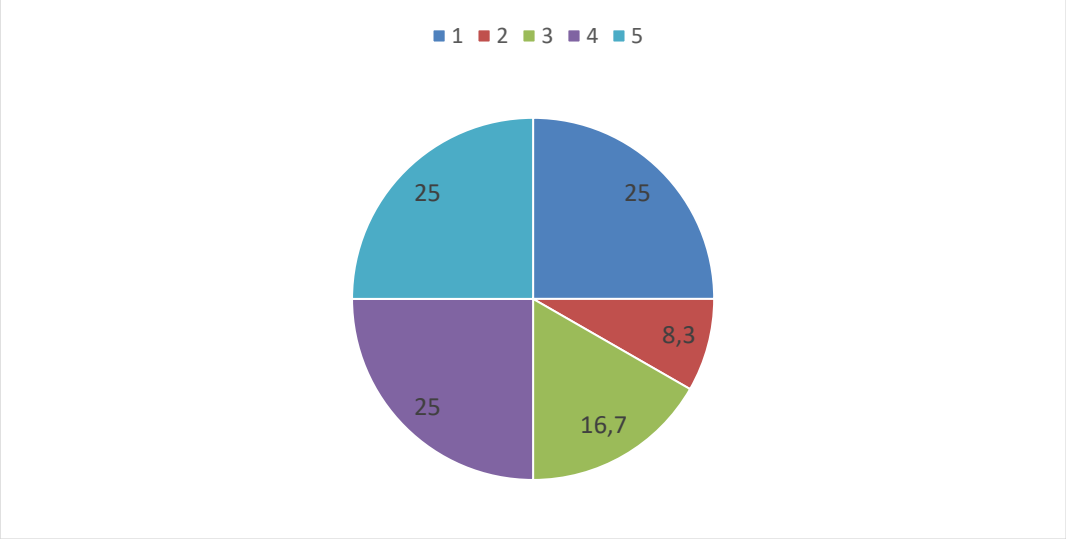

Figure 2. To what extent do you believe AI tools improve or hinder students' ability to complete assignments independently? (1=Significantly hinder, 5 = Significantly improve)

Perceived Impact of AI Tools on Students' Ability to Complete Assignments Independently (Figure 2): Teachers were asked to rate how AI tools impact students' independence in completing assignments. Responses were evenly distributed across the spectrum, with 25% of teachers rating both level 1 and level 5 (indicating opposing views on whether AI tools hinder or improve independence). Another 25% selected level 4, while 16.7% chose level 3, suggesting mixed opinions on whether AI promotes or limits independent learning. This distribution indicates diverse perspectives on AI's role in fostering independence. Some teachers view AI as a supportive tool for self-directed learning, while others express concerns about potential over-reliance.

Overall Perceptions of AI's Impact on Student Motivation and Academic Progress (Figure 3): When evaluating the overall impact of AI tools on students' motivation and academic progress, responses leaned toward a positive perception. Most teachers (41%) rated this impact as 3, suggesting a neutral stance, while 25% rated it as 5 (very positive), and 17% rated it as 2 and 4. These findings imply that, while some teachers observe a strong positive influence of AI on student motivation and progress, others remain neutral or have minor concerns about the overall benefits.

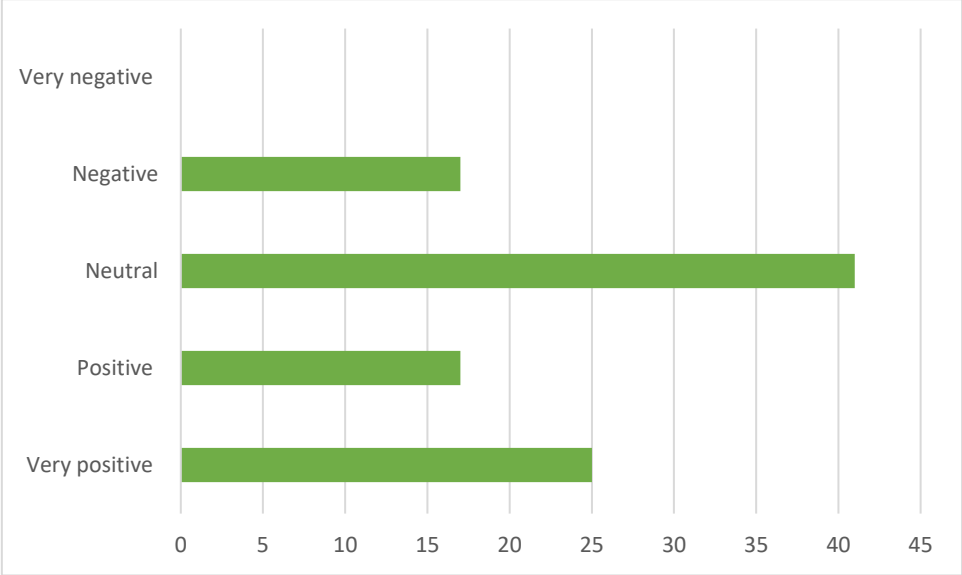

Figure 3. Overall, how do you perceive the impact of AI tools on students' motivation and academic progress? (1 = Very negative, 5 = Very positive)

Storytelling results

One week after the initial story-writing exercise, students were asked to retell their AI-assisted stories to assess retention. Approximately half of the students were able to recall and retell the stories with reasonable accuracy. This suggests moderate retention of the AI-generated content, with some students demonstrating a stronger grasp of their stories than others. The timing of the experiment, conducted at the end of the term, may have impacted students' ability to focus and retain content. Fatigue from the busy term-end schedule was noted as a possible factor contributing to reduced engagement and retention among some students.

Student engagement with the AI-generated story task was generally low. Several students did not complete the assignment, which could also be attributed to end-of-term fatigue. Among the students who completed their stories, most read them with minimal customization beyond the initial AI-generated suggestions. However, these students demonstrated a basic understanding of the content by answering questions and engaging in a brief Q&A with peers. This indicates that, although customization was limited, students could comprehend and discuss their stories to some degree. During follow-up interviews, students shared that they found the experience of creating stories with AI tools to be interesting. This positive response to the novelty of AI-assisted storytelling suggests that, despite low engagement levels, students

were intrigued by the AI-based approach and may benefit from further structured guidance to maximize their engagement and creativity.

Research Discussion

The findings of this research highlight both the potential benefits and challenges of integrating AI tools into the educational process, particularly for secondary school students. While AI provides an innovative way to enhance learning engagement and aid in content creation, the experiment revealed nuances in how young students interact with AI-assisted tasks and retain AI-generated content.

The results suggest that AI tools have the potential to stimulate initial interest among students, as evidenced by their positive feedback during interviews. This aligns with the broader understanding that novel technologies can increase engagement by making learning activities more dynamic and interactive. The students' interest in AI storytelling points to the value of incorporating such tools to create a more engaging educational experience. However, this engagement may be largely due to the novelty of AI; it remains uncertain whether this enthusiasm will persist once students become more accustomed to these tools. Long-term studies could help determine whether AI maintains its engagement factor or if its appeal diminishes over time.

A key consideration in using AI for educational purposes, especially at the secondary level, is the risk of fostering over-reliance. In this study, many students minimally customized the AI-generated stories, indicating a tendency to rely on the tool's output rather than engaging critically with the content. Compared to university students, who may have a stronger foundation in independent learning and critical thinking, secondary school students might be more susceptible to the passive use of AI, depending on it as a crutch rather than as a support tool. This reliance could undermine the development of essential skills such as creativity, problem-solving, and independent thought if not managed carefully.

The retention results showed that only half of the students could accurately retell their stories after a week. This suggests that while AI can facilitate the creation of content, it does not necessarily ensure deeper learning or retention. It is possible that the students' engagement with the AI-generated stories was surface-level, leading to moderate comprehension but limited long-term retention. These findings raise questions about the depth of learning that AI can support in young learners and suggest that AI-based learning activities need to be designed in a way that encourages active engagement and critical thinking to enhance retention.

Given these observations, it may be beneficial to balance AI-driven activities with traditional methods to create a holistic learning experience. AI should be integrated thoughtfully to complement, rather than replace, traditional pedagogical approaches. Teachers play a crucial role in this integration by guiding students to use AI tools as a means of exploration and experimentation rather than as a shortcut to completing assignments. By framing AI as a supplementary tool, educators can help students cultivate the ability to think critically and creatively while using AI.

This study underscores the importance of further research into the long-term impact of AI on younger learners, especially regarding the sustainability of engagement and the potential for over-reliance. Future research could investigate strategies for fostering a balanced approach to AI usage, where students are encouraged to engage critically and creatively rather than passively accepting AI outputs. Moreover, understanding how AI's role in education differs across age groups - such as between secondary school and university students - could provide insights into how to adapt AI integration to various developmental stages.

The integration of AI into education holds immense promise, but it must be implemented thoughtfully to avoid undermining the value of human educators and critical pedagogical practices. As highlighted by the research of Kassymova et al. (2021) and Rohde et al. (2023), AI offers substantial potential to personalize learning and improve outcomes, particularly in online and blended learning environments. However, careful consideration must be given to the ethical implications, such as algorithmic bias and the risk of depersonalizing education.

Conclusion

In conclusion, AI offers valuable opportunities for enhancing educational engagement but also presents new challenges in pedagogy. To maximize AI's benefits while mitigating risks, educators and researchers need to work together to develop structured, balanced approaches that promote meaningful engagement, skill-building, and independence among students. AI in education holds great promise, but its implementation should be carefully managed to avoid undermining essential learning processes. The key to

successful implementation lies in creating a balanced approach that combines the best of AI technology with traditional pedagogical strategies. AI should be seen not as a replacement for teachers but as a tool to empower them, enhancing their ability to support students and address individual learning needs.

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The Role of Gamification in Promoting Digital Literacy: Bridging the Gap between Fun and Learning

Abstract: Educators are exploring innovative methods to teach digital literacy engagingly as it becomes an essential skill in the 21st century. A powerful tool for enhancing student motivation and participation is gamification, which involves the use of game elements in non-game contexts. This article examines the role of gamification in promoting digital literacy among school-aged learners, emphasizing its ability to bridge the gap between fun and education. Using points, rewards, levels, and challenges as part of digital literacy lessons can create a more dynamic and interactive learning environment. This study explores the role of gamification in enhancing digital literacy among 5th and 6th-grade students. Involving 60 students aged 10 to 12, the research divided participants into two groups: one engaged in a fully gamified learning environment and the other instructed through traditional methods supplemented with gamification elements. Through pre-test and post-test assessments, the effectiveness of gamification strategies in improving digital literacy skills was evaluated. A variety of gamified approaches are described in the article, along with the benefits of increased student engagement and possible challenges about the balance between entertainment and educational objectives. Finally, practical strategies for implementing gamification in digital literacy programs are provided, offering educators a roadmap for fostering critical digital skills enjoyably and effectively.

Keywords: Gamification in Education, Digital Literacy, Educational Technology, Game-Based Learning, Technology Integration

Introduction

In recent years, the integration of gamification into educational frameworks has emerged as a powerful tool for enhancing student engagement, fostering motivation, and promoting digital literacy. In today's rapidly evolving digital landscape, digital literacy is fundamental for success in personal, academic, and professional spheres. Digital literacy encompasses more than just the ability to operate technology; it includes critical thinking, data management, and the safe, responsible use of digital tools (Azman et al., 2024). Gamification has gained popularity in education because of its potential to make learning more interactive, enjoyable, and effective. Gamification taps into the psychological principles that make games appealing, such as achievement, progression, and reward, and applies them in educational contexts (Sailer et al., 2017). By transforming otherwise mundane tasks into engaging activities, gamification helps cultivate a natural interest in learning digital literacy skills. For instance, educational platforms incorporating gamified elements, such as Duolingo for language learning or Kahoot for quizzes, illustrate how students can acquire new skills in enjoyable, manageable formats that motivate continuous participation (Agung et al., 2023; Plump & LaRosa, 2017).

Kassymova et al. (2021) explore the upgrading of learning quality through e-learning systems, suggesting that the integration of interactive technologies, including gamification, plays a crucial role in enhancing the overall learning experience. By providing real-time feedback and adaptable learning pathways, gamified systems can address individual learning needs and foster critical digital skills (Kassymova, Nursultan, & Xu, 2024). This individualized approach not only improves engagement but also helps develop digital

literacy more dynamically and enjoyably. Gamification in education is not merely about incorporating game-like elements but about strategically aligning these elements with educational objectives to promote deeper engagement. According to Rohde et al. (2023), artificial intelligence can be leveraged in conjunction with gamification to further personalize e-learning programs, making them more responsive to the learner's progress and interests. Moreover, the role of mobile applications in promoting digital literacy has been explored in studies on interactive learning tools, such as the Android-based application for teaching manufacturing technology (Mutarah et al., 2024). These mobile platforms offer hands-on experiences that blend traditional content with innovative, game-inspired mechanics, thereby supporting both technical and cognitive skill development.

Digital literacy programs that incorporate gamification are particularly effective in bridging the gap between traditional instruction and experiential learning. Unlike conventional learning, which often follows a rigid, didactic format, gamified learning offers an immersive experience. Learners become active participants, exploring complex topics through challenges, points, badges, and levels that reward effort and achievement (Koravuna & Surepally, 2020). This interactive environment fosters intrinsic motivation, encouraging students to engage with material more deeply than they might in a traditional setting (Deterding et al., 2011). For digital literacy, this means learners are more likely to retain critical concepts, such as information evaluation, digital safety, and privacy, because they have actively engaged with these skills in a dynamic, game-based context.

The rapid digitalization of education has heightened the need for innovative approaches that effectively engage students and develop essential digital literacy skills. As technology becomes increasingly integral to all facets of life, digital literacy—encompassing competencies such as evaluating information, navigating online environments, and using digital tools responsibly—has become a core element of modern education (Mazlan et al., 2023). However, traditional teaching methods may struggle to fully engage digital-native students, who are accustomed to interactive, technology-enhanced experiences. Consequently, educators and researchers are exploring gamification as a promising strategy to foster digital literacy in a way that is both engaging and effective.

One of the most compelling aspects of gamification is its adaptability. Digital literacy programs vary in their scope and complexity, depending on learners' needs and proficiency levels. Gamification is flexible, offering a personalized learning experience that can adjust to diverse skill levels. For example, adaptive gamified digital literacy programs allow learners to progress at their own pace, ensuring they master foundational skills before advancing to more complex topics. Studies have shown that this adaptive learning approach not only improves digital literacy skills but also fosters greater learner satisfaction (Stylianou & Savva, 2022). Moreover, because gamified learning can occur across various devices and settings, it enhances accessibility, allowing more people to engage with digital literacy education in ways that fit their preferences and schedules.

Gamification, the integration of game-like elements (such as points, rewards, and challenges) into non-game environments, leverages motivational design principles to create learning experiences that captivate students' attention and drive their involvement. By turning routine educational tasks into dynamic, interactive activities, gamification encourages students to actively participate in their learning. This approach has shown considerable potential in enhancing digital literacy by encouraging students to explore digital tools, solve complex problems, and collaborate with their peers in a digital context. Foundational studies, such as that by Molumby (2016), highlight the effectiveness of structured gamified environments in fostering student engagement, motivation, and complex problem-solving abilities. Meanwhile, Sun & Hsieh (2018) and (García Cabot et al. (2017) demonstrate how points, leaderboards, and achievements in online courses can positively impact academic performance and prolong engagement.

Critics of gamification argue that it may dilute educational content by focusing too heavily on entertainment rather than knowledge acquisition. However, well-designed gamification strikes a balance between fun and learning, promoting both enjoyment and meaningful engagement with the material (Hamari et al., 2014). In a gamified environment, learners encounter structured challenges that enhance problem-solving skills, a vital aspect of digital literacy. These challenges can range from decoding complex information to navigating online safety scenarios, providing real-world relevance and practical application (Asigigan & Samur, 2022). Thus, gamification not only makes learning more enjoyable but also ensures that the lessons are both substantive and applicable in real digital environments.

Gamification also addresses the evolving expectations of digital-native learners who are accustomed to interactive multimedia content. Traditional instruction often fails to resonate with these learners, who find conventional learning methods disengaging. Gamified digital literacy programs, with their interactive design, appeal to this demographic by presenting information in formats that are familiar and engaging. This approach aligns with research suggesting that younger learners exhibit higher retention rates when educational content is visually stimulating and participatory (Kassymova et al., 2024). By incorporating gamified elements such as instant feedback, level progression, and collaborative tasks, educators can create a learning environment that resonates with students, keeping them motivated to engage in digital literacy education.

Despite its promising potential, the success of gamification in education heavily depends on context-specific factors, such as students' age, learning preferences, and cultural backgrounds. For example, while leaderboards may motivate some students, others might find them intimidating or discouraging (Dicheva et al., 2015). Similarly, the level of technological access and support available within schools can significantly influence how gamification is implemented and received. Recent studies, such as those by Carlos Fernández-Zamora & Arias-Aranda (2017) and Muangsrinoon & Boonbrahm (2019), emphasize the importance of aligning gamified designs with theoretical frameworks like Self-Determination Theory to address both intrinsic and extrinsic motivations, ultimately supporting students' sustained engagement and digital skill development.

Given the growing body of research and practical applications, this article explores the role of gamification in promoting digital literacy. It aims to bridge the gap between fun and learning by examining how gamified environments not only enhance motivation but also foster critical digital competencies. Through a review of existing literature, theoretical frameworks, and specific case studies, this article sheds light on the potential of gamification to transform digital literacy education and offers insights into designing effective gamified learning environments that balance engagement with skill acquisition.

Literature review

As the digital landscape continues to evolve, digital literacy has emerged as an essential skill set, encompassing a wide range of competencies from basic technological skills to more advanced information analysis and problem-solving abilities (List, 2019). However, traditional methods of teaching digital literacy often struggle to fully engage learners, particularly younger, digitally native audiences. In response to this challenge, educators and researchers have explored gamification—the integration of game-like elements into non-game contexts — as a method for enhancing digital literacy education by making it more accessible, interactive, and appealing (Turan & Meral, 2018). This section reviews existing literature on the role of gamification in promoting digital literacy, focusing on its impact on learner engagement, motivational outcomes, adaptability to different learning levels, and criticisms of its implementation.

The exploration of gamification in educational contexts has become increasingly prominent in recent years, reflecting a growing recognition of its potential to enhance student motivation and engagement. The foundational work by Molumby (2016) highlights the critical role that gamified learning environments play in fostering student competencies. By establishing clear instructions and well-defined purposes, educators can significantly boost engagement levels, thereby supporting the development of complex problem-solving skills. This study underscores the necessity for empirically validated gamified designs, advocating for the integration of specific gamification principles—such as visual status, social engagement, and rapid feedback—within educational frameworks.

Building on this foundation, García Cabot et al. (2017) expand the discussion by examining the integration of gamification elements within MOOCs. Their research modifies the Elgg social platform, demonstrating how points, achievements, and leaderboards can enhance academic performance and prolong engagement in e-learning environments. This work emphasizes that while gamification can effectively drive user behavior, its success heavily relies on the context and characteristics of the users involved (Kassymova et al., 2021).

Furthering this conversation, Carlos Fernández-Zamora & Arias-Aranda (2017) explore the implementation of gamification in a master's program, aiming to combat distractions inherent in the digital age. They argue that gamification not only fosters motivation and active participation but also cultivates a sense of flow and self-directed learning among students. Their findings align with the notion that

gamification, characterized by game elements such as goals, rules, and feedback, can create engaging educational experiences that enhance student involvement.

Liivak (2018) contributes to the discourse by investigating gamification within an English as a Foreign Language (EFL) textbook set. This study illustrates how gamification can transform traditional educational paradigms, fostering greater emotional connections and social positioning among students. By addressing both intrinsic and extrinsic motivations, gamification emerges as a powerful tool for enhancing student engagement and learning outcomes, particularly in language acquisition contexts (Utaminingsih et al., 2024).

Muangsrinoon & Boonbrahm (2019) provide a systematic review that identifies a variety of game elements applicable across different fields, including education and healthcare. Their analysis reveals the relationship between gamification and Self-Determination Theory, suggesting that elements such as feedback, competition, and cooperation can significantly motivate learners. This broad applicability of gamification underscores its potential as a versatile framework for enhancing educational practices.

Chong (2019) further examines the diverse applications of gamification in higher education, noting its effectiveness in improving student motivation and performance across various disciplines. However, the study also highlights the criticisms surrounding measurement and the need for a deeper understanding of gamification's design and implementation processes. This call for more robust conceptual frameworks suggests that while gamification shows promise, further research is necessary to optimize its application in educational settings.

Prados Sánchez et al. (2023) shifts the focus to the specific domain of reading instruction, illustrating how gamification can positively influence students' attitudes and motivation toward reading. The findings indicate that platforms like Read Theory can serve as effective alternatives to traditional methods, fostering independent reading habits among students. This study emphasizes the importance of integrating gamification into curriculum design to enhance language development and learner autonomy.

Finally, Jack et al. (2024) explore gamification within flipped classroom environments, reinforcing the idea that gamified elements can significantly enhance student engagement and learning outcomes. Their recommendations for educators aim to leverage gamification strategies to foster active participation and motivation, suggesting a promising avenue for future research in this dynamic field.

Table 1. Summary of Key Studies on Gamification in Educational Contexts

Authors	Focus	Key findings	Gamification elements
Molumby (2016)	Role of gamified environments in fostering competencies	Gamified learning boosts engagement and problem-solving skills through clear	Visual status, social engagement, rapid feedback
García Cabot et al. (2017)	Gamification in MOOCs	Integration of points, achievements, and leaderboards in e-learning enhances academic performance and engagement. Context and user characteristics impact effectiveness	Points, achievements, leaderboards
Carlos Fernández-Zamora & Arias-Aranda (2017)	Gamification in a master's program	Gamification promotes motivation, participation, flow, and self-directed learning, fostering engaging educational experiences	Goals, rules, feedback
Liivak (2018)	Gamification in EFL education	Gamification in EFL settings boosts emotional connections, social positioning, and engagement. Addresses both intrinsic and extrinsic motivations	Various motivational elements

Prados Sánchez et al. (2023)	Gamification in reading instruction	Gamification positively impacts reading motivation and attitudes. Tools like ReadTheory support independent reading and language development	Points, levels, progress tracking
Jack et al. (2024)	Gamification in flipped classroom environments	Gamification significantly enhances engagement and learning in flipped classrooms. Recommends gamification strategies for improved student motivation	Points, challenges, progress feedback

Overall, the literature collectively underscores the transformative potential of gamification in education, highlighting its ability to bridge the gap between engagement and learning. Through a critical evaluation of the various studies, it becomes evident that while gamification presents numerous benefits, its effectiveness is contingent upon thoughtful implementation tailored to specific educational contexts and learner needs.

Methodology

Participants

The study involved 60 students from four 5th and 6th-grade classes in a private school, aged between 10 and 12 years old. The students were divided into two experimental groups and two control groups, each consisting of 15 students. The students were chosen to represent typical digital literacy levels and engagement behaviors among early adolescent learners, a demographic particularly responsive to interactive and gamified learning environments.

The approach used in this study was quasi-experimental design that compared two groups: one group received a gamified digital literacy program, while the other group followed a traditional, non-gamified curriculum. This allowed the researchers to assess differences in learning outcomes and engagement that were directly attributable to the gamification elements. It also used pre- and post-assessment tests to measure improvements in digital literacy competencies, such as information processing and digital ethics, between the gamified and non-gamified groups. This design helped isolate the effects of gamification, providing a controlled basis for comparing how different teaching methods impact digital literacy.

Results and discussion

This study employed a quasi-experimental design with a pre-test/post-test structure to assess the impact of gamification on digital literacy skills. Digital literacy was evaluated across specific sections, each focusing on a distinct area (e.g., online information evaluation, digital communication, and online safety). The study spanned three weeks, during which one group of students engaged in gamified digital literacy activities, while the other followed a traditional instructional approach supplemented with limited gamified elements.

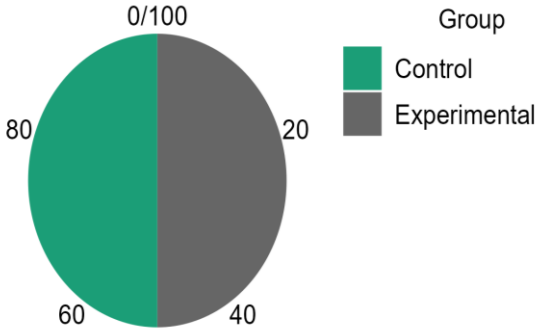

Figure 1. Proportion of Students in Control and Experimental Groups

- *Experimental Group (Gamified Format):* Two classes participated in a digital literacy program heavily incorporating gamification elements, such as points, badges, challenges, and immediate feedback mechanisms. Activities were designed to encourage students' engagement and reinforce digital skills in a fun, interactive way.
- *Control Group (Traditional Format with Limited Gamification):* The other two classes followed a traditional instructional approach with limited gamification features, using standard teaching methods supplemented by only a few game-like elements (e.g., occasional points or quizzes but without the comprehensive gamified structure of the experimental group).

All students completed a digital literacy pre-test, divided by sections, to assess their baseline skills and knowledge. This test was structured to capture performance across the same digital literacy competencies targeted in the program.

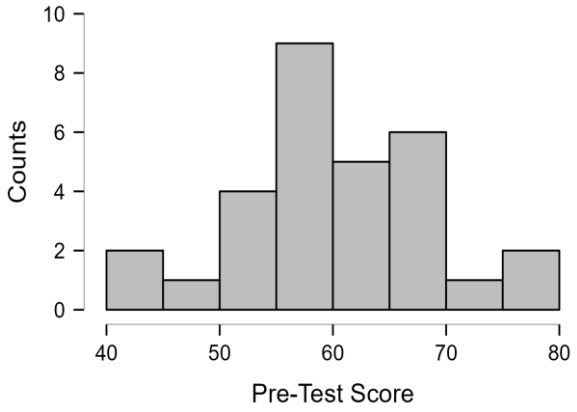

Figure 2. Distribution of Pre-Test Scores Among Students

Intervention

- *Experimental Group:* The two experimental classes engaged in a fully gamified curriculum, incorporating various game design elements such as levels, points, feedback loops, and collaborative tasks, to foster engagement and reinforce learning outcomes. This intervention was conducted over three weeks, with daily sessions designed to be interactive and responsive to students' progress.
- *Control Group:* The two control classes received instruction on the same digital literacy topics but through a traditional teaching format. They participated in teacher-led instruction, with periodic quizzes and discussions but minimal interactive elements.

At the end of the three-week intervention, all students took a post-test structured identically to the pre-test, divided by sections. This allowed for a direct comparison of pre- and post-intervention results to evaluate changes in digital literacy skills and the potential influence of gamification elements on student engagement and performance.

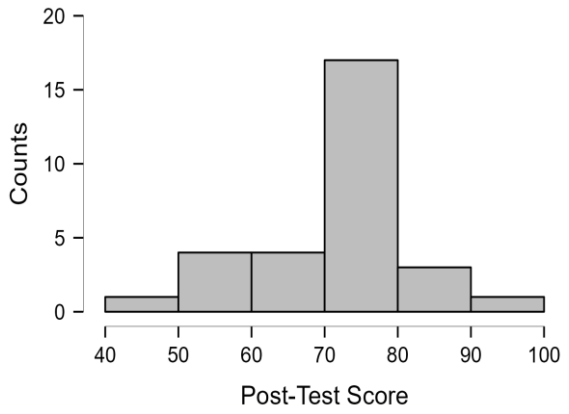

Figure 3. Distribution of Post-Test Scores Among Students

After three weeks of engaging in gamification elements, post-test scores ranged from 44.65 to 90.43, with a mean score of approximately 73.76. The distribution plot in of post-test scores illustrated the effectiveness of the intervention in the Fig. 3.

Table 2. Descriptive Statistics

	Student	Gender	Group	Pre-Test Score	Post-Test Score
Valid	30	30	30	30	30
Mode	1.000 [a]	1.000	1.000	57.660 [a]	44.650 [a]
Median	15.500			58.140	74.500
Mean	15.500			59.897	72.105
Std. Error of Mean	1.607			1.556	1.872
Std. Deviation	8.803			8.522	10.255
Coefficient of variation	0.568			0.142	0.142
Variance	77.500			72.625	105.159
Range	29.000			34.920	45.780
Minimum	1.000			40.870	44.650
Maximum	30.000			75.790	90.430
25th percentile	8.250			55.318	65.578
50th percentile	15.500			58.140	74.500
75th percentile	22.750			65.948	77.487

Note. Not all values are available for *Nominal Text* variables

Education serves as a fundamental driver of social progress, and for educational institutions to adapt their pedagogical approaches effectively, it is crucial to assess students' learning outcomes. In this analysis (Table 2), we examine the performance data of 60 students, focusing on their pre- and post-test scores while considering various demographic factors. The sample consists of students aged 10 to 12, with a balanced representation of male and female participants. This equitable distribution helps minimize age and gender biases in our study, allowing for a more nuanced examination of student performance.

An analysis of performance by gender reveals interesting trends. Pre-test averages for male and female students are similar, yet post-test results indicate that female students have a slight advantage in digital literacy skills following the intervention. This phenomenon suggests the need for further investigation into the factors influencing learning outcomes that may be specific to gender in the context of gamified learning environments.

Age also plays a significant role in academic performance, as older students may exhibit greater cognitive maturity and academic preparedness. However, our data indicates no significant correlation between test scores and age within the 10-12 age range. Both 10-year-old and 11-year-old students demonstrate comparable levels of achievement, implying that factors beyond age may contribute to variations in learning outcomes.

A closer look at individual student data reveals a spectrum of performance outcomes. Some students show marked improvement between the pre- and post-tests, while others either progress minimally or even regress. This variability underscores the importance of employing personalized teaching strategies tailored to the diverse needs of individual learners, particularly in gamified educational settings. Such tailored

approaches are essential to ensure that all students benefit from the engaging learning experiences gamification offers, aligning with the objectives of this study.

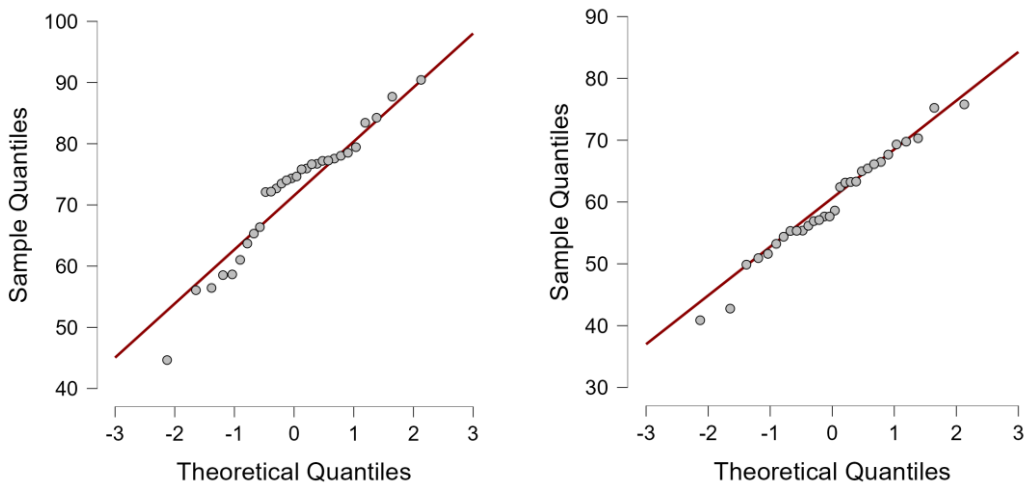

Figure 4. Comparing Pre-test and Post-test t Scores to Normal Distribution

Fig. 4 shows the post-test scores, ranging from 44.65 to 90.43, which should ideally show a shift towards a normal distribution. If the plot indicates a more centralized distribution compared to the pre-test, it signifies that gamification has effectively engaged students, improving their overall digital literacy skills. This shift reinforces the article's argument that fun and engaging educational methods can lead to better outcomes (Sadera et al., 2014). A marked difference in the shapes and central tendencies of the two plots provides empirical evidence to support the argument for the effectiveness of gamified learning. The comparison of the post-test distribution to the pre-test plot revealed shifts in the central tendency and shape, indicating the impact of gamification on students' learning outcomes.

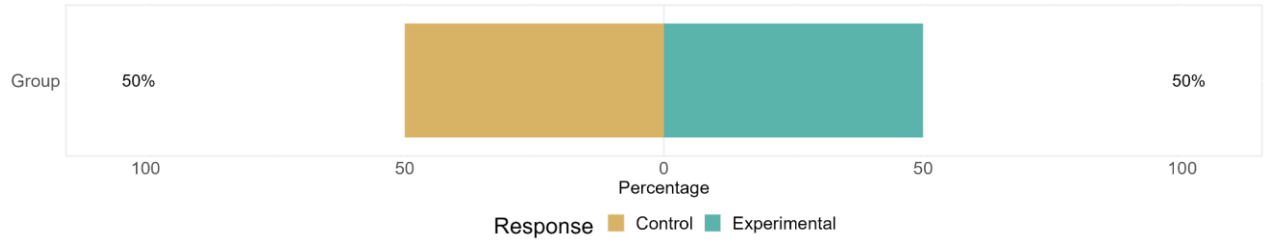

Figure 5. Likert plots of students' post-scores

Statistical analysis was conducted to evaluate the significance of the differences in performance across groups. The data from this study will provide insights into the effectiveness of gamification in enhancing digital literacy and offer practical recommendations for integrating gamification into early adolescent education. This study demonstrates the significant potential of gamification in enhancing digital literacy among 5th and 6th-grade students (Saxena & Mishra, 2021). By comparing pre-test and post-test scores, we observed substantial improvements in digital literacy skills among students exposed to a gamified learning environment, with female students showing particularly notable gains. These findings underscore the effectiveness of engaging, interactive educational strategies that foster motivation and participation, ultimately bridging the gap between traditional learning and modern educational needs.

Despite the positive outcomes, the analysis revealed complexities in student performance that highlight the importance of personalized teaching approaches. The absence of a strong correlation between age and academic achievement suggests that factors beyond mere age, including individual learning styles and prior knowledge, significantly influence educational outcomes. This variability calls for educators to

implement differentiated instruction tailored to the diverse needs of students, ensuring that all learners benefit from gamified strategies.

Conclusions

In conclusion, integrating gamification into educational practices presents a promising avenue for improving digital literacy and overall engagement in learning. As educational institutions strive to adapt to the demands of the digital age, embracing gamified methodologies can create dynamic and inclusive learning environments that cater to the varied needs of students. The convergence of gamification and e-learning represents a transformative approach to education. By aligning fun with learning objectives, gamified systems not only make digital literacy more accessible but also cultivate a generation of learners who are better equipped to thrive in the increasingly digital world. Future research should explore the long-term effects of gamification on learning outcomes and investigate specific elements that contribute to its effectiveness, further refining strategies to maximize its benefits in diverse educational contexts.

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Wetting and interaction of titanium melt with barium zirconate

Abstract: The paper presents the results of a study of the reaction interaction and the contact angle of wetting during contact of titanium melt with the surface of a barium zirconate substrate. It is shown that the titanium melts at 1720°C wets the barium zirconate substrate. The wetting process is considered, accompanied by gas evolution, penetration of the titanium melt through capillaries between $BaZrO_3$ particles and partial dissolution of the substrate. Upon completion of the spreading process, the contact angle of wetting of the $BaZrO_3$ substrate by the titanium melt is 18°. The high wettability of $BaZrO_3$ ceramics and its dissolution in the titanium melt does not allow its use as components of lining and molding materials for melting and casting of titanium alloys in cases where high requirements are imposed on the castings for chemical composition and, accordingly, mechanical properties.

Keywords: titanium, wetting, barium zirconate, interaction, alloys.

Introduction

Recent studies have made significant contributions to the understanding of material interactions and technological advancements in metallurgy. Panichkin et al. (2019) explored the interaction of titanium melt with refractory oxides of various metals, shedding light on the complex behaviors during alloy production, which can influence the properties of the final material. Similarly, Kenzhaliyev (2019) presented innovative technologies for improving the extraction of non-ferrous, precious, and rare earth metals, emphasizing the need for efficiency in metallurgical processes. In a more specialized area, Chukmanova et al. (2023) examined the use of ceramic molds based on yttrium oxide for casting titanium alloys, an approach that promises to enhance the precision and quality of castings in advanced material applications. Additionally, Panichkin and Kshibekova (2023) assessed how flux composition affects the removal of non-metallic inclusions in high-chromium cast iron, providing valuable insights into refining techniques aimed at improving the quality of iron alloys. These studies collectively highlight the ongoing developments in the fields of metallurgy and materials science.

Due to high specific strength and corrosion resistance, titanium and titanium alloys are widely used in various fields of technology. However, the volumes of production of titanium products are small due to high production costs associated not only with the increased cost of raw materials but also with the high

cost of all stages of processing. The production of titanium alloy castings is in demand in chemical engineering, orthopedics and prosthetics in dentistry. Improving the quality of castings and reducing production costs play an important role in ensuring the competitiveness of products. Vacuum induction furnaces are the most accessible of the furnaces that provide the ability to melt titanium in a vacuum. Their use can significantly increase the scale of obtaining titanium castings. However, the high reactivity of Ti-based alloys makes it impossible to use traditional refractory and molding materials for lining induction furnaces and for obtaining casting molds (Panichkin et al., 2016). The development of refractory materials characterized by minimal interaction with titanium melts is necessary for the further development of foundry production in the titanium industry.

For many decades, studies have been conducted to find materials that are inert or relatively inert to titanium melts (Panichkin et al., 2016; Fashu et al., 2020; Kenzhaliyev et al., 2024; Li et al., 2010; Klotz et al., 2019; Zhang et al., 2006; Chen 2018; Zhu et al., 2002; Li et al., 2018). These studies examined the interaction of titanium melts with many simple and complex oxides, nitrides, carbides, and graphite. It was found that titanium melt interacts least actively with the oxides Y_2O_3, $CaZrO_3$, and $BaZrO_3$. This made it possible to propose using these compounds for lining induction furnaces and manufacturing crucibles for melting titanium alloys. However, ceramics made of Y_2O_3, despite the best resistance to titanium melts, are expensive and can only be used in low-tonnage production. Refractories and molding materials made of $CaZrO_3$, $BaZrO_3$ (Kenzhaliyev et al., 2024; Li et al., 2010; Klotz et al., 2019; Zhang et al., 2006; Chen et al., 2018; Zhang et al., 2018) are more economically attractive. However, as studies have shown (Mamayeva et al., 2022; Zhang et al., 2013), $CaZrO_3$, when in contact with titanium melt, still interacts and causes contamination of the titanium melt with zirconium and oxygen. This calls into question the prospects for using ceramics, lining and molding mixtures based on this compound in the titanium industry. The work describes the absence of a boundary reaction layer between a crucible made with $BaZrO_3$ alloyed with Y_2O_3 and a TiNi alloy (Zhang et al., 2013). The authors propose this material as a crucible coating or as part of $BaZrO_3/Al_2O_3$. Although the work by Chen et al. (2018) considers the interactions between $BaZrO_3$ crucibles and titanium melts, where it is shown that the dissolution of $BaZrO_3$ refractory in titanium melts led to crucible erosion and melt contamination, the degree of which increased with increasing Ti content in the melts.

To assess the prospects for using $BaZrO_3$ in titanium alloy casting, it is necessary to continue research on the interaction of this compound with titanium alloys. In particular, it is necessary to study the processes of reactive diffusion and wetting of the $BaZrO_3$ surface with titanium melt.

The works devoted to the general theory of wetting are extensive (Passerone et al., 2016; Zhu et al., 2002; Eustathopoulos 1998; Li et al., 2018; Barbosa et al., 2006; Lin et al., 1999). Wetting of ceramics by metal is determined by two types of interactions occurring at the interface, leading to non-reactive wetting and reactive wetting ((Mamayeva et al., 2022; Zhang et al., 2013; Kenzhaliyev, 2019)). Non-reactive wetting occurs in liquid/solid systems in which mass transfer across the interface is very limited and has little effect on the interfacial energy. Wetting involving chemical change and/or diffusion of chemicals across the interface is reactive wetting, which often occurs in metal/ceramics systems at high temperatures. However, only a small number of studies on interfacial phenomena and wettability of ceramics by titanium melts are reported in the literature.

The paper examines the processes of interaction of liquid titanium with zirconates and titanates of some alkaline earth metals (Kenzhaliyev et al., 2024). Characteristic reactions between ceramics and titanium melt during short-term contact are presented. The results of a study of the interaction of titanium melt with BaZrO3 and $SrZrO_3$ zirconates, as well as $SrTiO_3$ titanate under vacuum and inert atmosphere are presented. However, no studies were presented on determining the contact angle of titanium melt on these substrates, so there is a need to consider the wettability process with the measurement of the contact angle.

In this regard, the aim of this work is to consider the processes developing during contact of titanium melts with barium zirconate by the method of determining the contact angle of wetting and studying the transition zone.

Research Method

The synthesis of $BaZrO_3$ zirconate was carried out by the solid-phase method. The batch of barium oxide BaO and zirconium oxide ZrO_2 was subjected to joint-intensive milling and mixing in a mill. Then,

tablets of ∅40 mm and 5 mm in height were obtained from the obtained mixed powders on a hydraulic press at a pressure of 40 MPa. These tablets were subjected to heat treatment at 1550-1670°C for 5 hours in a normal atmosphere in an RHTV 120-600/C 40 "Nabertherm" tubular furnace. The phase composition of the obtained ceramic tablets was studied on a D8 Advance X-ray diffractometer (BRUKER), the results are presented in Table 1.

Table 1. Phase composition of synthesized barium zirconate

Pattern #	**Compound Name**	**Formula**	**S-Q**
PDF 01-070-3667	Barium Zirconium Oxide	$Ba(ZrO_3)$	100%

To determine the parameters of wetting of ceramic substrates with titanium melt, an experimental setup was created in the metal science laboratory of JSC "IMOB" in Almaty (Figure 1). This setup ensures the heating of a ceramic substrate with a titanium alloy cylinder installed on its surface to a specified temperature, with a video recording of the process of spreading titanium melt over the surface of the ceramic sample in horizontal projection. The heating process occurs under high vacuum conditions, which is ensured by a two-stage vacuum pumping system. During the heating process, the melt temperature is recorded using a stationary infrared spectral ratio pyrometer Thermoscope-800-2S-VT1.

A cylinder of titanium alloy grade VT1-0 (Grade2) ∅ 10 mm and 5 mm high was installed in the centre of the BaZrO3 substrate. They were placed on a molybdenum tray in the furnace of the installation to determine the contact angle of wetting. After pumping out the installation chamber to a residual pressure of 3-5*10-3 Pa, the furnace was heated. At the moment of the beginning of titanium melting, the video recording was turned on, while the melt temperature was continuously recorded. After reaching the specified temperature, isothermal holding was carried out. Upon completion of the holding, the furnace heating was stopped and the sample was cooled under conditions of continuous pumping to 50-100°C.

When measuring the contact angle, still frames of a video of the melt-spreading process on the substrate were used. The contact angle measurements were performed using the Image J program. The structure of the contact zone of the melt and the ceramic substrate and the composition of the phases formed in it were studied using a Leica DM IRM optical inverted microscope and a JEOL JXA-8230 electron probe microanalyzer (Japan). These studies were performed on transverse sections.

Figure 1. External view of the installation for determining the contact angle under high vacuum conditions

Results and Discussion

Figure 2 shows the key stages of interaction between the titanium melt and the surface of the barium zirconate substrate after melting (Figure 2 a) and during holding at 1720 °C. As follows from the presented freeze frames, at the moment of melting, the titanium melt poorly wets the $BaZrO_3$ substrate, the contact angle is 105 °C. Upon reaching 1720 °C, the interaction of the melt with the substrate begins. At the initial stage, dynamic oscillation of the melt droplet is observed with a periodic increase in its size

(Figure 2 b, c). This indicates the release of a gas phase in its volume. The release of gas bubbles onto the melt surface causes partial splashing of the melt. At the same time, melt spreading also intensifies. Oscillation of the droplet causes a change in the contact angle in the range of 83-126 °C. After 20 seconds, the stage of intensive interaction and melt spreading is completed (Figure 2 d). The contact angle stabilizes at 18-20°. The dependence of the contact angle of wetting of the BaZrO3 substrate by the titanium melt at 1720°C on the contact time is shown in Figure 4.

a b c d

a - after melting; b - 1720 °C 18 s; c -1720 °C 22 s; d - 1720 °C 24-105 s

Figure 2. Still frames of the process of wetting the $BaZrO_3$ substrate with titanium melt

Figure 3. View of the sample after the experiment on the wettability of titanium melt on a $BaZrO_3$ substrate

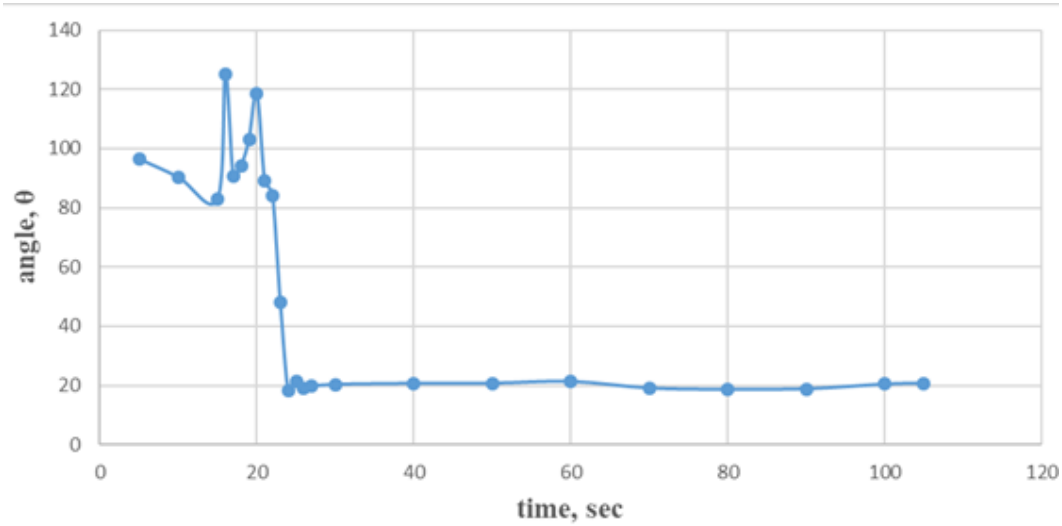
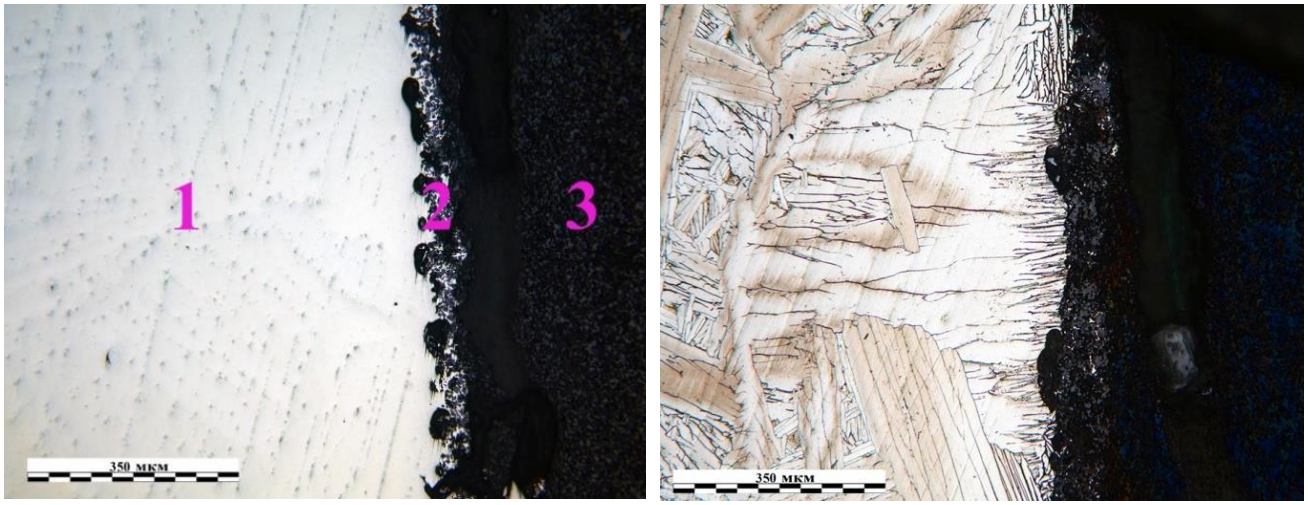


Figure 4. Dependence of the contact angle θ on time

Metallographic analysis showed that characteristic areas are revealed in the contact zone of titanium and $BaZrO_3$ ceramics (Figure 5 a): 1 - titanium, 2 - transition layer, 3 - ceramic zone impregnated with titanium melt. A crack formed at the boundary between the transition layer and the ceramic substrate, which is explained by the difference in the temperature coefficients of linear expansion of titanium and $BaZrO_3$. Titanium has a structure characteristic of β-titanium (Figure 5 b). A chain of pores is found in the transition layer, which indicates the formation of a gas phase during the reaction interaction. The width of this layer varies in different areas in the range of 70-120 μm. The layer is two-phase and is formed by discrete particles of a polyhedral shape in a metal matrix. The characteristic colour and shape of the particles allow us to conclude that the discrete particles are ceramic particles impregnated with the melt.



a b

Figure 5. Microstructure of the $BaZrO_3$+Grade2 contact zone before and after revealing the titanium structure (x150)

The study of the structure of the contact zone by scanning electron microscopy confirmed that in the transition layer between $BaZrO_3$ and titanium, as a result of physicochemical interaction, a ceramic layer impregnated with titanium melt is formed. EDS analysis of this section (Figure 6, points 5, 7, 8, 9 of Table 2) shows that the concentration of Zr, O, Ba, Ti in the ceramic particles corresponds to $BaZrO_3$. The analysis at point 6 shows that $BaZrO_3$ particles dissolve in the titanium melt without forming other intermediate phases. At the same time, at points 1, 2, 3 and 4, the concentration of barium, zirconium and oxygen in titanium decreases with distance from the reaction zone. Thus, at a distance of 130 μm from the reaction zone at point 1, oxygen and barium are not detected in the titanium composition. However, oxygen is detected in white layers between the branches of the dendrites of the solid solution of zirconium in titanium (point 4). This indicates that oxygen and barium in the form of a vapour-gas mixture are predominantly removed from the contact zone, which manifests itself in the form of pore formation and melt bubbling. However, some oxygen remains in the titanium and is displaced by the crystallization front during solidification.

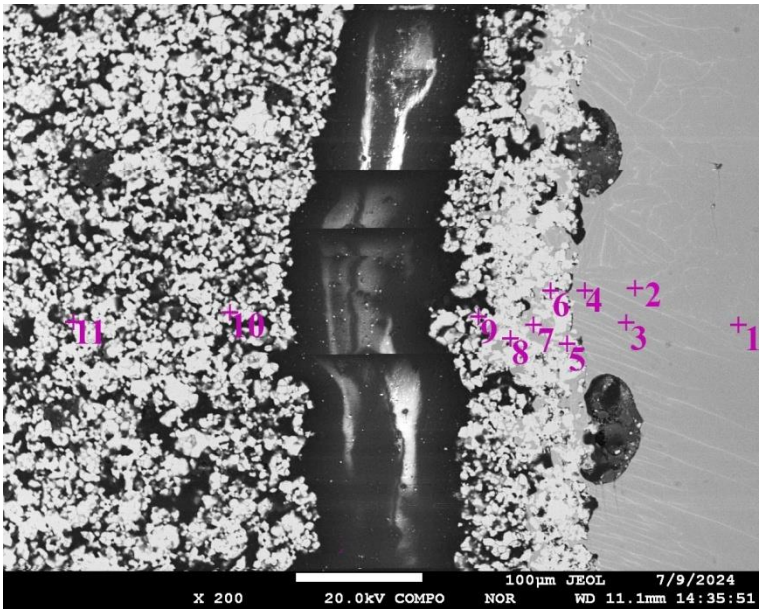


Figure 6. Structure of the transition layer formed between titanium melt and barium zirconate, EDS analysis points

Table 2. Results of microprobe analysis of the transition zone at the points indicated in Figure 6.

№	**Ti**	**Zr**	**O**	Ba
	mol%	**mol%**	**mol%**	**mol%**
1	97.98	2.02	-	-
2	91.35	8.65	-	-
3	81.80	9.48	-	7.42
4	52.94	7.08	39.58	-
5	-	20.76	60.91	17.6
6	13.95	15.87	56.95	13.23
7	1.30	19.31	61.70	17.69
8	-	18.95	64.87	16.18
9	0.97	20.13	62.37	16.53
10	-	16.47	70.80	12.73
11	-	13.20	78.87	7.93

Conclusions

Thus, the conducted studies indicate that the barium zirconate substrate at 1720 °C is well-wetted by the titanium melt. When the titanium melt contacts the $BaZrO_3$ substrate, the molten titanium penetrates through the channels between the $BaZrO_3$ particles under the action of capillary force and physical wetting. In this case, the surface of the particles dissolves. Zirconium and partially oxygen diffuse in the volume of the melt. Barium and partial oxygen evaporate at the interface, which causes the melt to bubble. Based on the results of the conducted studies, it can be said that the contact angle of wetting correlates with the reaction interaction of barium zirconate with titanium.

Thus, the established features of the interaction of titanium melt and barium zirconate, indicating the development of wetting and dissolution of the $BaZrO_3$ ceramics surface by the titanium melt, show that lining materials, crucibles and molding materials based on $BaZrO_3$ cannot be used for melting and casting titanium alloys in cases where high requirements are imposed on the castings for chemical composition and, accordingly, mechanical properties. A promising area may be the search for additives that reduce the interaction of BaZrO3 ceramics with titanium melts.

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Subjective Factors Contributing to the Development of Dependent Behavior in University Students

Abstract: *Introduction.* This article explores dependent behavior, specifically drug addiction, as a subjective issue stemming from imbalances in human development. The subjective factors contributing to the development of dependent behavior are identified, including "I-concept", "life script", and relational styles. The importance of implementing advisory strategies focusing on the subjective aspects of health is emphasized, as these strategies can help improve students by fostering their internal wholeness. The purpose of this work is to explore and explain the subjective factors involved in the formation of dependent behaviors and to assess the effectiveness of advisory techniques that focus on the subjective dimension of health in addiction prevention. *Materials and methods.* The method of the research is the logical-theoretical analysis of psychological-pedagogical and ecological-valeological literature devoted to the problems of self-preservation behavior and health; diagnostic methods, including observation, description, conversation, questioning, testing, and methods of statistical data processing. *Results.* The subjective prerequisites for the development of addictions in students of pedagogical University, as well as the conditions that prevent their development, are identified and described. The technology of Advisory activity on the subjective component of health as a technology of prevention and correction of dependent behavior is developed. *Discussion.* Based on the study, it is noted that dependence on external circumstances and the will of others reduces the level of the subjectivity of students and leads to various health problems, so prevention and psychocorrection of dependent behavior (personal improvement) are considered as a resolution of internal contradictions of the "I-concept". The solution to this problem occurs within the framework of counseling on the issues of the subjective component of health. *Conclusion.* The research concludes that university students possess subjective factors that lead to the development of dependent behaviors. Psychological support is essential for fostering inner harmony by addressing contradictions in the "I-concept". This support can be provided through advisory techniques aimed at improving students' health and encouraging internal coherence.

Keywords: "I-concept", Advisory activity, health, subjective component, dependent behavior, health improvement, attitude, University students.

Introduction

In the context of university students, these subjective prerequisites influence not only their academic performance but also their social interactions, decision-making, and overall behavior. The study by Arpentieva et al. (2022) explores the ecology of human understanding, emphasizing how individuals interpret and interact with the world around them. For university students, this means that their perceptions of

learning environments, peer relationships, and even institutional structures play a key role in shaping their behavior. Roney et al. (2024) further emphasize the importance of understanding how environmental and internal factors converge, especially in the context of drug discovery, which can be seen as a metaphor for the student's journey of discovery and decision-making.

At present, the spread of drug addiction among young people is an alarming problem. Raising awareness among students should protect them from drug addiction and motivate them to maintain their health. A healthy generation ensures the progress of society and the future of Russia: people who are mentally and physically healthy, capable of self-development, have universal aspirations, social standards of life, value orientations and positively realize themselves in society. Research by Lenskaya et al. (2022), Roney & Aluwi (2024) and others showed that teenagers start taking drugs for many reasons: dysfunctional families, the pernicious influence of peers, the desire to look "cool" and independent in the eyes of acquaintances, accidental or forced initial use and too rapid addiction to a narcotic substance. However, most specialists Gladding (2002), Arpentieva et al. (2022) agree that the problem of drug addiction should be considered as a physiological and personal problem, noting that both genetic predisposition and environmental conditions determine the development of addiction: in 50–60% of cases, the likelihood of drug addiction is associated with genetic factors, and in 40–50%, addiction is caused by intrapersonal contradictions.

It has been found that if a parent is addicted to drugs or alcohol, the risk of developing addiction for the child increases 8 times (Burns, 1986).

We consider addiction as compensation for the one-sidedness of human development, as a lack of development experience (Valeeva, 2018). There is no specific psychological reason for the formation of addiction, there is a set of violations of subjective factors ("Self-concept", "meaning of life", "hierarchy of development priorities", "type of relations with the World" (dominance, submission, partnership, isolation). With a certain nature of the interaction of natural and social conditions of the environment with subjective factors, addictive behaviour is formed (use of substances that change the mental state of a person and cause organic lesions in the body). The set of violations of subjective factors relates to the subjective component of health. At the same time, the subjective component of health plays an integrating and guiding role, therefore psychological assistance is aimed primarily at it.

Research Materials and Methods

The study of subjective prerequisites for the formation of addictive behavior in students was conducted at the South Ural State Humanitarian and Pedagogical University over a period of 8 years (from 2011 to 2018). It involved 2,010 first-year students, including 1,340 girls aged 17 to 19.

To collect empirical data, the following were used: "The program for comprehensive diagnostics of the subjective component of health "Harmony" (Valeeva, 2018) and the "Self-actualization test (A. Maslow)". To study the "I-concept" as a system-forming factor that makes it possible to describe the subjective component of health, the technology of personal development "Psychology of the image" was used. The study of students' propensity for deviant behavior was carried out using the method of Orel (2015).

Research Results

The study revealed the students' attitudes to factors that contradict the concept of a "healthy lifestyle". Of the 159 first-year students, 30.2% do not smoke; 37.08% smoke, 14.4% do not drink alcohol; 24% drink alcohol; 61.5% sometimes drink alcohol. Students (37.6%) are afraid of drug use; 53.8% of students sympathize with those who already use drugs, and 8.6% of students are at risk.

Studying the tendency to deviant behavior in first-year students (girls aged 17-19) using the method of Orel (2015), we note that 20% of students have a predisposition to self-harming and self-destructive behavior; 20% - escape from reality by changing their mental state, they are prone to an illusory-compensatory way of solving personal problems; 20% of students show signs of aggression and violence; 20% of students are prone to illegal actions that are harmful to others (delinquent behavior); 33% of subjects tend to overcome norms and rules and 13% - experience weak volitional control over emotional situations.

Analysis of the obtained data confirmed the need to study the subjective prerequisites for the formation of addictive behavior and the possibility of psychological assistance.

Processing of the materials showed that 50% - 62% of first-year students need psychological support since they have various manifestations of psycho-emotional maladaptation (not health - not illness) and an average and low level of psychological readiness for recovery is noted.

Objective indicators of the social component of health are normal for all respondents: positive dynamics of academic performance, attendance of classes and the presence of essay groups. However, subjective indicators are as follows: 100% of students have extremely high stress levels (more than 300 points in the stress resistance assessment according to Holmes and Rage) - a threat of psychosomatic disease. Current needs of students (A. Maslow Test): protection and safety are relevant for 44% of students; love and belonging for 32%; self-esteem for 24%. The values of approximately 50% of students are egocentric.

Therefore, at the social level, we can characterize the students' lifestyle as subjectively dangerous, but objectively safe - "The Illusion of Danger". The subjective component of health is determined by the influence of the internal system of factors (the "I-concept", the meaning of life, the hierarchy of development priorities, and the technology of building relationships with the World) on maintaining a dynamic balance between the adaptive capabilities of the organism and the constantly changing environmental conditions. The core of this system of factors is the "I-concept". The quality of the subjective component of health is characterized by the state of the psychological characteristics of the individual. The problem of the subjective component of health lies in the totality of subjective difficulties expressed through the states of the mental characteristics of the individual, which are impaired in 50%-62% of students.

The analysis of the data obtained during the study of the "I-concept" showed that 50% of students are impulsive, 30% exhibit an emotional type of perception and response, and only 20% of girls exhibit diversity in perception and response; 70% of respondents are diagnosed with pronounced egocentrism, but 30% can consider someone else's point of view as worthy of attention; for 60% of respondents, problems associated with personal development are relevant, and for 40%, issues of relationship with the "World" are relevant; 40% of female students dream of "being needed" and "developing"; 20% dream of emotional diversity; 60% are afraid of losing control, 40% - of becoming unnecessary; 70% - see a resource in their emotional-volitional characteristics, 10% - in their attitude to life, 20% - are not aware of it. 80% of students have an "inanimate" "I-concept", which indicates the absence of manifestations of subjective activity and a high level of dependence on external circumstances and someone else's will, and 50% of students have "I-concepts" that do not have a specific structure and belong to the realm of illusions ("flight of fantasy", "fantasy", "world", "sky", "pink haze", etc.).

Analysis of the request for psychological help showed that the students themselves understand their health problems. 43% of students seek psychological help due to impaired self-esteem ("I am not confident in myself"); 23% - regarding interpersonal relationships and difficulties in the emotional-sensory sphere; 19% - regarding self-realization; 8% - with the definition of life goals; 7% - regarding psychosomatic manifestations.

To provide psychological assistance to students on issues of the subjective component of health, we have developed a technology for individual and group consulting activities on issues of the subjective component of health. By consulting on the subjective component of health we mean the organization and support of the process of awareness and resolution by a person of suffering caused by the violation of the dynamic balance between his adaptive capabilities and the constantly changing conditions of the environment. Such consulting is a creative process, during which both the study of the attitude to the violation of this balance and the search for ways to restore it at a new level of development occur [4; 5].

The technology of consulting activities on the subjective component of health includes six stages: coordination of expectations; analysis of the subjective component of health; psychological work with the "I-concept" and "life scenario" as system-forming factors of lifestyle; definition and correction of the style of relationships; forecasting a healthy lifestyle; modeling a healthy lifestyle scenario by a student. After the process of counseling on the subjective component of health, which includes up to twelve sessions, the level of psychological readiness for recovery increases: maladaptation in the psychoemotional, cognitive, psychophysical components of psychological readiness for recovery and the indicator "aggression" (value-motivational component) statistically significantly decreases ($p < 0.03$ (0.025); $p < 0.02$ (0.011); $p < 0.01$ (0.002) (0.000); (0.000; 0.001) (0.002)); and the formation of "values-means" corresponding to the formed readiness for activity statistically significantly increases ($p < 0.03$ (0.025)).

Research Discussion

The results of the study on the formation of dependent behavior allow us to conclude that most respondents are dependent on external circumstances and someone else's will and find it difficult to perceive themselves as subjects.

"Self-concepts" lead to the formation of a limiting life scenario "Denial" - "Don't do (do nothing)", "Don't feel" "Feeling is dangerous", which manifests itself at the social and emotional-sensory level of a person's relations with the World and does not allow self-affirmation through unity (professional, personal, social). Limitation is born from a conflict between the actual needs for self-affirmation, and love and the limiting attitudes "I have no right", "I am a small person", and "Feeling is dangerous", as internal components of the "Self-concept". This conflict forms an avoidant, dependent behavior (Valeeva, 2018; Tyumaseva & Valeeva, 2018).

Research of deviant behavior of first-year students (girls aged 17–19) using the method of A.N. Orel showed that future teachers are inclined to overcome norms and rules, which is expressed in the development of addictions that are associated with a weak level of volitional control over emotional situations and a tendency to self-harming and self-destructive behavior. Students of pedagogical universities have subjective prerequisites for the development of addictions. To carry out the prevention and psychocorrection of addictive behavior of students, it is necessary to resolve the internal contradiction of the "I-concept". The solution to this problem occurs within the framework of counseling on issues of the subjective component of health (Tyumaseva & Valeeva, 2019).

The path to personal recovery begins with accepting responsibility for one's problem (stage 1 of counseling), realizing the real problem, which is always connected with the conflict "I can" - "I want" (stage 2 of counseling), realizing the meaning of life, one's "I-concept" and life scenario, as well as the possibility of changing them, which allows the individual to manage his life and develop in harmony with himself and his purpose, and this makes a person's life meaningful, and himself happy (stage 3 of counseling). At the fourth stage of counseling, a person, relying on the meaning of life, the changed "I-concept" and life scenario, learns the technology of subject-subject interaction with the World, which allows him to be truly successful. At the fifth stage of counseling, the student, relying on a new understanding of himself and his capabilities about the World, learns to predict and model a healthy lifestyle through building a hierarchy of development priorities, as the main condition for personal self-government. The consultation ends with the consultant and the student modeling a healthy lifestyle scenario: alternative options for a person's attitude to life, more promising forms of behavior, expansion of the motivational sphere of the individual, etc.

A statistically significant increase in the level of psychological readiness for recovery after the process of consulting on the subjective component of health indicates an increase in the internal integrity of respondents and, accordingly, a decrease in the threat of developing addictive behavior.

Conclusions

Ultimately, the formation-dependent behavior of university students is not only a reflection of their academic capabilities but also a product of how they perceive, interpret, and respond to the world around them. By exploring these subjective prerequisites, we gain a deeper understanding of how university students navigate their educational experiences, driven by a mix of personal interpretations and external influences.

In conclusion, we note that the students' lifestyle at the social level is characterized as "subjectively dangerous, but objectively safe - "Illusion of danger". They have subjective prerequisites for the development of addictions, but good social control of behavioral reactions and the cultural and social environment of the university, as well as a healthy environment, reduces this risk to 50% of students. To improve a person's health (prevention and psychocorrection of addictive behavior), it is necessary to resolve the internal contradiction of the "I-concept" using the technology of consulting activities on the subjective component of health. The results showed that the tested technology of consulting activities allows providing psychological assistance to students, they become calmer, more tolerant towards others, flexible and efficient. Their ideas about their capabilities become more holistic. The means of achieving goals change to more altruistic ones: sensitivity, cheerfulness, responsibility, broad-mindedness, honesty, tolerance for the shortcomings of others, and their professional competence and adaptability also grow.

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Linguo-coaching as a Learner-centered Approach in Language Teaching and Learning: A Literature Review

Abstract: Linguo-coaching is a learner-centred method that combines language instruction with coaching methods. This review synthesises findings from several studies to examine the theoretical foundations, methods, and applications of linguo-coaching and associated practices. The article identifies gaps in the literature and suggests opportunities for future research, especially in Kazakhstan, by drawing on research that emphasises reflective and digital coaching for teachers. According to the results, linguo-coaching holds promise as a framework for encouraging learners' and teachers' autonomy, motivation, and professional development.

Keywords: EFL teaching, learner autonomy, linguo-coaching, language acquisition

Introduction

The increasing focus on learner-centred approaches in language teaching has led to the exploration of new methodologies aimed at enhancing student engagement and autonomy. With a greater focus on learner-centered strategies that promote autonomy and self-efficacy, language instruction has seen significant change. A paradigm for resolving enduring issues including learner motivation, reducing progress, and engagement deficiencies is offered by linguo-coaching, which incorporates coaching ideas into language instruction (Suvorova & Khanin, 2022). Linguo-coaching encourages learners to take charge of their educational path by emphasizing goal-setting, reflection, and tailored guidance. This approach is in line with contemporary pedagogical movements toward autonomy and personalized learning.

Linguo-coaching has special potential in Kazakhstan, where fluency in English is becoming more and more necessary for success in school and the workplace. Classrooms are dominated by traditional teacher-centered practices, which frequently hinder students' capacity to interact effectively with the language. By providing flexible, student-centered solutions, including linguo-coaching could overcome systemic gaps as the nation carries out educational reforms Göker (2017).

This review focuses on the methods, applications, and theoretical foundations of linguo-coaching, combining data from related fields to suggest ways to use it in various settings.

Previous Studies

Theoretical Foundations

The challenges of language acquisition are addressed by linguo-coaching, which combines concepts from coaching and education. Kolb (2014) suggested that learning consists of cycles of experience, reflection, and application, which form the basis of linguo-coaching. This method closely resembles linguo-coaching techniques, in which students evaluate their development, modify their approach, and try out the language in authentic settings. Schön (2013) expanded on this by highlighting reflection-in-action, a key coaching idea that enables students to assess their method in real-time while they are learning.

Additional theoretical support is offered by Vygotsky's sociocultural theory, which emphasizes the value of interaction and scaffolding in learning (Vygotsky, 1978). Linguo-coaching makes use of this by

establishing cooperative settings in which the coach helps students overcome obstacles, promoting competence and self-assurance. These theories are supported by the GROW model, which is frequently used in coaching and provides an organized method for creating goals and organizing actions, assisting students in concentrating on attainable results (Whitmore, 2017). According to Passmore (2016), neuro-linguistic programming (NLP) is another essential component that helps students overcome their emotional and cognitive obstacles while increasing their resilience and engagement.

Learner-centred Pedagogy in Language Teaching

The foundation of linguo-coaching lies in the principles of coaching psychology, which focus on developing the learner's self-awareness, goal-setting skills, and intrinsic motivation. This approach is aligned with the learner-centred pedagogy, which places the learner at the core of the educational process, as discussed in several studies of best practices in modern education (Aarreniemi-Jokipelto et al., 2019). Learner-centred teaching is characterized by a shift from a teacher-centred model, where the teacher is the primary source of knowledge, to one where learners are active participants in their learning process. This model fosters greater student engagement, as learners are encouraged to take ownership of their learning through problem-solving, collaboration, and self-reflection. Research on learner-centred approaches in education highlights their potential to enhance learner motivation, critical thinking, and language proficiency (Richards & Lockhart, 2017). In the context of language teaching, a learner-centred approach promotes the idea that language acquisition is most effective when it is tailored to the individual needs, interests, and goals of the student. This approach contrasts with traditional methods, which may rely on rote memorization and standardized testing, often overlooking the unique learning styles and preferences of individual learners.

Methodological Insights

Due to the complexity of the methodology, a variety of approaches are employed in linguo-coaching research. Qualitative research frequently examines the experiences of educators and students to offer deep insights into the transformational power of coaching. To illustrate this, Suvorova and Khanin (2022) looked at the benefits of coaching sessions that included strategies like SMART goal-setting and visualization for foreign language instructors. To demonstrate how coaching fosters professional development and flexibility, participants reported increased self-reflection and methodological competencies.

Additionally, quantitative research has demonstrated the measurable advantages of coaching in the classroom. Tschannen-Moran and Woolfolk Hoy (2012) provided evidence of how coaching interventions enhance teachers' self-efficacy, specifically in the areas of instructional techniques and classroom management. Göker (2021) evaluated the effects of reflective coaching on pre-service teachers using a pre/post-test methodology and found statistically significant increases in confidence and efficacy as teachers. These results highlight how linguo-coaching can improve teacher practices and learner outcomes.

Mixed-methods research combines qualitative and quantitative techniques to provide a thorough understanding. The study conducted by Korkealehto (2019) on digital coaching programs showed how organized guidance, peer feedback, and self-assessments improve digital pedagogical abilities. The flexibility of linguo-coaching in changing educational environments is demonstrated by the participants' reported enhanced confidence in using digital tools and creating successful online courses. This is particularly significant in the post-pandemic period because teachers need to be especially proficient in digital skills.

Table 1. Summary of Key Studies on Linguo-coaching in Educational Context

Authors	The focus of the study	Methodology	Key findings
Suvorova & Khanin (2022)	Coaching in advanced training for language teachers	Qualitative: Analysis of coaching sessions using SMART goals and visualization	Coaching improved teacher reflection, methodological skills, and adaptability.
Göker (2021)	Reflective coaching for pre-service EFL teachers	Mixed-methods: Pre/post-tests, reflective diaries	Statistically significant improvement in teacher efficacy and classroom management skills.

Korkealehto (2019)	Coaching programs for digital pedagogy among language teachers	Mixed-methods: Peer feedback, self-assessments, workshops	Teachers gained confidence in digital teaching skills and designing online courses.
Tschannen-Moran & Woolfolk Hoy (2012)	Teacher self-efficacy development through coaching interventions	Quantitative: Pre/post-test design	Coaching interventions increased teacher efficacy in instructional strategies and classroom management.
Brooks (2018)	Gamification in reading instruction	Review of coaching methodologies	Coaching enhanced learner motivation and autonomy in EFL settings.
Kennedy & Smith (2013)	Coaching and mentoring in professional development	Qualitative: Interviews and case studies	Peer coaching fostered collaborative learning and professional growth among educators.
Ellison & Hayes (2014)	Cognitive coaching for reflective teaching	Qualitative: Dialogues and case studies	Cognitive coaching facilitated deeper self-reflection and critical thinking among teachers.
Salmon (2013)	Use of e-tivities in coaching for online learning	Mixed-methods: Surveys and activity tracking	Coaching enhanced engagement and interactivity in online learning environments.

Linguo-coaching applications

Linguo-coaching has been used to enhance the development of both teachers and learners in a variety of settings. The effects of coaching programs on teachers making the switch to online instruction were examined by Korkealehto (2019), who emphasized the value of organized mentoring in developing digital abilities. Brooks (2018) investigated the use of coaching in EFL classes and discovered that linguo-coaching greatly increases student autonomy and motivation, making it a useful tool in a variety of cultural contexts.

According to Suvorova and Khanin (2022), methodological skills significantly improved when coaching techniques were incorporated into teacher training programs. Their results show how linguo-coaching can help with the particular difficulties of shifting from teacher-centered to learner-centered paradigms, and they propose an efficient strategy for national adoption. Applications including this highlight how linguo-coaching can help bridge the gap between conventional teaching approaches and contemporary educational requirements.

Research Discussion

Linguo-coaching addresses both the cognitive and emotional components of learning, which has major advantages for language instruction. It enables students to take charge of their language learning process by utilizing goal-setting, introspection, and customized techniques. These methods encourage self-reliance and long-term drive, both of which are essential for successful learning. Learners can become more confident and overcome their nervousness by using strategies like visualization and guided reflection, which can help them interact with the language more actively.

By encouraging reflective practices and improving classroom adaptation, linguo-coaching offers educators chances for professional growth. Programs that use coaching frameworks have demonstrated increases in the effectiveness of instruction, especially when it comes to integrating technology and overcoming the difficulties associated with online learning. These developments demonstrate how linguo-coaching may meet the demands of contemporary schooling.

Nevertheless, several obstacles prevent its wider adoption. It is challenging to apply linguo-coaching consistently across various educational situations due to the lack of defined frameworks. Furthermore, there

isn't much long-term research looking at its long-term effects on learner autonomy and language retention. To properly scale linguo-coaching, these deficiencies must be filled by thorough research and specific adjustments.

Conclusion

Linguo-coaching represents a promising learner-centred approach to language teaching and learning. By integrating coaching principles with language instruction, it empowers learners to take an active role in their language acquisition, setting goals, reflecting on progress, and using personalized strategies to overcome challenges. Focusing on learner autonomy, incentive, and reflective practice, linguo-coaching is a revolutionary method of teaching languages. It improves learner and teacher development by incorporating coaching strategies to address issues like fear and disengagement. Despite the enormous promise, issues including the absence of standardized frameworks and the paucity of long-term research must be resolved. To ensure its wider acceptance future research and culturally sensitive models will be essential. Linguo-coaching has the potential to revolutionize language instruction and meet the demands of global learning with further innovation.

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