Institute of Metallurgy and Ore Beneficiation

SATBAYEV UNIVERSITY

CHALLENGES OF SCIENCE

Materials of International Scientific-Practical Internet Conference

ҒЫЛЫМНЫҢ ӨЗЕКТІ МӘСЕЛЕЛЕРІ

Халықаралық ғылыми-практикаолық Интернет-конференция материалдары

Almaty, 2025

Institute of Metallurgy and Ore Beneficiation JSC

Satbayev University

Materials of International Scientific-Practical Internet Conference
“Challenges of Science”

Issue VIII

Almaty, Kazakhstan - 2025

УДК 001
ББК 72
Ғ 96

Ғ 96 «**Ғылымның өзекті мәселелері**» Халықар. ғыл.-тәж. Интернет конф. Материалдары. Құраст.: Касымова Г.К., Қуанышұлы А., Айтжанова Н.М. – Алматы: АҚ «Металлургия және кен байыту институты», Satbayev University; 2025 ж., 110 б.

ISSN 2707-9481

ISBN 978-601-323-547-9

*«**Ғылымның өзекті мәселелері**» атты халықаралық ғылыми-тәжірибелік интернет-конференция материалдарының жинағына әлемнің әртүрлі елдеріндегі жоғары оқу орындары мен ғылыми мекемелердің ғалымдары, оқытушылары, студенттері, магистранттары мен докоранттарының ғылыми баяндамалары енгізілді.*

Жинақта ұсынылған техникалық және гуманитарлық ғылымдар саласындағы материалдар жоғары оқу орындары мен ғылыми ұйымдардың қызметкерлеріне, оқытушыларға, мектеп пен колледж мұғалімдеріне, сондай-ақ докоранттарға, магистранттар мен студенттерге арналған.

*Международная научно-практическая интернет-конференция «**Актуальные проблемы науки**» объединяет научные доклады ученых, преподавателей, студентов, магистрантов и докторантов из различных стран мира.*

Материалы сборника представляют интерес для научных сотрудников, преподавателей, докторантов, магистрантов и студентов, специализирующихся в области технических и гуманитарных наук.

УДК 001
ББК 72

DISCLAIMER

This volume contains abstracts and full papers that have been reviewed and approved by the Conference Review Committee. Responsibility for the content, accuracy, and originality of the contributions rests solely with the authors.

The views and opinions expressed in the papers are those of the authors and do not necessarily reflect the official position of the International Scientific-Practical Internet Conference. These conference materials are published as open-access content.

INTERNATIONAL SCIENTIFIC COMMITTEES

All members of the International Committee have identified their affiliated institutions along with the corresponding countries. The publisher remains neutral with regard to jurisdictional claims in institutional affiliations.

UDC 001
ISSN 2707-9481
ISBN 978-601-323-547-9

"ҚАЗАҚСТАН РЕСПУБЛИКАСЫНЫҢ ҰЛТТЫҚ МЕМЛЕКЕТТІК КІТАП ПАЛАТАСЫ"

ХАЛЫҚАРАЛЫҚ СТАНДАРТТЫҚ КІТАП НОМЕРІ ISBN.
ӘМБЕБАП ОНДЫҚ ЖІКТЕУ,
КІТАПХАНАЛЫҚ-БИБЛИОГРАФИЯЛЫҚ ЖІКТЕУ,
ШТРИХ - КОД
БЕРІЛДІ (ТІРКЕЛДІ)

"НАЦИОНАЛЬНАЯ ГОСУДАРСТВЕННАЯ КНИЖНАЯ ПАЛАТА РЕСПУБЛИКИ КАЗАХСТАН"

ПРИСВОЕНЫ (ЗАРЕГИСТРИРОВАНЫ)
МЕЖДУНАРОДНЫЙ СТАНДАРТНЫЙ КНИЖНЫЙ НОМЕР ISBN
УНИФИЦИРОВАННЫЙ ДЕСЯТИЧНЫЙ КЛАССИФИКАТОР,
БИБЛИОТЕЧНО-БИБЛИОГРАФИЧЕСКИЙ КЛАССИФИКАТОР,
ШТРИХ-КОД.

ISBN 978-601-323-547-9

9 786013 235479

E-mail: conference@kims-imio.kz URL: http://kims-imio.kz/en/conference/

PREFACE

This volume contains peer-reviewed papers presented at the International Scientific-Practical Internet Conference "Challenges of Science," held on 18–19 December 2025. The conference was dedicated to the 80th anniversary of the founding of the Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University, and aimed to highlight current scientific advances and innovative technologies, particularly in the mining, processing, and utilization of rare and rare earth metals.

The proceedings bring together original research addressing contemporary challenges across science, engineering, and education, reflecting the interdisciplinary scope of the conference. A substantial portion of the volume is devoted to educational research and pedagogical innovation, including studies on numeracy literacy assessment, bibliometric analyses of digital platforms in education, the integration of robotics into physics education, the development of digital competence among educational psychologists, student motivation for independent learning, and technology adoption in STEM education.

Another major section focuses on materials science, metallurgy, and chemical engineering. The included papers examine ion dissociation processes during metal oxide reduction, selenium extraction from non-ferrous metallurgical feedstock, recovery of rare and dispersed elements, vacuum thermal decomposition processes, heap leaching technologies for gold-bearing ores, and improved methods for rare earth element recovery from secondary resources. These contributions demonstrate both fundamental research and industrial applicability.

All papers included in this volume were reviewed and approved by the Conference Review Committee and selected based on scientific quality, originality, and relevance. The proceedings are intended for researchers, educators, graduate students, and industry practitioners engaged in addressing modern scientific and technological challenges.

On behalf of the Organizing Committee, I would like to express my sincere gratitude to all authors, reviewers, and participants whose contributions ensured the success of the conference. Your engagement is essential to 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
November 22, 2025

Issue VIII, 22 November 2025
e-ISSN 2707-9481 Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University, Almaty, Kazakhstan
ISBN 978-601-323-547-9 https://doi.org/10.31643/2025.01

Zafrullah Zafrullah
Universitas Negeri Yogyakarta, Yogyakarta, Indonesia
E-mail: zafrullah.2022@student.uny.ac.id
ORCID ID: https://orcid.org/0009-0008-3752-8841

Siti Nurjanah
Universitas Negeri Yogyakarta, Yogyakarta, Indonesia
E-mail: siti960pasca.2023@student.uny.ac.id
ORCID ID: https://orcid.org/0009-0006-0727-0830

Ima Aprilia Fitri
Sekolah Menengah Pertama Negeri 1 Banguntapan, Yogyakarta, Indonesia
E-mail: ima.aprilia48@gmail.com

Era Mutiara
Universitas Negeri Yogyakarta, Yogyakarta, Indonesia
E-mail: eramutiara.2023@student.uny.ac.id
ORCID ID: https://orcid.org/0009-0004-0955-4795

Resky Nuralisa Gunawan
Universitas Negeri Yogyakarta, Yogyakarta, Indonesia
E-mail: reskynuralisa.2022@student.uny.ac.id
ORCID ID: https://orcid.org/0009-0009-1805-9928

Ghany Desti Laksita
Universitas Negeri Yogyakarta, Yogyakarta, Indonesia
E-mail: ghanydesti.2023@student.uny.ac.id
ORCID ID: https://orcid.org/0009-0007-8475-0966

Analysis of Numeracy Literacy Question Items in Junior High School Mathematics: Analysis using Classical Test Theory

Abstract: Item analysis is an important part of evaluating student performance because it can identify the extent to which the questions can measure students' abilities accurately and fairly. This research aims to analyse Numeracy Literacy questions for 31 students from Class VIII at one of the Junior High Schools in Bantul, Special Region of Yogyakarta, using interview methods and analysis techniques for levels of difficulty and differences in questions based on gender and overall, with the help of the AnBuSo 8.0 application. The results showed that although the majority of questions were in the "Easy" category and were effective in measuring students' overall abilities, there were differences in the level of difficulty and differential ability of questions between genders, where questions were more effective in differentiating the abilities of male students compared to female students. These findings indicate the need to improve and develop questions to be more fair and equitable in measuring the abilities of students from both gender groups. By taking these differences into account, better question design can improve the accuracy and consistency of evaluations, providing a more accurate picture of students' overall abilities.

Keywords: numeracy literacy, question items, classical theory test, education.

Introduction

Education is an important foundation for the progress of a country (Reimers, 2024; Zafrullah et al., 2024). Developed countries always place education as a top priority in development. The existence of quality education determines the future of the nation, because, through education, the young generation is prepared to face global challenges and contribute to national development (Adeniyi et al., 2024; Ramadhani et al., 2024). Therefore, education must be a main concern in state policy, starting from improving the curriculum to providing adequate facilities and infrastructure (Valencia, 2024; Zafrullah & Zetriuslita, 2021). All of this must be pursued to create a conducive learning environment, which will ultimately lead to improving the quality of human resources. So, quality education is not just a dream, but a reality that can be felt by every child of the nation (Izzulhaq et al., 2024; Sanyal, 2024). All of these efforts started from one institution that has a central role in the education process, namely the school.

School is the main foundation in the process of forming the knowledge and character of the nation's children (Sakhiyya & Rahmawati, 2024). Schools act as places where moral, ethical and scientific values are taught and applied in everyday life (Qazi et al., 2024). The character of each individual is greatly influenced by the school environment that guides them during their growth and development (Alajmi, 2024). Schools make students ready to face life's challenges with adequate knowledge and skills (Ramdas et al., 2024). Thus,

schools must be able to create a conducive and inspiring learning environment, where every student feels valued and motivated to continue to develop in the classroom.

The classroom is a space where educational interaction between teachers and students takes place intensively (Barker, 2024). Classes are challenged to always create an atmosphere that supports students' intellectual, emotional and social growth. Classes are an important element in education that can facilitate the process of critical thinking, creativity and collaboration (Pamuji & Mulyadi, 2024). In class, every student is given the opportunity to explore their potential and develop skills that are relevant to future needs (Bleazby, 2020). Thus, classes must be designed and managed well to be able to accommodate various effective and comprehensive teaching methods to achieve the ultimate goal of the learning process.

Learning is a crucial process in supporting student development and progress (Puspitasari et al., 2021). Learning encompasses a variety of components, including strategies, resources, and interactions, all of which work to advance students' overall knowledge and proficiency (Maree, 2022). Different requirements and learning styles are taken into consideration while designing instruction, together with the academic objectives to be met (Kennedy & Sundberg, 2020). As a consequence, studying helps pupils comprehend the subject matter better and prepares them to handle obstacles in the future. (Cebrián et al., 2020). Learning must always be supported by an objective and thorough evaluation procedure to guarantee the effectiveness of it.

Evaluation is a piece of crucial equipment for continuously assessing and tracking students' progress (Huang et al., 2021). Evaluation is crucial for determining how well learning objectives have been accomplished and indicating areas in need of development (Thornhill-Miller et al., 2023). Through evaluation, both teachers and students may determine the learning process's advantages and disadvantages and create plans for future development (Thornhill-Miller et al., 2023). Therefore, evaluation serves as both a measuring instrument and a source of constructive feedback during the teaching and learning process (Tang et al., 2020). Effective and targeted learning can be achieved by appropriate evaluation, as outlined in Classical Test Theory.

Classical Test Theory is a foundational method in educational and psychometric assessment that emphasizes using tests to measure a person's unique skills and traits (MacPhail et al., 2024; Minkos & Gelbar, 2021). With the assumption that test outcomes are composed of two primary components, true scores and measurement error, classical test theory offers a framework for comprehending how tests can be assessed and examined. (Darling-Hammond et al., 2020). The use of classical test theory is beneficial for the creation and assessment of test instruments as well as for the interpretation of test results to provide accurate feedback (El-Sabagh, 2021). Thus, in a variety of educational and research situations, the application of this theory enables the construction of more quantifiable and efficient evaluation systems.

Previous research yielded some notable conclusions about the quality of daily test questions and scientific literacy ability exams. The first study revealed that the validity of the questions remained poor, the reliability was insufficient, the level of difficulty and discrimination was pretty good, and the efficiency of the distractors was less than optimal. (Hassan et al., 2021). Meanwhile, the second study compared the quality of the questions using the classical test theory approach and the Rasch Model. The validity of the questions differed between the two approaches, with the classical test theory classifying 3 questions as valid and 12 as invalid, while the Rasch Model classified 6 as valid and 9 as invalid (Ahmad, 2020). The reliability score in the classical test theory is 0.40 (medium), while the Rasch Model shows 0.43 (medium), with a person reliability value in the Rasch Model of 0.54 (bad) and product reliability of 0.91 (very good). The level of difficulty of the questions is also different, with classical test theory grouping questions into easy, medium and difficult categories, while the Rasch Model has four categories of difficulty. In the aspect of differential power, both approaches show similar results, namely the majority of questions are classified as bad with only a few questions considered good.

Based on the background and previous research, the author is interested in analyzing the items on the mathematical Numeracy Literacy questions using classical test theory.

Research Methods

This research is descriptive quantitative research that analyzes question items to evaluate the quality of the questions in the context of Numeracy Literacy. Quantitative research is an approach that focuses on collecting and analyzing numerical data to obtain objective and measurable results (Hooda et al., 2022). This research was conducted at one of the junior high schools in Bantul, Daerah Istimewa Yogyakarta, Indonesia,

involving 31 grades from Class 8 (Table 1). The questions used are 9 essay questions on Numeracy Literacy in Algebra Form material following the Kurikulum Merdeka. Data collection was carried out through interviews with teachers to obtain relevant information about the implementation and effectiveness of the questions. In the analysis of these questions, AnBuSo 8.0 software was used which takes into account the level of difficulty and differentiation to provide an in-depth picture of the quality of the questions used in the learning process. The criteria for levels of difficulty and different strengths can be seen in Table 2 and Table 3.

Table 1. Details of Respondents in Research

Gender	Male	16 (51,61%)
	Female	15 (48,39%)
	Total	**31 (100%)**
Age	13	20 (64,52%)
	14	11 (35,48%)
	Total	**31 (100%)**

Source: Data from Researcher

Table 2. Difficulty Level Criteria

Difficulty Level	Description
0,00-0,30	Hard
0,31-0,70	Medium
0,71-1,00	Easy

Source: (Istiyono, 2020)

Table 3. Differential Power Criteria

Criteria	Description
$D \leq 0{,}199$	Bad (Rejected)
$0{,}200 - 0{,}299$	Good enough (Needs revision)
$0{,}300 - 0{,}399$	Medium (No Revision Required)
$D \geq 0{,}400$	Very Good

Source: (Istiyono, 2020)

Research Results

This research focuses on analyzing test items using Classical Test Theory on Algebra Form material for grade 8 at one of the state schools in Bantul, Special Region of Yogyakarta, Indonesia. This research involved 31 students in grade 8 as research subjects. Details of the questions used and scoring in this study are in Table 4. Researchers will analyze based on gender and overall.

Table 4. Details of Material in Question Item Analysis using Classical Test Theory

Number	Learning Materials	Value Details	Total
1	Understand and know the structure of algebraic forms	8.5	20
2		11.5	
3	Simplify Forms of Many Tribes	7	20
4		13	
5	Understanding Explanations Using Algebraic Forms	20	20
6	Understand how Changing Eq	20	20
7	Understanding Multiplication and Division of Tribal Forms Single	3	20
8		3	
9		14	
Total			100

Source: Data from Researcher

Difficulty Level

The level of difficulty is an important indicator in evaluating the quality of questions, which measures the extent to which students can answer questions correctly (Owan et al., 2023). In this analysis, researchers focused on difficulty levels based on gender and the overall student population to see whether there were significant differences in ability to answer questions between these groups. Thus, the results of this analysis can provide deeper insight into how gender factors influence question difficulty and help in designing questions that are fairer and more effective for all students.

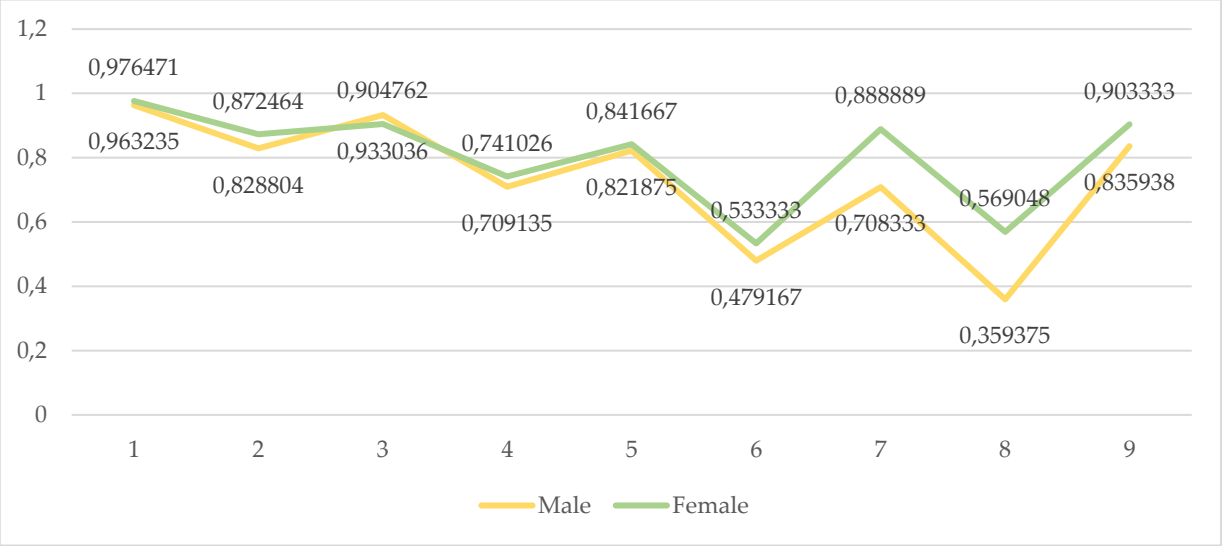


Fig. 1. Results of Difficulty Levels Based on Gender Analyzed with AnBuSo 8.0

Based on Figure 1, the level of difficulty of the questions for male students shows that of the nine question numbers, most of them fall into the "Easy" category with scores between 0.71 to 1.00. Question numbers 1, 3, 5, and 9 fall into this category, with difficulty values of 0.963, 0.933, 0.822, and 0.836 respectively, indicating that most male students can answer these questions correctly. Meanwhile, question number 6 with a value of 0.479 and question number 8 with a value of 0.359 are in the "Medium" category, indicating a medium level of difficulty. Question number 2 with a value of 0.829 and question number 4 with a value of 0.709 are also included in the "Easy" category, although the value of number 4 is close to the lower limit of this category.

In contrast, data for female students shows a slightly different pattern. Most of the question numbers also fall into the "Easy" category, with question numbers 1, 2, 3, 5, 7, and 9 showing a level of difficulty above 0.71, meaning most female students were able to answer these questions correctly. However, two question numbers indicate a "Medium" level of difficulty, namely number 6 with a value of 0.533 and number 8 with a value of 0.569, which shows that these questions are more challenging for female students than the other questions. There were no question numbers in the "Hard" category for female students, indicating that overall, these questions tended to be more accessible to female students than to male students, although this difference was not significant.

Based on an analysis of the level of difficulty of the questions between male and female students, it can be seen that most of the questions fall into the "Easy" category for both groups, although female students tend to find these questions slightly easier than male students. Questions that fall into the "Medium" category show that some questions are more challenging for both groups, with a slightly larger difference for female students. There were no questions classified as "Hard" for either of them, indicating that overall, the questions tended to be easier and more accessible for female students compared to male students, although the difference was not significant.

Apart from analyzing gender, researchers also analyzed it as a whole which can be seen in Figure 2.

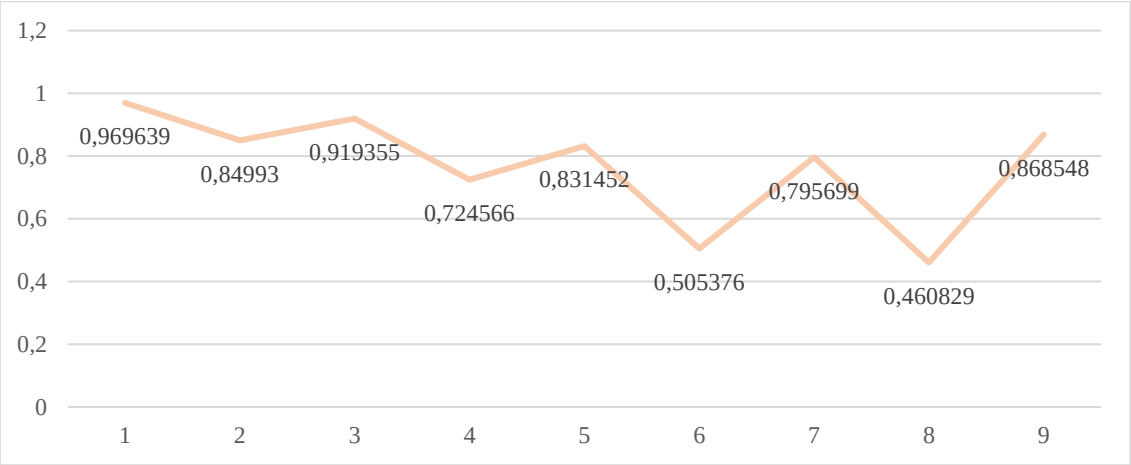


Fig. 2. Results of Difficulty Levels Overall Analyzed with AnBuSo 8.0

Based on data on the overall difficulty level of the questions, the majority of the questions fall into the "Easy" category, indicating that the majority of students were able to answer correctly. Question numbers 1, 3, 4, 5, and 9 are all in this category, with difficulty ratings indicating that the questions are relatively easy for students to access. This indicates that these questions, in general, succeeded in measuring students' abilities without causing excessive difficulty.

However, several questions fall into the "Medium" category, namely numbers 6 and 8, indicating that these questions are more challenging for students overall. This moderate level of difficulty may indicate that the questions require a deeper understanding or a more complex solution strategy. There are no questions that fall into the "Hard" category, which means all questions have a level of difficulty that students can reach, although with varying levels of success. This shows a fairly good balance in the distribution of question difficulty levels, although there is room for improvement in designing questions that are challenging but still accessible to all students.

Overall, analysis of the difficulty levels of the questions showed that the majority of the questions were in the "Easy" category, with only a few questions in the "Medium" category, and none in the "Hard" category. This indicates that these questions can generally be answered well by students, although some offer greater challenges. In conclusion, these questions were successful in measuring students' understanding of the material tested with a balanced level of difficulty, but there is an opportunity to design questions that are more varied in difficulty to be more effective in identifying differences in levels of understanding between students.

Different Power

Just like the level of difficulty, this research will focus on analyzing the power of differences based on gender and overall to see whether there are differences in the effectiveness of the questions in differentiating the abilities of male and female students, as well as to reflect the general performance of the questions in measuring variations in ability across the student population.

Fig. 3. Results of Different Power Based on Gender Analyzed with AnBuSo 8.0

Based on the analysis of the differential power of questions for male students, the results show that the majority of questions have a differential power that is in the "Very Good" category with a value of more than 0.400. Question numbers 2, 3, 4, 5, 6, and 8 all fall into this category, indicating that the questions can differentiate well between students with high and low ability. However, numerous questions do not match the good criterion, such as questions 1 and 9, which are in the "Bad" category with a power difference value of less than 0.200, indicating that they are ineffective in discriminating student abilities and may need to be revised or replaced.

Meanwhile, the analytical results suggest that differential power varies more widely among female students. Question numbers 3, 4, and 5 exhibit very good discrimination, with scores in the "Very Good" category, indicating that the questions are successful at discriminating female students' talents. However, numerous questions demonstrate little distinguishing power, such as question number 6, which is in the "Bad" category, and question number 1, which is only in the "Medium" category. This demonstrates that, while some questions perform well, others require adjustment to be more successful in assessing differences in female students' abilities. Female students generally have a greater ability to differentiate questions than male pupils.

Based on the examination of the questions' distinguishing power, it appears that the questions are more effective in differentiating the abilities of male students than female students, with the bulk of male-specific questions falling into the "Very Good" category. Meanwhile, the questions for female students revealed a higher variety in discriminating power, with some having good discrimination power and others performing badly. This shows that the questions for male students are generally more consistent in measuring differences in ability, so it can be concluded that in terms of differential power, the questions are more effective and consistent in differentiating the abilities of male students compared to female students.

Apart from analyzing gender, researchers also analyzed it as a whole which can be seen in Figure 4.

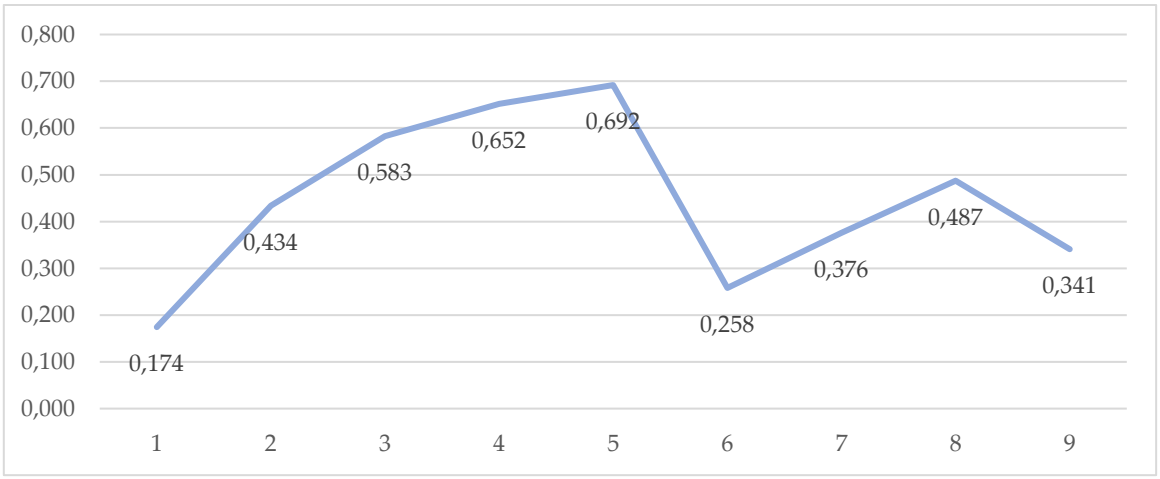


Fig. 4. Results of Different Power Overall Analyzed with AnBuSo 8.0

Based on the overall discriminative power analysis, the results show that the majority of questions have quite good discriminative power in differentiating between students with high and low abilities. Question numbers 2, 3, 4, 5, and 8 are all in the "Very Good" category with different power values above 0.400. This indicates that the questions are very effective in differentiating students' overall ability levels, so they do not require further revision.

However, there are several questions that have lower discrimination power, such as question numbers 1 and 6 which are in the "Bad" category with scores below 0.200 and 0.300, which means these questions are less effective in differentiating students' abilities and may require revision. or repair. Question numbers 7 and 9 are in the "Medium" category with sufficient differential power, but there is still room for improvement to be more optimal in evaluating students' abilities. Overall, although most of the questions have good discrimination, some require more attention to improve measurement quality.

Overall, the discriminating power analysis showed that the majority of questions had good qualities in discriminating students' abilities, with the majority being in the "Very Good" category. However, several questions require revision because they have low distinguishing power, especially questions numbers 1 and

6, which are less effective in measuring differences in student abilities. Although in general, the quality of the questions is quite adequate, improvements to some questions will further optimize the test's ability to evaluate differences in student abilities more accurately and consistently.

Research Discussion

Education creates a strong foundation for classroom development (Cobb et al., 2020). The classroom is the main forum for an effective learning process. Learning that takes place in the classroom requires appropriate evaluation to ensure the achievement of educational goals (Schildkamp et al., 2020). This evaluation then becomes an important tool in assessing student learning outcomes, and one method that is often used is classical test theory. Classical test theory plays an important role in providing an analytical framework for measuring the validity, reliability and distinguishability of questions so that evaluation results can be used to improve the overall quality of education.

This research focuses on analyzing test items using Classical Test Theory on Algebra Form material for grade 8 students at one of the state schools in Bantul, Daerah Istimewa Yogyakarta, Indonesia, involving 31 students as research subjects. Based on Table 4, the material tested covers various aspects of algebra, such as understanding the structure of algebraic forms, simplifying multi-term forms, as well as understanding the multiplication and division of single-term forms. Each question item is given a certain value which reflects its weight in the total assessment. Analysis was carried out both overall and based on gender, to identify the quality of the test items and their conformity with the principles of Classical Test Theory.

From the results of the difficulty level by gender, the analysis shows that the majority of questions are in the "Easy" category for both groups of students, although female students generally find these questions slightly easier than male students. Although most of the questions were easy for both groups to answer, there were a few questions that indicated a difficulty level of "Medium", meaning some questions presented a greater challenge for students, especially for female students. There were no questions classified as "Hard" for either group, indicating that overall, these questions tended to be more accessible to female students. Therefore, even if the difference in difficulty is not significant, adjustments in designing more challenging questions can help create tests that are more effective in measuring students' abilities equally across both genders.

As for the overall difficulty level results, the analysis shows that the majority of questions fall into the "Easy" category, which means the majority of students were able to answer correctly. This demonstrates that the questions were effective in testing students' abilities without incurring significant difficulty. Several problems, however, fall into the "Medium" category, indicating a larger challenge for students, which may necessitate deeper comprehension or more advanced problem-solving techniques. There were no questions in the "Hard" category, showing that the difficulty level of the questions remained within students' reach, albeit with varying degrees of success. According to Classical Test Theory, a balanced distribution of difficulty levels is needed to ensure that tests can accurately measure students' diverse abilities (Rajagukguk & Naibaho, 2023). As a result, while these questions have been useful in measuring student knowledge, there is room to construct questions with varied levels of difficulty to be more effective in finding disparities in levels of understanding among students.

In terms of gender differentiation outcomes, the analysis shows that the questions are more effective in differentiating the abilities of male students than female students, with the majority of the questions falling into the "Very Good" category. Meanwhile, the questions for female students showed a higher variance in discriminating power, with some questions having excellent discrimination power and others doing poorly. This demonstrates that questions for male students are more consistent in measuring differences in ability. Thus, while the findings varied between the two genders, the questions are more successful and consistent in distinguishing the talents of male students from female students.

Meanwhile, in terms of overall discriminating power results, the study shows that the majority of questions are of good quality in separating students' skills, with the majority falling into the "Very Good" group. This indicates that the questions effectively differentiate students' overall ability levels, so they do not require further revision. However, several questions have lower discrimination power, which indicates that these questions are less effective in differentiating students' abilities and may require improvement. In this context, Classical Test theory emphasizes the importance of good discrimination to ensure that each question can accurately measure differences in ability between students (Vincent & Shanmugam, 2020). Therefore, although in general the quality of the questions is quite adequate, improvements to some questions that

have low differential power will further optimize the test's ability to evaluate differences in student abilities more accurately and consistently.

So, from all the analysis above, it can be concluded that although the majority of the questions are in the "Easy" category and can measure students' abilities without causing excessive difficulty, there are differences in the level of difficulty and the different power of questions based on gender, where the questions are more effective and consistent in differentiating the abilities of male students compared to female students. This shows that there needs to be improvements to several questions to increase the validity of the measurement, especially in ensuring that the test can evaluate students' abilities fairly and evenly between the two gender groups. Develop questions that not only measure the material in a representative manner but also take into account various levels of student ability, so that the test can be more effective in identifying differences in levels of understanding among students as a whole (Sistyawati & Apriani, 2024). As a consequence, designing more hard questions with more evenly distributed power will increase the quality of evaluating student abilities..

Conclusion

To sum up, this study is a lighthouse that illuminates the way to a better comprehension of how we assess prospective teachers' digital literacy abilities. The results paint a picture of a world full of growing curiosity and a spirit of cooperation, where scholars, organizations, and countries are working together to understand the complexities of digital literacy evaluation in teacher preparation. Spatial mapping becomes a potent tool as the scholarly conversation on this subject develops, not just for visualization but also for promoting cross-border interdisciplinary cooperation Researchers are better able to negotiate the difficulties of digital literacy assessment research with fresh focus and direction thanks to this approach, which enables them to identify research objectives, collaborative opportunities, and emerging trends. In the end, this study not only advances our knowledge of digital literacy assessment but also establishes a solid framework for further research in this crucial field of education, which could influence practice, policy, and instructional strategies for teacher preparation globally.

CRediT author statement: **Z. Zafrullah**: Conceptualization, Methodology, Software, Validation, Writing draft preparation; I.A. **Fitri**: Supervision, Data curation; **R.N. Gunawan**: Visualization, Investigation; **S. Nurjanah:** Reviewing; **E. Mutiara & G.E. Laksita**: Editing.

Acknowledgements. The authors would like to thank anonymous reviewers and the conference editors for their comments on earlier versions to improve this study's quality.

Cite this article: Zafrullah, Z., FitriI, A., Gunawan, R.N., Nurjanah, S., Mutiara, E., Laksita, G.E. (2025). Analysis of Numeracy Literacy Question Items in Junior High School Mathematics: Analysis using Classical Test Theory. Materials of International Scientific-Practical Internet Conference "Challenges of Science". Issue VIII, pp. 5-13. https://doi.org/10.31643/2025.01

References

Adeniyi, I. S., Al Hamad, N. M., Adewusi, O. E., Unachukwu, C. C., Osawaru, B., Onyebuchi, C. N., Omolawal, S. A., Aliu, A. O., & David, I. O. (2024). Educational reforms and their impact on student performance: A review in African Countries. *World Journal of Advanced Research and Reviews*, *21*(2), 750–762.

Ahmad, T. (2020). Scenario based approach to re-imagining future of higher education which prepares students for the future of work. *Higher Education, Skills and Work-Based Learning*, *10*(1), 217–238.

Alajmi, M. (2024). Promoting equity and equality in student learning: principals as social justice leaders in Kuwaiti schools. *International Journal of Educational Management*.

Barker, E. (2024). *National Character: and the factors in its formation*. Taylor & Francis.

Bleazby, J. (2020). Fostering moral understanding, moral inquiry & moral habits through philosophy in schools: a Deweyian analysis of Australia's Ethical Understanding curriculum. *Journal of Curriculum Studies*, *52*(1), 84–100.

Cebrián, G., Palau, R., & Mogas, J. (2020). The smart classroom as a means to the development of ESD methodologies. *Sustainability*, *12*(7), 3010.

Cobb, P., Jackson, K., Henrick, E., & Smith, T. M. (2020). *Systems for instructional improvement: Creating coherence from the classroom to the district office*. Harvard Education Press.

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. *Applied Developmental Science*, *24*(2), 97–140.

El-Sabagh, H. A. (2021). Adaptive e-learning environment based on learning styles and its impact on development students' engagement. *International Journal of Educational Technology in Higher Education*, *18*(1), 53.

Hassan, M. A., Habiba, U., Majeed, F., & Shoaib, M. (2021). Adaptive gamification in e-learning based on students' learning styles. *Interactive Learning Environments*, *29*(4), 545–565.

Hooda, M., Rana, C., Dahiya, O., Rizwan, A., & Hossain, M. S. (2022). Artificial intelligence for assessment and feedback to enhance student success in higher education. *Mathematical Problems in Engineering*, *2022*(1), 5215722.

Huang, Y., Richter, E., Kleickmann, T., Wiepke, A., & Richter, D. (2021). Classroom complexity affects student teachers' behavior in a VR classroom. *Computers & Education*, *163*, 104100.

Istiyono, E. (2020). Pengembangan instrumen penilaian dan analisis hasil belajar fisika dengan teori tes klasik dan modern. *Yogyakarta: UNY Press. L, I.(2019). Evaluasi Dalam Proses Pembelajaran. Jurnal Manajemen Pendidikan Islam*, *9*, 478–492.

Izzulhaq, B. D., Gunawan, R. N., Zafrullah, Z., Ayuni, R. T., Ramadhani, A. M., & Fitria, R. L. (2024). Research Trends on Leadership in Indonesian Schools: Bibliometric Analysis (2008-2024). *Elementaria: Journal of Educational Research*, *2*(1), 19–38.

Kennedy, T. J., & Sundberg, C. W. (2020). 21st century skills. *Science Education in Theory and Practice: An Introductory Guide to Learning Theory*, 479–496.

MacPhail, A., Tannehill, D., & Ataman, R. (2024). The role of the critical friend in supporting and enhancing professional learning and development. *Professional Development in Education*, *50*(4), 597–610.

Maree, J. G. (2022). The psychosocial development theory of Erik Erikson: critical overview. *The Influence of Theorists and Pioneers on Early Childhood Education*, 119–133.

Minkos, M. L., & Gelbar, N. W. (2021). Considerations for educators in supporting student learning in the midst of COVID-19. *Psychology in the Schools*, *58*(2), 416–426.

Owan, V. J., Abang, K. B., Idika, D. O., Etta, E. O., & Bassey, B. A. (2023). Exploring the potential of artificial intelligence tools in educational measurement and assessment. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(8), em2307.

Pamuji, S., & Mulyadi, Y. (2024). Formation Of Students' Character Through Islamic Education. *International Journal of Islamic Thought and Humanities*, *3*(1), 26–35.

Puspitasari, D., Widodo, H. P., Widyaningrum, L., Allamnakhrah, A., & Lestariyana, R. P. D. (2021). How do primary school English textbooks teach moral values? A critical discourse analysis. *Studies in Educational Evaluation*, *70*, 101044.

Qazi, M. A., Sharif, M. A., & Akhlaq, A. (2024). Barriers and facilitators to adoption of e-learning in higher education institutions of Pakistan during COVID-19: Perspectives from an emerging economy. *Journal of Science and Technology Policy Management*, *15*(1), 31–52.

Rajagukguk, M. J. T., & Naibaho, D. (2023). Mampu Memilih Soal Berdasarkan Tingkat Kesukaran. *Jurnal Pendidikan Sosial Dan Humaniora*, *2*(4), 12736–12747.

Ramadhani, A. M., Yakob, N. Y. B., Ayuni, R. T., Zafrullah, Z., & Bakti, A. A. (2024). Trends in implementation of game use as learning at primary schools level in scopus database: a bibliometric analysis. *Jurnal Penyelidikan Sains Sosial*, *7*(23).

Ramdas, B., Rao, M. V., & Chandrika Reddy, D. N. (2024). Analysis On New National Education Policy 2020–School Education In India. *Turkish Online Journal of Qualitative Inquiry*, *15*(3).

Reimers, F. M. (2024). The sustainable development goals and education, achievements and opportunities. *International Journal of Educational Development*, *104*, 102965.

Sakhiyya, Z., & Rahmawati, Y. (2024). Overview of education in Indonesia. In *International Handbook on Education in South East Asia,* 1–25. Springer.

Sanyal, B. C. (2024). *Higher education and employment: An international comparative analysis*. Taylor & Francis.

Schildkamp, K., van der Kleij, F. M., Heitink, M. C., Kippers, W. B., & Veldkamp, B. P. (2020). Formative assessment: A systematic review of critical teacher prerequisites for classroom practice. *International Journal of Educational Research*, *103*, 101602.

Sistyawati, R. I., & Apriani, D. (2024). Pengembangan Soal PISA Materi Bangun Ruang Kubus Untuk SMP. *Jurnal Pendidikan Matematika Sebelas April*, *3*(1), 48–56.

Tang, T., Vezzani, V., & Eriksson, V. (2020). Developing critical thinking, collective creativity skills and problem solving through playful design jams. *Thinking Skills and Creativity*, *37*, 100696.

Thornhill-Miller, B., Camarda, A., Mercier, M., Burkhardt, J.-M., Morisseau, T., Bourgeois-Bougrine, S., Vinchon, F., El Hayek, S., Augereau-Landais, M., & Mourey, F. (2023). Creativity, critical thinking, communication, and collaboration: assessment, certification, and promotion of 21st century skills for the future of work and education. *Journal of Intelligence*, *11*(3), 54.

Valencia, A. (2024). The Future of Higher Education in Latin America and the Caribbean: A Foresight Reflection. *The Bloomsbury Handbook of Context and Transformative Leadership in Higher Education, Edited by M. Drinkwater and P. Deane*, 302-332.

Vincent, W., & Shanmugam, S. K. S. (2020). The role of classical test theory to determine the quality of classroom teaching test items. *Pedagogia: Jurnal Pendidikan*, *9*(1), 5–34.

Zafrullah, Z., Ramadhani, A. M., Awliya, D., & Ayuni, R. T. (2024). Implementasi Project-based Learning di Sekolah: Analisis Bibliometrik (1998-2023): Indonesia. *Ciencias: Jurnal Penelitian Dan Pengembangan Pendidikan*, *7*(2), 11–23.

Zafrullah, Z., & Zetriuslita, Z. (2021). Minat belajar siswa kelas VII terhadap media pembelajaran matematika berbantuan Adobe Flash CS6. *Math Didactic: Jurnal Pendidikan Matematika*, *4*(2), 114–123.

Issue VIII, 22 November 2025
e-ISSN 2707-9481 Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University, Almaty, Kazakhstan
ISBN 978-601-323-547-9 https://doi.org/10.31643/2025.02

Siti Nurjanah
Yogyakarta State University (Universitas Negeri Yogyakarta), Jl. Colombo No. 1, Indonesia
E-mail: siti960pasca.2023@student.uny.ac.id,
ORCID ID: https://orcid.org/0009-0006-0727-0830

D'aquinaldo Stefanus Fani Seran
Yogyakarta State University (Universitas Negeri Yogyakarta), Jl. Colombo No. 1, Indonesia
E-mail: daquinaldo0001pasca.2023@student.uny.ac.id,
ORCID ID: https://orcid.org/0009-0000-5089-8187

Shaufi Ramadhani
Yogyakarta State University (Universitas Negeri Yogyakarta), Jl. Colombo No. 1, Indonesia
E-mail: shaufiramadhani.2023@student.uny.ac.id,
ORCID ID: https://orcid.org/0009-0006-0208-8810

Rooskartiko Bagas Rahoetomo
Yogyakarta State University (Universitas Negeri Yogyakarta), Jl. Colombo No. 1, Indonesia
E-mail: rooskartikobagas.2023@student.uny.ac.id,
ORCID ID: https://orcid.org/0009-0009-3971-1233

Zafrullah
Yogyakarta State University (Universitas Negeri Yogyakarta), Jl. Colombo No. 1, Indonesia
E-mail: zafrullah.2022@student.uny.ac.id,
ORCID ID: https://orcid.org/0009-0008-3752-8841

Sandry Rory
Yogyakarta State University (Universitas Negeri Yogyakarta), Jl. Colombo No. 1, Indonesia
E-mail: sandryrory.2023@student.uny.ac.id,
ORCID ID: https://orcid.org/0009-0003-8999-9542

Mapping Research Trends of TikTok in Education: A Bibliometric Analysis

Abstract: The popularity of TikTok as a social media platform beloved by the general public enables reaching a broader audience through its engaging interface. The global proliferation of TikTok has transformed it from merely an entertainment platform into a potential educational tool. This study aims to identify research trends related to the use of TikTok in the field of education using bibliometric analysis. Data was obtained from 46 publications obtained from the Scopus database in 2020–2023, which were filtered based on TikTok keywords in the context of education. Data analysis was carried out with the biblioshiny package of the RStudio application. The results showed that publications increased sharply in 2022. Geographically, China and the United States contributed the most. The main keywords included "social networking", "TikTok", and "students" representing the research trends on utilising TikTok for learning. The most cited articles indicate TikTok's potential as an innovative pedagogical tool to increase learners' engagement and motivation and expand public access to education and health information. Further research was recommended to enrich multidisciplinary perspectives and maximise the benefits of TikTok for learning.

Keywords: bibliometric analysis, education, TikTok.

Introduction

Education continues to grow globally, especially since the end of the Second World War (Dunlop, 2023; Zafrullah et al., 2023; Zafrullah & Zetriuslita, 2021). The transformation in education was significantly driven by technological developments. Technological advances open up new opportunities in the delivery of subject matter, enabling the utilisation of innovative and interactive learning tools (Secundo et al., 2021). Technology-enabled education has been not only a trend but also a very promising opportunity to improve learning effectiveness and accessibility (Ali, 2020; Burbules et al., 2020; Criollo-C et al., 2021; Haleem et al., 2022). The use of technology in education has given students easier access to information, facilitated more interactive and creative learning, and equipped them with skills relevant to the modern era (Dakhi et al., 2020; Musyafak & Subhi, 2023). The integration of technology in education, particularly through interactive multimedia and mobile platforms, has demonstrated significant effectiveness in fostering engaging learning environments and enhancing student motivation (Gayatri et al., 2024; Pratama et al., 2024). Additionally, the accessibility and instant feedback capabilities offered by educational technology allow students to pursue self-paced learning, resulting in improved comprehension of challenging subjects such as programming

(Gayatri et al., 2024). The combination of education and technology not only created advancements in learning methods but also opened the door to vast opportunities for the development of student's potential in the future.

Students could undergo the learning process well because of the teacher's efforts to create a conducive situation, including by providing the right learning media. According to Wibawanto, quoted in the learning media book, learning or educational media could be interpreted as humans and objects or events that make student conditions possible to acquire knowledge, skills, or attitudes (Nurfadhillah, 2021). The availability of learning media allows students to think more concretely, so learning media is needed to support success in the teaching and learning process (Rejeki et al., 2020). The use of learning media provided many positive benefits that were enormous in facilitating the student's learning process. Learning media has been a vital component of learning that acts as a bridge to convey subject matter. The existence of learning media was crucial as one of the supporting factors for the success of teaching and learning at school. This was due to the function of learning media, which can increase the effectiveness of delivering information and knowledge to students. In addition, the use of learning media also plays a role in increasing student interest in learning (Nurfadhillah, 2021). Therefore, learning media has been a fundamental component that teachers must pay attention to to support the success of learning and improve the quality of education.

The rapid development in the field of technology, multimedia, and social media today has opened opportunities for instructors to utilise it optimally as a learning medium. The development of social media was no longer limited to connecting to exchange news between one individual and another but could also play a role as a medium for learning, such as an application that was behind the public spotlight known as TikTok.

TikTok is a social media platform that enables users to create short-form videos ranging from 15 to 60 seconds, enhanced by various creative features including music, filters, stickers, and other interactive elements (Lahooti et al., 2023). There were supporting features in the TikTok application that could make content more attractive and easier to market. This application was first launched by a company from China, ByteDance (Bahri et al., 2022). The majority of TikTok app users in Indonesia were millennials, and school-age children, commonly known as Generation Z (Abutalip et al., 2023). The popularity of TikTok allows many people to easily market their content. The popularity of TikTok allows many users, especially young people, to use this platform to obtain various information and knowledge that was packaged densely and clearly through TikTok content (Bahri et al., 2022). The use of the TikTok application has the potential to be used as an innovative learning medium in today's digital era.

The growth of TikTok over the past few years reflects a positive trend involving various fields, not only limited to increasing popularity among users but also bringing positive impacts in sectors such as education. The widespread use of TikTok has encouraged educational researchers to conduct research related to it. Many researchers discuss topics related to user experience and interest in technology, the use of TikTok applications in various fields, changes in one's motivation through TikTok, and the potential use of TikTok applications in various fields (Wang, 2020; Omar & Dequan, 2020; Su et al., 2020). Realising the amount of research and interest that educational researchers put into this topic, it was necessary to conduct a bibliometric analysis to map research trends on this topic.

The bibliometric analysis could be done with the biblioshiny package in the Rstudio application. Rstudio was superior to other data analysis tools because it was an open-source application, had rich statistical computing features, mature algorithms, and attractive visualisations. R was a statistical and graphical computing program (Team, 2022). Currently, R has been widely recognised as one of the most powerful programs in data mining. Bibliometric research with RStudio and the biblioshiny package has been conducted by previous studies (de Oliveira Dias & de Miranda Rocha, 2023, 2024; de Paulo et al., 2023; Desul et al., 2023; Dias et al., 2023; Thakuria et al., 2023). However, research that analyses TikTok research trends in the context of education using bibliometric analysis using RStudio, especially the biblioshiny package, has rarely been done before. Therefore, this research would fill this gap by conducting bibliometric analyses on research on TikTok in the context of education. This research would focus on bibliometric analysis related to TikTok in the context of education. By conducting this research, it was hoped that the trends, developments, and impacts of TikTok used in education would be identified, opening up space for a deeper understanding of the role of this platform in supporting the learning process and modern education. This research aims to conduct a bibliometric analysis examining TikTok's educational applications. The study addresses several key research questions, including publication profiles, annual publication trends, journal frequency analysis,

country-wise productivity metrics, author analysis and collaboration networks, institutional productivity, emerging keyword trends, and content analysis of highly cited documents. Through investigating these aspects, this research seeks to identify trends, developments, and the impact of TikTok in supporting contemporary learning and educational practices.

Research Methods

This study implements a bibliometric analysis method to map contemporary research trends on the topic of TikTok in the realm of educational studies. Bibliometric analysis was chosen as an appropriate method because it was a quantitative and systematic approach to analysing publication and citation data to map and monitor the development of a field of science (Oluwadele et al., 2023). The data used in this study was secondary data obtained from the Scopus database. The Scopus database was chosen as the main data source because it has a more comprehensive collection of indexed documents than other databases (Mongeon & Paul-Hus, 2016).

We applied several filters to filter the documents to be analysed. The filters were applied with the main consideration of fulfilling the research objectives. We made sure the filters used were in line with the research objectives. The first filter used the keywords "TikTok" OR "TikTok" OR "TikTok" in the article title search. This filter was chosen because this research aims to map trends in educational research on the topic of TikTok. Thus, we included all possible spellings of the word TikTok in the article title search. The second filter utilises the source title feature, where they must contain keywords such as "education" OR "educational" OR "teach" OR "teaching" OR "teacher" OR "pedagogy" OR "pedagogies." We made this restriction because we wanted the analysed articles to focus on the field of education. For scientific fields, we limited it to the social sciences. These two filterings were done because Scopus does not have a specific filter to select the subject area of education, so we chose the subject area of social sciences. The subject area of education was assumed to be covered by the subject area of social sciences. By applying these three filters, we obtained 46 documents ready for bibliometric analysis. The data was analysed using R software with the biblioshiny package (Aria & Cuccurullo, 2017). The data analysis was conducted using R software with the biblioshiny package. The dataset, exported from Scopus in CSV format, was analyzed using R's biblioshiny package, which facilitates comprehensive data visualization and in-depth exploration of publication metrics through its extensive features. The analysis encompasses publication distribution by year, country, and journal, as well as author collaboration network mapping. This methodological approach enables the research to provide a comprehensive overview of research dynamics and academic contributions in this emerging field.

Research Results

Publication Profile. This study explored scientific publications related to the topic of TikTok on the subject of education in the Scopus database for the period 2020–2023. The literature search yielded 46 relevant publications. The distribution of publication types is presented in Table 1.

Table 1. Distribution of Publication Types related to TikTok in Education (2020-2023)

Publication Type	Number of Document	Persentage
Journal Articles	30	65%
Conference Papers	9	20%
Book Chapters	5	11%
Research Note	1	2%
Other Types of Publications	1	2%
Total	46	100%

Publication Results by Year. Figure 1 presents publication distribution data by year of publication during the literature review period from 2020 to 2023.

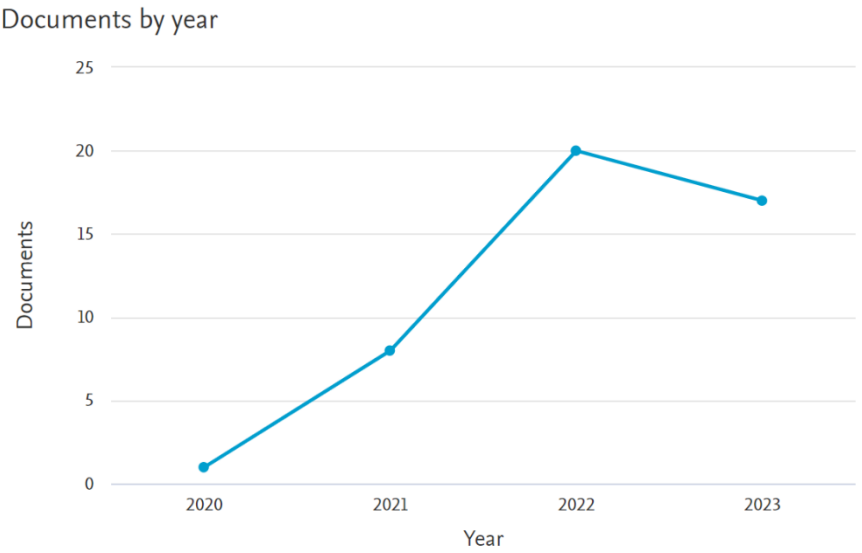


Fig.1. Publication Frequency Every Year (2020-2023)

Journal Frequency Analysis. Research publications related to the topic of TikTok in education were spread across 41 sources during the period 2020 to 2023. Table 2 presented the five sources with the most document contributions.

Table 2. The Publication Frequency by Source (2020-2023)

Journal	Number of Document	Percentage
Education and Information Technologies	3	6.52 %
Routledge Handbook of Media Education Futures Post-Pandemic	2	4.34 %
Journal of Hospitality Leisure Sport and Tourism Education	2	4.34 %
International Journal of Learning Teaching and Educational Research	2	4.34 %
Teaching Sociology	1	2.17 %

Most Productive Countries. Figure 2 presents the ten countries with the highest number of publications on the topic of TikTok used in education over the period 2020–2023.

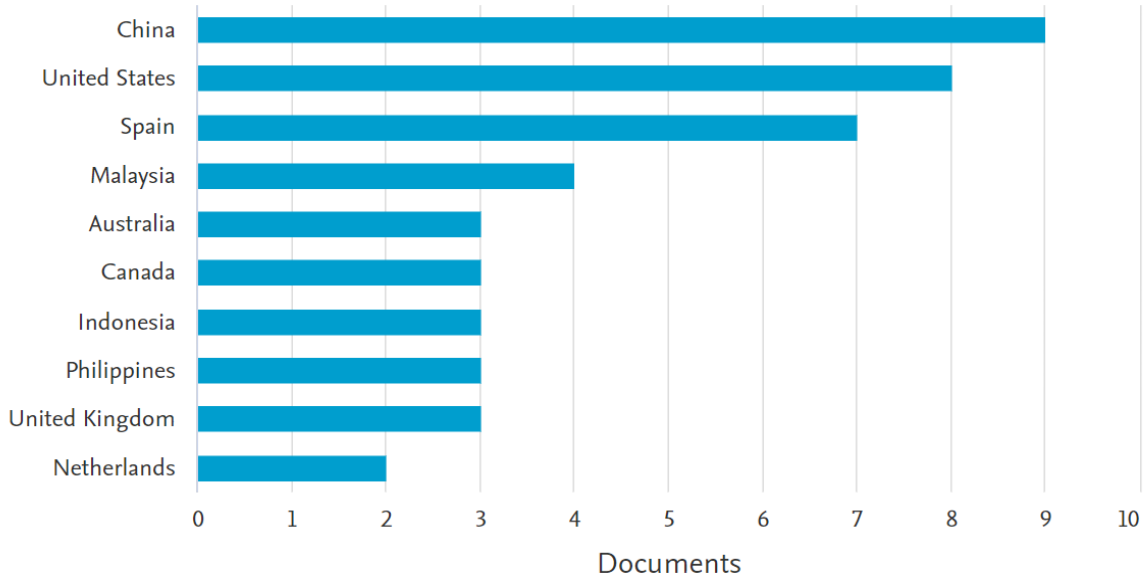


Fig. 2. Publication Output by Country (2003–2021)

Author/Co-Author. Table 3 shows the ten authors or colleagues who have published the most.

Table 3: Publication Frequency by Author (2020-2023)

Author	Number of Document	Persentage
Vizcaíno-Verdú, A.	2	4.35 %
Abd Halim, N.D.	1	2.17 %
Abidin, C.	1	2.17 %
Abzhekenova, B.	1	2.17 %
Adriaansen, R.J.	1	2.17 %
Aini, N.	1	2.17 %
Alguacil, M	1	2.17 %
Anindhita, H.	1	2.17 %
Arcega, K.C.A.	1	2.17 %
Arias, D.	1	2.17 %
Vizcaíno-Verdú, A.	1	2.17 %

A total of 112 authors contributed to 46 publications related to the topic of TikTok in education during the period 2020–2023, either as the main author or co-author. Most authors were involved in only one publication. Table 3 highlights the ten authors with the highest number of publications as lead or co-authors. Vizcaíno-Verdú, A. ranked the highest with 2 publications, or about 4.35% of the total publications. Followed by Abd Halim, N.D., Abidin, C., Abzhekenova, B., Adriaansen, R.J., Aini, N., Alguacil, M., Anindhita, H., Arcega, K.C.A., Arias, D., and Vizcaíno-Verdú, A. with 1 publication each (2.17%).

Figure 3 presents a visualisation of the collaboration network between authors on publications related to the topic of TikTok in education. 16 clusters of collaboration between authors were formed.

Fig.3. Collaboration Network between Authors

Most Productive Institutions. Figure 4 presents the 10 most productive institutions in publishing publications related to the topic of TikTok in education during the period 2020–2023.

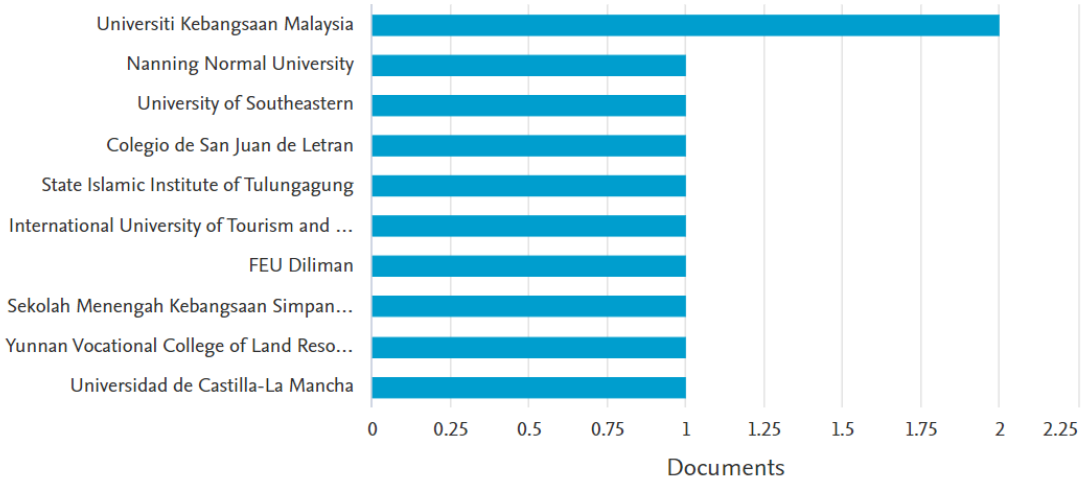


Fig. 4. The Most Productive Institutions (2020–2023)

Word Trend. Figure 5 presents a visualisation of the most frequently discussed keywords in TikTok-related publications in education journals over the period 2020–2023. The larger the word size and the closer it was to the center of the visualisation, the more frequently it appeared.

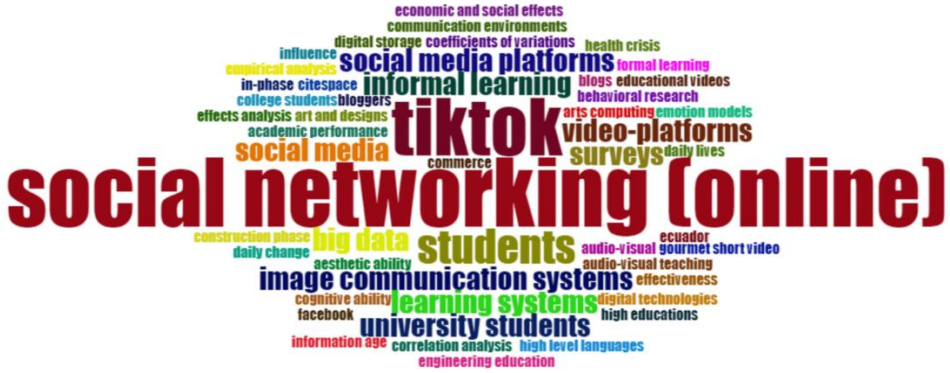


Fig.5. Publication Frequency by Institution (2020-2023)

Figure 6 presents the development of keyword frequency in TikTok and education-related publications from year to year during 2020 to 2023.

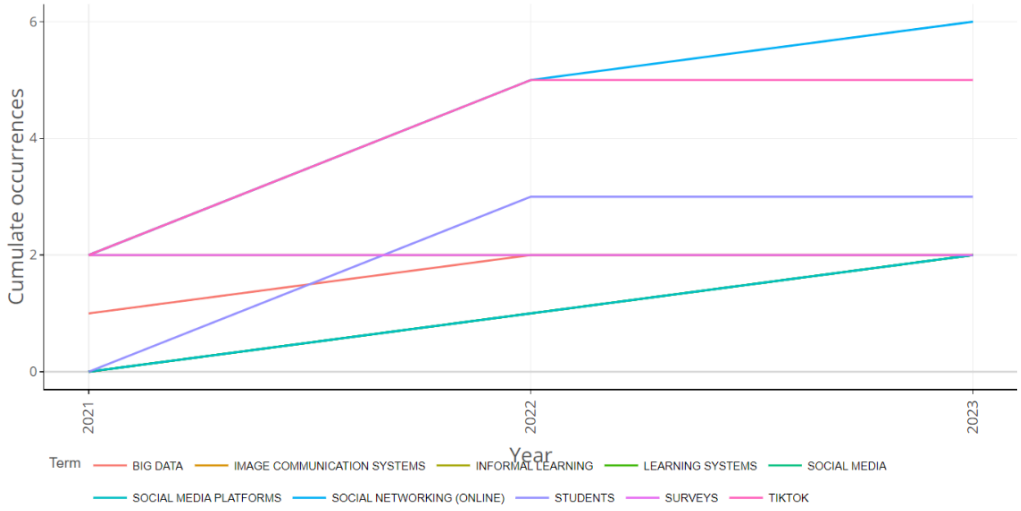


Fig.6. Word's Frequency over Time

Research Discussion

Publication Profile. The research topic was more widely studied and published in the form of journal articles than other types of publications. Publication in scientific journals indicates that this topic has been researched in depth and meets the standards for publication in reputable international journals that use a rigorous peer-review process. Meanwhile, publications in the form of conference papers indicate that this topic was also the focus of discussion and the exchange of ideas in scientific forums. The existence of publications in the form of book chapters was also important to disseminate research findings to academic and practitioner audiences through reference books. With this diversity of publication forms, research related to this topic appears to have grown rapidly in the last four years. This topic was also projected to continue to grow in the future. TikTok has a great opportunity for educational research because it fits the characteristics of Generation Z as the main users. Its creative and engaging short video features could increase students' interest in learning. TikTok also facilitates visual and auditory learning styles and could make learning more fun (Syah et al., 2020).

Publication Results by Year. The average number of journal articles published per year is 11.5 documents. There was a significant increase in publications from year to year. In 2020, only one journal article was published. This number increased to 8 in 2021 and peaked in 2022 with 20 journal articles. In 2023, 17 journal articles were found. This pattern of increasing publications indicated that the research topic has received greater attention and interest from researchers in the last 4 years. The year 2022 became the year with the highest research productivity, with a total of 20 documents, or 43.48% of all publications found. The factor that caused this increase in publications could be the pandemic in 2020, so that the use of social media platforms, including TikTok, became increasingly widespread. The rise of this phenomenon has led to a surge in research interest in this topic. By recognising this factor, we hope to support efforts to improve the quality and quantity of research in the future.

Journal Frequency Analysis. The Education and Information Technologies journal ranked first with a total of 3 published articles or 6.52% of all publications on this topic. The high contribution of Education and Information Technologies indicated that this journal has a focus that was relevant to the topic of study, namely information technology in education. Therefore, many researchers were interested in publishing research results related to the used of TikTok as a new technology in education in this journal. The dominance of Education and Information Technologies also showed that the topic of TikTok in education was in line with the scope and interests of the journal's readers. Researchers who want to published similar research results in the future could maked Education and Information Technologies a prospective journal for submitting manuscripts.

Most Productive Countries. China ranked first with a total of nine published documents, or 19.6% of the total publications. This was followed by the United States with 8 documents (17.4%), Spain with 7 documents (15.2%), Malaysia with 4 documents (8.7%), and Australia, Canada, Indonesia, and the Philippines with 3 documents each (6.5%). Furthermore, the Netherlands contributed 2 documents (4.3%). This pattern of geographical distribution of publications showed that TikTok-related research in education has attracted global interest, especially in China as the country of origin of TikTok. China's dominance could be explained by the country's widespread access to and use of TikTok, so many researchers were interested in studying its implementation in education. Significant contributions from the United States and other countries were also reasonable, given TikTok's growing popularity globally.

Author/Co-Author. The author's publication frequency distribution pattern indicated that research on TikTok topics in education was dominated by many researchers with low productivity levels. Only a few researchers have consistently focused on this topic in recent years. The publication productivity of Vizcaíno-Verdú, A. is commendable, demonstrating their commitment to pioneering research in this area. In the future, collaboration between researchers needed to be improved so that the contribution of each author was more evenly distributed and sustainable, so that research on this topic could develop more comprehensively.

Figure 3 shows that VizcainoVerduu have important role in initiating and developing research collaboration on this topic. Meanwhile, most authors were in separate and relatively small clusters. This fragmented pattern of collaboration indicates that there was limited networking and research synergy between researchers on TikTok and education. Broad collaborations were needed for research on this topic to develop more comprehensively and impactfully. For example, interdisciplinary collaboration between technology, education, and behavioral experts. Going forward, key researchers like VizcainoVerduu could

play a strategic role in bridging and expanding collaborations with more researchers from diverse disciplines. This would enrich research perspectives and methodologies and lead to more significant contributions.

Most Productive Institutions. Universiti Kebangsaan Malaysia (UKM) ranked first with a total of 2 publications, or 4.34% of the overall data. UKM was followed by 9 other institutions with the number of publications between 1 document. The dominance of UKM showed the role of this institution as the main contributor to research on TikTok topics and education compared to other institutions. The high number of publications from SMEs was commendable, reflecting the institution's concern for this relevant and cutting-edge research topic. SMEs' productivity could be explained by their research focus on technology and educational innovation, which was in line with the trend of TikTok usage. In the future, other research institutions and universities need to increase attention to this topic so that research could develop more evenly and comprehensively from various scientific perspectives.

Word Trend. The most dominant keyword was "social networking (online)," which represents discussions about social networking and online social media in general. Followed by the keywords "tiktok" and "students," which specifically discuss the main topics, namely TikTok and students. Furthermore, there were also relevant keywords such as "big data," "image communication systems," "informal learning," "learning systems," "social media," "social media platforms," and "surveys." This overall keyword pattern illustrates that the focus of the publications lies on the utilisation of TikTok as a popular social media platform among students for informal learning purposes. These results confirmed the alignment of publication topics with frequently used keywords. For further research, content and textual analyses of the articles could be conducted to understand the context and perspectives used in the discussion of these keywords.

The keyword "social networking (online)" showed a steady and significant increase, becoming the most frequent keyword consistently every year. The word "tiktok" also experienced a similar upward trend until 2022, but decreased in 2023. Meanwhile, the word "students" continued to increase until 2022 and reached a saturation point in 2023. The keywords "surveys" and "image communication systems" were quite stable without significant fluctuations during the analysis period. The word "big data" had a sharp increase in 2021 and 2022 and then decreased in 2023, with a similar pattern but a lower scale than "tiktok." The words "social media" and "social media platforms" showed a moderate and consistent increase from year to year. Overall, these keyword trends showed a progression of research focus from social networks and social media in general towards a specific discussion of TikTok and its application in learning, reaching a saturation point in 2023. These results provided useful information on topics and approaches that have started and stopped trending over the past four years.

Content analysis of the most cited documents. We would present a content analysis of the three most-cited documents in the Scopus database. Hayes et al. (2020) explored the use of TikTok as a pedagogical tool with 65 sports science students in Spain. The results of the mixed study showed TikTok could increase student motivation and engagement as well as develop creativity and curiosity. Therefore, TikTok was recommended for body expression courses in sport science undergraduate programs. Comp et al. (2021) found that during the COVID-19 pandemic, TikTok has been effectively utilised by medical professionals to disseminate information and conduct training with short videos. This study recommended healthcare and medical education institutions consider using TikTok to reach a wider audience. Escamilla-Fajardo et al. (2021) reported that an educational TikTok video on chemistry created by students had 8,500 views. Surveys showed the video increased viewers' interest in and understanding of chemistry. Thus, TikTok has the potential to be a tool to increase student and public engagement with science education. Taken together, these three studies showed that TikTok was an innovative multimedia platform for educational purposes and the dissemination of health and science information to students and the general public.

Conclusion

Scientific publications on the topic of TikTok in education have shown a rapid increase in the last 4 years (2020–2023). This indicates that this research topic has been increasingly receiving widespread attention from academics. 2022 was the year with the highest publication productivity (43.48%), likely triggered by the surge in Tik-Tok usage during the COVID-19 pandemic. Geographically, China and the United States contributed the most. Education and Information Technologies was the main journal that published articles related to this topic. Geographically, China and the United States ranked highest in terms of the number of publications, in line with TikTok's popularity in those two countries. In terms of institutions, Universiti Kebangsaan Malaysia contributed the most. The dominant keywords in the publications include

"social networking," "TikTok," "students," "social media," and "learning systems," which generally represent a focus on the use of TikTok for informal learning among students. Content analysis of the most cited articles indicated that TikTok has the potential to be an innovative pedagogical tool to increase learner engagement and motivation and expand public access to education and health information. Overall, these findings confirm that research on the application of TikTok in education continues to grow rapidly and shows great potential to be utilised in future learning practices. Further research was needed to enrich multidisciplinary perspectives and maximise the impact of implementing TikTok as an effective and innovative pedagogical tool.

CRediT author statement: **Siti Nurjanah**: Conceptualization, Methodology, Software, Validation, Writing draft preparation. **Shaufi Ramadhani**: Data curation, Software, Writing draft preparation. **Zafrullah**: Methodology, Writing draft preparation. **D'aquinaldo Stefanus Fani Seran:** Reviewing. **Rooskartiko Bagas Rahoetomo**: Visualization. **Sandry Rory**: Editing.

Acknowledgements. The authors would like to thank anonymous reviewers and the conference editors for their comments on earlier versions to improve this study's quality.

Cite this article: Nurjanah, S., Ramadhani, S., Zafrullah, Seran, D.S.F, Rahoetomo, R.B., Sandry Rory. (2025). Mapping Research Trends of TikTok in Education: A Bibliometric Analysis. Materials of International Scientific-Practical Internet Conference "Challenges of Science". Issue VIII, pp. 14-23. https://doi.org/10.31643/2025.02

References

Abutalip, D., Yesbossyn, M., Pertiwi, F.D., Suleimen, S.B., Kassymova, G.K. (2023). Career guidance for Generation Z: modern methods of professional orientation in a stress Period. Challenges of Science. Issue VI, 2023, pp. 15-21. https://doi.org/10.31643/2023.02

Ali, W. (2020). Online and remote learning in higher education institutes: A necessity in light of COVID-19 pandemic. Higher Education Studies, 10(3), 16–25. https://doi.org/10.5539/hes.v10n3p16

Aria, M., & Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. Journal of Informetrics, 11(4), 959–975. https://doi.org/10.1016/j.joi.2017.08.007

Bahri, A., Damayanti, C. M., Sirait, Y. He., & Alfarsy, F. (2022). Aplikasi Tiktok sebagai media pembelajaran bahasa inggris di Indonesia (Tiktok application as english learning media in Indonesia). Jurnal Indonesia Sosial Sains, 3(1), 1–9. https://doi.org/10.36418/jiss.v3i1.505

Burbules, N. C., Fan, G., & Repp, P. (2020). Five trends of education and technology in a sustainable future. Geography and Sustainability, 1(2), 93–97. https://doi.org/10.1016/j.geosus.2020.05.001

Comp, G., Dyer, S., & Gottlieb, M. (2021). Is TikTok the next social media frontier for medicine? AEM Education and Training, 5(3). https://doi.org/10.1002/aet2.10532

Criollo-C, S., Guerrero-Arias, A., Jaramillo-Alcázar, Á., & Luján-Mora, S. (2021). Mobile learning technologies for education: Benefits and pending issues. Applied Sciences, 11(9), 4111. https://doi.org/10.3390/app11094111

Dakhi, O., JAMA, J., & IRFAN, D. (2020). Blended learning: A 21st century learning model at college. International Journal Of Multi Science, 1(08), 50–65.

de Oliveira Dias, F., & de Miranda Rocha, G. (2023). Geographical indications: A bibliometric analysis of scientific production through RStudio® and VOSviewer® (2013-2022). Revista de Gestao Social e Ambiental, 17(8). https://doi.org/10.24857/rgsa.v17n8-017

de Oliveira Dias, F., & de Miranda Rocha, G. (2024). Territorial development: A bibliometric analysis of scientific production through RStudio® AND VOSviewer® (2013-2022). Revista de Gestao Social e Ambiental, 18(2). https://doi.org/10.24857/rgsa.v18n2-045

de Paulo, R. C., de Araújo Rabelo, T. T., de Oliveira Dias, F., Vilela, D. C., & Mafra, R. Z. (2023). ST&I public policies: A bibliometric study of scientific production. Revista de Gestao Social e Ambiental, 18(1). https://doi.org/10.24857/rgsa.v18n01-023

Desul, S., Mahapatra, R. K., Patra, R. K., Sethy, M., & Pandey, N. (2023). Semantic technology for cultural heritage: a bibliometric-based review. Global Knowledge, Memory and Communication. https://doi.org/10.1108/GKMC-04-2023-0125

Dias, F. D. O., Bonfim, H. D. S., Bombardelli, J., & Matos, G. B. D. C. (2023). Bibliometric analysis of scientific production on carbon credits (2012-2021). Revista de Gestao Social e Ambiental, 17(1). https://doi.org/10.24857/RGSA.V17N1-026

Dunlop, E. (2023). Regional favouritism, elections, and legacies of inequality: The dynamics of education redistribution in post-war burundi. Journal of Intervention and Statebuilding, 1–25. https://doi.org/10.1080/17502977.2023.2212994

Escamilla-Fajardo, P., Alguacil, M., & López-Carril, S. (2021). Incorporating TikTok in higher education: Pedagogical perspectives from a corporal expression sport sciences course. Journal of Hospitality, Leisure, Sport and Tourism Education, 28. https://doi.org/10.1016/j.jhlste.2021.100302

Gayatri, T. N., Maryono, D., & Yuana, R. A. (2024). Development of android-based interactive multimedia in python basic programming material for grade 10 senior high school. IJIE (Indonesian Journal of Informatics Education), 8(1), 1. https://doi.org/10.20961/ijie.v8i1.75959

Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. Sustainable Operations and Computers, 3, 275–285. https://doi.org/10.1016/j.susoc.2022.05.004

Hayes, C., Stott, K., Lamb, K. J., & Hurst, G. A. (2020). "Making every second count": Utilizing TikTok and systems thinking to facilitate scientific public engagement and contextualization of chemistry at home. Journal of Chemical Education, 97(10), 3858–3866. https://doi.org/10.1021/acs.jchemed.0c00511

Lahooti, A., Hassan, A., Critelli, B., Westerveld, D., Newberry, C., Kumar, S., & Sharaiha, R. Z. (2023). Quality and popularity trends of weight loss procedure videos on TikTok. Obesity Surgery, 33(3), 714–719.

Mongeon, P., & Paul-Hus, A. (2016). The journal coverage of web of science and scopus: A comparative analysis. Scientometrics, 106(1), 213–228. https://doi.org/10.1007/s11192-015-1765-5

Musyafak, M., & Subhi, M. R. (2023). Strategi pembelajaran pendidikan agama islam dalam menghadapi tantangan di era revolusi industri 5.0. Asian Journal of Islamic Studies and Da'wah, 1(2), 373–398.

Nurfadhillah, S. (2021). Media pembelajaran (Learning media). jejakpublisher.

Oluwadele, D., Singh, Y., & Adeliyi, T. T. (2023). Trends and insights in e-learning in medical education: A bibliometric analysis. Review of Education, 11(3), 1–28. https://doi.org/10.1002/rev3.3431

Omar, B., & Dequan, W. (2020). Watch, share or create: The influence of personality traits and user motivation on TikTok mobile video usage. International Journal of Interactive Mobile Technologies, 14(4), 121–137. https://doi.org/10.3991/IJIM.V14I04.12429

Pratama, S. N. F., Basori, B., & Kurniasari, K. (2024). The effect of technology utilization in learning on learning motivation of grade 11 PPLG students of state vocational schools in Surakarta. IJIE (Indonesian Journal of Informatics Education), 7(2), 125–132. https://doi.org/10.20961/ijie.vXiY.abcde3

Rejeki, R., Adnan, M. F., & Siregar, P. S. (2020). Pemanfaatan media pembelajaran pada pembelajaran tematik terpadu di sekolah dasar (Utilization of learning media in integrated thematic learning in elementary schools). Jurnal Basicedu, 4(2), 337–343. https://doi.org/10.31004/basicedu.v4i2.351

Secundo, G., Gioconda, M., Del Vecchio, P., Gianluca, E., Margherita, A., & Valentina, N. (2021). Threat or opportunity? A case study of digital-enabled redesign of entrepreneurship education in the COVID-19 emergency. Technological Forecasting and Social Change, 166, 120565. https://doi.org/10.1016/j.techfore.2020.120565

Su, Y., Baker, B. J., Doyle, J. P., & Yan, M. (2020). Fan engagement in 15 seconds: Athletes' relationship marketing during a pandemic via TikTok. International Journal of Sport Communication, 13(3), 436–446. https://doi.org/10.1123/ijsc.2020-0238

Syah, R. J., Nurjanah, S., & Andri Mayu, V. P. (2020). Tikio (TikTok App Educational Video) based on the character education of Newton's laws concepts preferred to learning for generation Z. Pancaran Pendidikan, 9(4). https://doi.org/10.25037/pancaran.v9i4.325

Team, R. C. (2022). R: A language and environment for statistical computing.

Thakuria, A., Chakraborty, I., & Deka, D. (2023). A bibliometric review on serendipity literature available in Web of Science database using HistCite and Biblioshiny. Information Discovery and Delivery. https://doi.org/10.1108/IDD-01-2023-0001

Wang, Y. (2020). Humor and camera view on mobile short-form video apps influence user experience and technology-adoption intent, an example of TikTok (DouYin). Computers in Human Behavior, 110, 106373. https://doi.org/https://doi.org/10.1016/j.chb.2020.106373

Zafrullah, Z., Suyanto, S., Wahyuni, A., Ayuni, R. T., & Novilanti, F. R. E. (2023). Development of android-based learning to improve computational thinking skills in junior high school. Jurnal Cendekia: Jurnal Pendidikan Matematika, 7(2), 1309–1320. https://doi.org/10.31004/cendekia.v7i2.2239

Zafrullah, Z., & Zetriuslita, Z. (2021). Learning interest of seventh grade students towards mathematics learning media assisted by Adobe Flash CS6. Math Didactic: Jurnal Pendidikan Matematika, 7(2), 114–123. https://doi.org/10.33654/math.v7i2.1272

Issue VIII, 22 November 2025
e-ISSN 2707-9481 Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University, Almaty, Kazakhstan
ISBN 978-601-323-547-9 https://doi.org/10.31643/2025.03

Bakytali Dauleshyar
Master's Student, SDU University
Almaty, Kazakhstan
E-mail: bakytali@inbox.ru

Abdikhassim Alishev
Master's Student, Abal Kazakh National Pedagogical University, Almaty, Kazakhstan
E-mail: Alishev1983.83@gmail.com

Studying the Perspectives and Career Guidance of 8th-grade Students on Science, Physics, and Future Professions through the Integration of Robotics into Physics Education

Abstract: This study aims to evaluate the perspectives and career guidance of 8th-grade students towards science by integrating robotics into physics education. The research focuses on analyzing students' interest in physics, their mastery of scientific research methods, and their attitudes toward future professions after participating in robotics activities. The study was conducted using a modified version of the TOSRA (Test of Science-Related Attitudes) questionnaire. This questionnaire has proven reliability and validity in studies conducted among secondary school students in Pakistan and was adapted to the context of 8th-grade students in Kazakhstan to explore the effects of integrating robotics into physics education. The findings reveal that incorporating robotics into physics lessons significantly enhances students' interest in the subject and fosters the development of critical thinking and scientific research skills. Additionally, students involved in robotics activities demonstrated a notably higher motivation for choosing future careers, particularly in the fields of engineering, technology, and natural sciences. This study underscores the positive impact of using robotics in physics lessons on students' career orientation and their increased interest in pursuing future careers in scientific and technological domains.

Keywords: robotics, physics education, STEM, student engagement, career orientation, research skills development.

Introduction

Students often face challenges when performing tasks solely focused on academic learning. However, they show remarkable enthusiasm when addressing real-life problems, such as conducting engineering or scientific research (Rogers, 2009). The use of robotics provides students with opportunities to develop creativity in problem-solving, build confidence, foster teamwork skills, and enhance their understanding of fundamental scientific concepts. Integrating robotics into physics education allows students to comprehend science not only theoretically but also practically. Robotics bridges science and engineering, enabling students to deepen their knowledge through innovative research (Rogers, 2009).

In the modern era, science, technology, engineering, and mathematics (STEM) play a crucial role in global education systems. However, the demand for STEM professionals remains unmet in many countries. In OECD member and partner countries, only 27% of undergraduate students enrol in STEM programs, leading to a shortage of qualified scientific personnel (OECD, 2022). Addressing global challenges, such as climate change and sustainable development, will require technical and scientific expertise, further emphasizing the importance of STEM education (Ministry of Education and Science of the Republic of Kazakhstan, 2022).

In Kazakhstan, STEM education has been rapidly developing over the past decade. For instance, since 2016, elective robotics courses have been introduced in 2,500 schools nationwide (Japashov et al., 2022). However, research and methodologies on STEM integration remain insufficient, particularly in the context of combining physics and robotics (Goldin & Shteingold, 2001). Consequently, incorporating robotics into physics lessons is an effective way to enhance students' interest in science. Robotics provides students with opportunities to solve real-world engineering and scientific problems, encouraging creative thinking, confidence-building, and teamwork skills development.

Studies highlight the relationship between teaching methods employed by educators and students' attitudes toward learning (Christidou, 2011). These findings demonstrate that aligning teaching strategies with students' interests can increase their engagement in science and enhance the overall effectiveness of the educational process. By integrating physics with robotics, students can grasp the practical relevance of science and apply their knowledge in new contexts. Teaching robotics systems captivates students' attention and establishes a connection between physics lessons and real-world issues.

This approach promotes active participation in the learning process, incorporates visual aids, facilitates review and discussion, and encourages deeper exploration of materials. These strategies make the educational process more meaningful for students and contribute to a better understanding of physics concepts (Dauletiyar et al., 2023).

Literature review

The integration of robotics into physics education offers a powerful approach to both engaging 8th-grade students and providing them with career guidance in STEM fields. Several recent studies highlight the potential benefits of this integration by focusing on aspects such as digital literacy, AI, collaborative teaching, and interactive learning.

The relationship between science and physics. Research shows that students ' interest in science is mainly depending on the teaching methods used by educators. Christidou (2011) explores relationships among the teaching strategies and ways of teaching students, this approach highlights teachers have a significant impact on students ' perception of the topic. The study also found that in this approach the attitude towards science varies according to gender, age and cultural factors. In addition, many studies have shown that teaching methods have a significant impact on students ' relationship with the subject (Goldin & Shteingold, 2001). However, in general, Kazakhstan adopted the attitude of students to physics and science that has not yet been studied.

Sheriyev et al. (2016) address the role of human-computer interaction (HCI) systems in education. In the context of robotics in physics education, HCI systems are key to helping students engage directly with robots and digital platforms. By interacting with these systems, students develop a deeper understanding of how technology works, preparing them for careers in fields like AI, robotics, and human-computer interaction.

The role of robotics in increasing activity. Church et al. (2009) showed that robotics is an effective tool for increasing students ' interest in the lesson. When students choose specific technology problems, their creativity is improved, and a deep understanding of the relevance of the discipline is formed (Church et al., 2009). This study aims to test this concept in the context of Kazakhstan's study of the influence of robotics on physics lessons. Further, Mutarah et al. (2024) discuss the development of interactive mobile applications in education, which can play a vital role in making robotics-based physics lessons more engaging and accessible. Such applications can allow students to interact with robots or physics simulations on their smartphones or tablets, making learning more hands-on and accessible both in and outside of the classroom. This technology can also serve as a bridge to careers in app development, design, and technology.

The impact of robotics on career guidance. Cyrus et al. (2014) took advantage of the interest in STEM careers A questionnaire to assess students ' interest in future careers (STEM-GUS). His research highlighted the important role of STEM education in increasing interest in these areas. A new aspect of this research is the study of how robotics works It affects the perception of future careers of students in Kazakhstan, especially in the field of the mint. Gaps in research and the contribution of this study. A review of the literature shows that if important data on the impact of robotics on students ' research skills and career prospects, much of the research work was also carried out outside Kazakhstan. This study was one of the first to bridge this gap study of the impact of robotics on physics education in the Kazakh context. It aims to provide insights into how robotics can influence students' attitudes toward science and their interest in STEM-related careers, thereby contributing valuable knowledge to both local and global discussions on STEM education.

AI-driven robotics tools. The study by Rzabayeva et al. (2024) discusses the role of gamification in promoting digital literacy, demonstrating that gamified learning experiences can bridge the gap between fun and education. When robotics is introduced into physics education, it offers an excellent opportunity to incorporate gamified experiences that can motivate students, increase their engagement, and develop their digital literacy. Similarly, Talgatov et al. (2024) explore the implications of AI in the classroom. AI can enhance

the learning of physics concepts through robotics, offering students interactive simulations and personalized feedback. However, this integration of AI requires careful consideration of its impact on traditional pedagogical practices. Moreover, the research by Kassymova et al. (2019) emphasized the importance of cognitive competence in learning, which is further strengthened through e-learning platforms. Robotics-based lessons, delivered via digital platforms, allow students to engage in problem-solving and critical-thinking exercises. In addition, Muti'ah et al. (2021) highlight the significance of collaborative teaching strategies in schools. The interdisciplinary nature of robotics - where physics, engineering, and computer science intersect - provides a perfect context for teachers from different fields to collaborate and deliver a more holistic education. This collaboration is crucial for ensuring that students see the practical applications of physics in real-world technologies, encouraging them to explore future careers in these domains.

Research Objectives

1. To determine students' interest in physics; to conduct surveys and interviews to assess students' interest in physics and science in general; to investigate the influence of gender, age, and social factors on students' interest in physics.

2. To evaluate the development of scientific research skills through robotics and identify how robotics projects can enhance students' scientific research skills; to assess the impact of robotics on students' research methods and critical thinking abilities.

3. To examine changes in students' perceptions of future careers; to evaluate the influence of robotics on students' interest in future careers; to study changes in students' interest in stem-related professions.

Scientific Novelty

*Impact of Robotics on Interest in Physics***.** This study is the first to analyze the effectiveness of robotics in enhancing school students' interest in physics in Kazakhstan. Unlike traditional teaching methods commonly used in physics classes, this research evaluates how robotics stimulates student engagement and interest, addressing a current and innovative educational challenge.

Influence of Robotics on Mastering Scientific Research Methods. The study investigates the extent to which robotics projects contribute to developing students' scientific research skills and critical thinking abilities. By assessing the impact of robotics on mastering research methodologies, the research introduces a novel perspective within the educational context of Kazakhstan.

Changes in Students' Career Perceptions in Kazakhstan**.** Exploring how robotics influences students' interest in future careers, this study fills a research gap by examining the effects of robotics on career orientation, particularly in STEM-related fields, within the context of Kazakhstan. This innovative approach sheds light on robotics' potential to shape professional aspirations and career interests.

Practical Significance:

1. Students ' interest in physics is growing. The results of this study will help identify effective methods for using robotics to increase students ' interest in physics. These methods allow teachers to introduce new and attractive tools and approaches to physics lessons, increase student motivation, and participate in the learning process.

2. Integration of robotics into the educational process. The study shows practical ways to effectively incorporate robotics into school curricula. This textbook supports teachers and school administrators in using robotics projects in Physics, Mathematics, and engineering classes and promotes the development of practical STEM-based educational practices.

3. Development of research skills of students. The use of robotics in education helps students master scientific research methods, improve critical thinking skills, solve problems, and make innovative decisions. The results of the study allow teachers to provide practical tools and strategies for effective teaching of research methods.

Research Methodology

This study used quantitative research approaches to study students' interest in physics and the MINT direction, as well as the place of robotics in the process of knowledge accumulation. The Tosra questionnaire (review of the points of view of science) was used for data collection (discriminatory validity and validity of the Urdu version of the Tosra test for communication with science in 2013). The Urdu version of this survey,

which has been confirmed and confirmed for students in Pakistan, has been adapted for Kazakhstan. The modified version was adapted to assess the impact of robotics integration on physics lessons in the 8th grade.

The subject of the investigation

The aim of the study as a research object is aimed at students of the 8th grade in Kazakhstan. A total of 195 students from different schools and social groups took part in the study. Their views on physics, science in general and the role of robotics in the learning process were analyzed.

Stages of the study

Preliminary study. Before the start of the studies, a first survey was conducted to determine the student's interest in physics and STEM. The survey is aimed at determining the attitude of students to the topic and assessing the state of their relationship with science before the integration of robotics.

Robot integration

During the study, the stage of introducing robotics into physics lessons was studied. Students used Lego® Arduino kits and other robotic tools to conduct scientific research and solve technical problems. This practical application is aimed at increasing interest in physics and STEM. Post-integration survey. After the integration of robotics, a final survey was conducted. This survey is designed to assess students' changing interest in physics and their attitude towards STEM subjects, in particular by focusing on how robotics affects their interaction with the subject.

Data Collection Tools

1. *TOSRA Survey*. The TOSRA (Test of Science-Related Attitudes) survey was used to assess students' attitudes toward science, physics, and robotics. The survey was structured using a Likert scale:
   - SA = Strongly Agree
   - A = Agree
   - NS = Neutral
   - DA = Disagree
   - SDA = Strongly Disagree

2. *Observation*. The process of students working on robotics projects was monitored by direct observation. Teachers followed the participation of students in group work, their creative abilities and the use of basic concepts of physics during the projects.

Methods for data analysis. The data collected in the questionnaires were analyzed using statistical methods. The Spss software was used to process survey results and evaluate changes in students' interest in physics and robotics. The observation data was compared with survey responses to understand how robotics influenced students' engagement with the subject matter.

*Research Ethics***.** Throughout the study, all student feedback and data were collected anonymously and used solely for academic purposes. Parental consent was obtained for students' participation, and all ethical guidelines were strictly followed.

Research Results

1. *Overall Data.* The initial survey results from 195 students are summarized as follows in Table 1.

Table 1. Initial survey results

Survey Category	*Mean*	*Median*	*Standard Deviation*	*Minimum*	*Maximum*
Social Impact of Science	3.66	3.67	0.443	2.33	4.83
Attitude Towards Scientific Research	3.52	3.50	0.485	2.17	5.00
Interest in Science Classes and Recreation	3.01	3.00	0.365	1.58	4.25
Interest in Careers in Science	3.28	3.20	0.510	2.00	4.60

2. *Statistical Analysis*. Statistical analysis of the collected data revealed that there were no significant differences based on gender, family size, or parental education level. This suggests that factors such as gender or family background did not have a notable impact on students' interest in science or robotics, at least within the context of this study. Here are the statistical analysis results based on family size in Table 2. Statistical Analysis is based on family size (Independent Samples T-Test).

Table 2. Statistical analysis results

Survey Category	*Statistic*	*df*	*p-value*	*Remark*
Social Impact of Science	Student's t	193	0.860	No statistically significant difference
Attitudes Towards Scientific Research Methods	Student's t	193	0.721	No statistically significant difference
Interest in Science Classes and Leisure	Student's t	193	0.259	No statistically significant difference
Interest in Careers in Science	Student's t	193	0.177	No statistically significant difference

3. *The Role of Robotics in Enhancing Engagement*. Church et al. (2009) demonstrated that robotics is an effective tool for increasing students' interest in lessons. When students solve real-life engineering problems, their creativity is enhanced, and they develop a deeper understanding of the subject's relevance (Church, Ford, & Perova, 2009). This study seeks to test this concept in the context of Kazakhstan by examining the impact of robotics on physics lessons.

4. *The Impact of Robotics on Career Orientation*. Kier et al. (2014) used the STEM Career Interest Survey (STEM-CIS) to assess students' interest in future careers. Their research highlighted the critical role of STEM education in fostering interest in these fields. A novel aspect of this study is to explore how robotics influences students' perceptions of future careers in Kazakhstan, particularly in STEM fields.

Research Gaps and Contribution of This Study. The literature review reveals that while there is substantial data on the impact of robotics on students' research skills and career perspectives, most of these studies have been conducted outside of Kazakhstan. This study addresses this gap by being one of the first to explore the impact of robotics on physics education within the Kazakhstani context. It aims to provide insights into how robotics can influence students' attitudes toward science and their interest in STEM-related careers, thereby contributing valuable knowledge to both local and global discussions on STEM education. There are no statistically significant differences based on family size ($p > 0.05$) in Table 3.

Table 3. Analysis Based on Parental Education Level (Independent Samples T-Test)

Survey Category	*Statistic*	*df*	*p-value*	*Note*
Social Impact of Science	Student's t	191	0.203	No statistical difference
Attitude Towards Scientific Research	Student's t	191	0.353	No statistical difference
Interest in Science Classes and Recreation	Student's t	191	0.086	No statistical difference
Interest in Careers in Science	Student's t	191	0.959	No statistical difference

Note**:** There are no statistically significant differences based on parental education level ($p > 0.05$).

Table 4 suggests that parental education level did not significantly influence students' attitudes toward science and robotics.

Table 4. Difference Between Complete and Incomplete Families (Mann-Whitney U Test)

Survey Category	*Statistic*	*p-value*	*Note*
Social Impact of Science	Mann-Whitney U	1623	No statistical difference
Attitude Towards Scientific Research	Mann-Whitney U	1605	No statistical difference
Interest in Science Classes and Recreation	Mann-Whitney U	1503	No statistical difference
Interest in Careers in Science	Mann-Whitney U	1296	No statistical difference

There are no significant differences between full and single parents. (P> 0.05), which suggests that the family structure did not have a significant impact on the attitude of students toward science and robotics.

Table 5. Teacher's Teaching Method and Suggestions for Changing the Lesson

Survey Category	***Statistic***	***p-value***	***Note***
Social Impact of Science	Mann-Whitney U	3143	No statistical difference
Attitude Towards Scientific Research	Mann-Whitney U	3333	No statistical difference
Interest in Science Classes and Recreation	Mann-Whitney U	2544	Statistical difference (p < 0.05)
Interest in Careers in Science	Mann-Whitney U	2641	Statistical difference (p < 0.05)

Table 5 showed significant differences between "interest in science education and leisure activities" and "interest in a scientific career" (p < 0.05). This suggests that the attitude of students toward science lessons and scientific careers may be influenced by the way the teacher teaches, highlighting the need to improve or change the way these aspects are taught.

Table 6. Teacher's Suggestions for Changing the Teaching Method

Survey Category	**Statistic**	**p-value**	**Note**
Social Impact of Science	Mann-Whitney U	2804	No statistical difference
Attitude Towards Scientific Research	Mann-Whitney U	2150	Statistical difference (p < 0.05)
Interest in Science Classes and Recreation	Mann-Whitney U	2012	Statistical difference (p < 0.05)
Interest in Careers in Science	Mann-Whitney U	2335	Statistical difference (p < 0.05)

Statistically significant differences were observed in the categories "Attitude Towards Scientific Research," "Interest in Science Classes and Recreation," and "Interest in Careers in Science" (p < 0.05) in Table 6. This indicates that suggestions for changing the teacher's teaching method have a meaningful impact on students' interest in science and scientific careers. Thus, improving the teaching approach can positively influence students' engagement with these aspects.

Pre-Study Results (Descriptive)

The survey results collected before the study showed that students had an average level of interest in physics and STEM fields. The data is summarized in Table 7.

Table 7. Pre-Study Results

Survey Category	***Mean***	***Median***	***Standard Deviation***	***Minimum***	***Maximum***
Social Impact of Science	3.66	3.67	0.443	2.33	4.83
Attitude Towards Scientific Research	3.52	3.50	0.485	2.17	5.00
Interest in Science Classes and Recreation	3.01	3.00	0.365	1.58	4.25
Interest in Careers in Science	3.28	3.20	0.510	2.00	4.60

The average scores suggest that students had moderate interest in science, scientific research, science classes, and careers in science before the integration of robotics into the learning process. The variability of responses also indicates some differences in student perspectives.

Gender, family size and differences in parenting

According to the results of Mann-Whitney Ut tests and data on the preschool education of students, there was a statistically significant influence of factors on students' interest in science in terms of answers,

family members and parental behaviour. Show it to me (p> 0,05). This shows that these demographic factors did not influence students' attitudes towards science or physics in this study.

Teacher's suggestion to change the way of learning

The teacher's proposal to significantly change educational equity (P < 0.05) was rejected. This shows that students have expressed the need to improve teaching methods to increase motivation and interest in physics. The statistical significance of these results shows that a change in the way students learn can help to increase their motivation and motivation for science lessons.

Results after the study: The effects of robotics integration

After the integration of robots into physics lessons, students' interest in natural sciences and their prospects improved significantly. The results of the survey after the study showed the following changes (Table 8).

Table 8. Results after the study

Survey Category	*Pre-Study Average*	*Post-Study Average*	*Change*	*p-Value*
Social Impact of Science	3.66	4.10	+0.44	< 0.05
Attitude Towards Scientific Research	3.52	4.05	+0.53	< 0.05
Interest in Science Lessons and Breaks	3.01	3.85	+0.84	< 0.01
Interest in Science Careers	3.28	3.74	+0.46	< 0.05

Basic observations

1. The social influence of science: the student's perception of the social significance of science increased significantly (p < 0.05).

2. Attitude to scientific research: students showed a positive change in their attitude to scientific research methods (B < 0.05).

3. Interest in science teaching: Students' interest in science teaching and the subject in general increased significantly (p < 0.01).

4. Interest in a scientific career: The students' interest in a scientific career has also improved (p < 0.05).

These results show that the integration of robotics has had a positive effect on the motivation of students and their general interest in natural sciences and the fields of natural sciences, technology, engineering and mathematics.

Pay attention to the lessons. The use of robots has significantly increased the interest of students in physics lessons. 85% of students said that courses with experiments and engineering projects are interesting and valuable.

Impact of Changes in Teaching Method. The changes in the teacher's instructional approach positively affected students' participation. The use of robotics elements in lessons enhanced students' activity in group work and strengthened their practical skills.

Final analysis

A comparison of the results before and after the study showed the effectiveness of integrating robotics into physics lessons. This method has helped to arouse students' interest in the subject, develop scientific thinking, and increase interest in future careers in science and technology. Finally, the introduction of robotics has proven to be a successful learning tool to increase students' activity and deepen their understanding of the concepts of physics.

Research Discussions

The results of the study showed that the integration of robotics into physics classes plays an important role in increasing students ' interest in the natural sciences, especially in the areas of Science, Engineering, Engineering and mathematics. In this section, we will analyze the results of

the study, paying special attention to the effectiveness of the introduction of robots into the educational process and their influence on the selection of students for future specialties.

1. Increased interest in science. At the beginning of their studies, students ' interest in physics, Natural Sciences, Engineering, Engineering and mathematics was moderate. According to the results of the survey, although most students had a positive attitude towards science, many did not find physics classes particularly attractive. However, after the introduction of robots in the classroom, interest in this topic increased significantly. Interest in teaching natural sciences and leisure activities increased from 3.01 to 3.85 ($p < 0.01$), and interest in natural sciences increased from 3.28 to 3.74 ($p < 0.05$).

These results demonstrate the effectiveness of integrating robots into physics lessons to increase students ' interest in the topic. Robotics allowed students to complete tasks according to specific scenarios and helped them understand the theoretical aspects of physics through practical experience. This method not only deepened their understanding of the topic but also developed practical skills. In the final survey, 85% of students said that the classes were interesting and that the experience of working with robots was valuable.

2. The role of the teacher's pedagogical approach. The study also showed that the teacher's teaching method has a significant impact on students ' interest in the subject. Before studying, students realized that it was necessary to update the methods of the teacher. After graduation, most students came to the opinion that it is necessary to modernize teaching methods. This shows that teachers need to think about introducing innovative teaching methods, including robotics, into their classrooms. Most of the students responded positively to the proposal to change the teaching methodology and showed their willingness to use updated teaching methods to improve the effectiveness of teaching. These results indicate the need to improve the quality of teaching by introducing robots into teacher training practices.

3. The influence of Robotics on interest in Science, Engineering, Engineering and mathematics. The introduction of robotics in physics classes increased students ' interest in Science, Engineering, Engineering and mathematics. Interest in careers in science increased from 3.28 to 3.74 ($p < 0.05$), indicating that students ' interest in careers in Science, Engineering, Engineering, and mathematics increased. This shows that integrating robotics into physics classes not only helps students develop their scientific and engineering skills but also changes their perspective on future career opportunities. With the help of robots in the classroom, students were able to work creatively in solving specific technical problems, which increased their motivation to participate in scientific research and projects. According to the final survey, 70% of students said they had an increased interest in science, technology, engineering and mathematics, and 50% wanted to work in physics and engineering.

4. Future views and suggestions. This study showed that integrating robots into physics lessons is an effective way to increase students ' interest in the subject. However, since research is limited to 8th-grade students, future research may expand the field of assessing the effectiveness of using the robot in classrooms and other educational institutions. In addition, the study of the integration of robotics with other sciences, technologies, engineering and mathematics helps students improve their general scientific knowledge and form the choice of a future profession. It is also recommended to support the effective use of robots in the classroom and organize additional training for teachers, as well as develop specific teaching guidelines. This will allow teachers to apply new techniques more effectively and will help increase students ' interest in the topic.

Conclusion

The research results show that the introduction of robots in physics lessons has significantly increased students' interest in the natural sciences and changed their attitude toward future careers. Teachers and educational institutions should comprehensively use innovative methods, including the use of

robotics, to increase student participation in science, technology, engineering and mathematics. This method helps students to develop their research skills, strengthen their creative abilities and increase their confidence in the professional future.

The main conclusion

1. Interest in physics. The introduction of robots in physics lessons helps to increase students' interest in this subject. According to the research results, interest in physics increased from 3.01 to 3.85. This change proves that robotics allows students to combine science with real problems.

2. Interested in natural sciences, technology, engineering and mathematics. The introduction of robotics into physics courses has led to an increased interest in the fields of natural sciences, technology, engineering and mathematics. The interest of students in scientific disciplines increased from 3.28 to 3.74, which shows that robotics strongly attracts students of engineering and natural sciences.

3. Teacher's teaching method. Changes in the teaching methods of teachers have led to an increased interest of students in this subject. The students pointed out that the use of robots in the classroom helps to deepen knowledge and develop creative abilities. This underlines the importance of modern teacher training methods.

4. Career guidance. The study shows that students are more interested in natural and technical sciences, engineering sciences and mathematics. The use of robots has expanded the horizons of the future careers of students. 50% of students noted the impact of robots on career guidance and said they wanted to work in the fields of physics and engineering.

Practical significance

The results of this research confirm that the integration of robots into physics courses is an effective way to develop knowledge of science, technology, engineering and mathematics. This method helps students to develop research skills, improve technical thinking, and increase confidence in future career choices. With the help of robots, teachers can provide students with a practical and interesting way to understand complex scientific concepts, which will make the fields of science, technology, engineering and mathematics more accessible and attractive.

Further research recommendations

1. Extensive integration of robots. It is very important to improve the methods of introducing robots into physics lessons and introduce them into the school curriculum. This allows students to gain practical knowledge and expand their understanding of scientific concepts, making physics more attractive and accessible.

2. Additional research. In order to more deeply study the influence of robots on the learning process, it is necessary to conduct long-term research. In addition, studying the integration of robotics with other natural, technological, engineering and mathematical sciences can help students improve their general scientific knowledge and raise awareness of their career choice.

To sum up, it can be said that the integration of robotics into physics lessons has significantly increased students' interest in the natural sciences and broadened their perspective on their professional future. This approach plays an important role in the development of scientific, technological, engineering and mathematical education, and contributes to the improvement of the education system. By developing creative and practical skills, robotics helps students combine theory with real-world applications and prepares them for future challenges in the scientific and technical fields.

Acknowledgements. The authors would like to thank anonymous reviewers and the conference editors for their comments on earlier versions to improve this study's quality.

Cite this article: Dauleshyar, B., Alishev, A. (2025). Studying the Perspectives and Career Guidance of 8th-grade Students on Science, Physics, and Future Professions through the Integration of Robotics into Physics Education. Materials of International Scientific-Practical Internet Conference "Challenges of Science". Issue VIII, pp. 24-33. https://doi.org/10.31643/2025.03

References

Christidou, V. (2011). Interest, Attitudes and Images Related to Science: Combining Students' Voices with the Voices of School Science, Teachers, and Popular Science. *International Journal of Science Education*, 33(13), 1847-1878.

Church, W., Ford, C., & Perova, N. (2009). The role of robotics in STEM integration. *Journal of Educational Technology*, 24(2), 45–52.

Dauletiyar, B., Abdulbakioglu, M., & Kassimov, F. (2023). Increasing students' interest in the subject of physics by integrating the science of robotics. *Q A Iasaýı atyndaǵy Halyqaralyq qazaq-túrik ýnıversıtetiniń habarlary (fızıka matematıka ınformatıka seriıasy)*, №4 (27), 51, p. 42-52. https://doi.org/10.47526/2023-4/2524-0080.04

Goldin, G., & Shteingold, N. (2001). Systems of representations and the development of mathematical concepts. In *The Roles of Representation in School Mathematics, 2001 Yearbook* (pp. 1–23). National Council of Teachers of Mathematics.

Japashov, N., Naushabekov, Z., Ongarbayev, S., Postiglione, A., & Balta, N. (2022). STEM Career Interest of Kazakhstani Middle and High School Students. *Educ. Sci.*, 12, 397. https://doi.org/10.3390/educsci12060397

Kassymova, G. K. (2019). Duisenbayeva Sh. S., Adilbayeva UB, Khalenova AR, Kosherbayeva AN, Triyono MB, Sangilbayev OS Cognitive Competence Based on the E-Learning. *International Journal of Advanced Science and Technology*, 28(18), 167-177.

Ministry of Education and Science of the Republic of Kazakhstan. (2022). *STEM Education Development Report 2016–2022*. Nur-Sultan: Ministry of Education and Science.

Mutarah, R., Azman, M.N.A., Kassymova, G.K., Kenzhaliyev, B.K. (2024). Android-Based Interactive Application Development in the Subject of Design and Technology for the Topic of Manufacturing Technology. AIP Conf. Proc. 2750, 040065. https://doi.org/10.1063/5.014927222

Muti'ah, U. N., Retnawati, H., Senen, A., & Kassymova, G. K. (2021). Teaching Collaborations in Elementary Schools: Teachers' Understanding, Strategies, and Obstacles. Al Ibtida: *Jurnal Pendidikan Guru MI*, 8(1), 1. https://doi.org/10.24235/al.ibtida.snj.v8i1.7519

OECD (Organization for Economic Cooperation and Development). (2022). *Education at a Glance 2022: OECD Indicators*. Paris: OECD Publishing.

Rogers, C. B. (2009). Engineering education for the 21st century. *Journal of Engineering Education*, 98(3), 321–330.

Rzabayeva, D., Kassymova, G., Pratama, H. (2024). The Role of Gamification in Promoting Digital Literacy: Bridging the Gap between Fun and Learning. *Challenges of Science*. Issue VII, pp. 135-144. https://doi.org/10.31643/2024.20

Sheriyev M.N., Atymtayeva L.B., Beissembetov I.K., Kenzhaliyev B.K. (2016). Intelligence system for supporting human-computer interaction engineering processes. *Applied Mathematics and Information Sciences,* Volume 10, Issue 3, pp. 927-935. https://doi.org/10.18576/amis/100310

Talgatov, Y., Kassymova, G.K., Nurtanto, M. (2024). AI in the Classroom: A Boon or a Threat to Pedagogical Practices? *Challenges of Science*. Issue VII, pp. 128-134. https://doi.org/10.31643/2024.19

The Discriminant Validity and Reliability for Urdu Version of Test of Science–Related Attitudes (TOSRA). (2013). *International Journal of Humanities and Social Science*, 3(2), 29-39.

Issue VIII, 22 November 2025
e-ISSN 2707-9481 Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University, Almaty, Kazakhstan
ISBN978-601-323-547-9 https://doi.org/10.31643/2025.04

Zhansaya K. Markhmadova
Abai Kazakh National Pedagogical University
050010, Dostyk ave., 13, Almaty, Kazakhstan
ORCID ID: https://orcid.org/0009-0006-6138-9939
E-mail: jan_27_2001@mail.ru

Gulzhaina K. Kassymova
Abai Kazakh National Pedagogical University
050010, Dostyk ave., 13, Almaty, Kazakhstan
ORCID ID: https://orcid.org/0000-0001-7004-3864
E-mail:g.kassymova@abaiuniversity.edu.kz

Ali Mufti Hasyim
Universitas PGRI Yogyakarta
Jl. IKIP PGRI I Sonosewu No.117, Sonosewu, Ngestiharjo, Kec. Kasihan,
Kabupaten Bantul, Daerah Istimewa Yogyakarta 55182, Indonesia
E-mail: muyijiaren83@gmail.com

Developing Digital Competence Among Educational Psychologists: Pedagogical Measurements and Comparative Analysis

Abstract: Digital competence is an important need in modern education and psychology. In today's rapidly developing educational space, digital competence has become essential for both teachers and students. These competencies include several skills necessary for effective navigation and use of digital technologies in the learning environment. Digital competence includes not only the ability to work with technology but also the ability to critically understand information, collaborate, and use digital tools to solve problems. The ability of educational psychologists to effectively apply modern technologies will improve their professional qualifications and establish effective relationships with students. This article discusses pedagogical criteria and methods for developing the digital competence of educational psychologists. In addition, the article examines the use of digital tools in psychological practice, their effectiveness, and their place in modern education. To compare the levels of digital competence of educational psychologists in Kazakhstan and Finland, pedagogical measurements and methods that can be used to enhance digital competence and support students in this important area, an action plan for educational psychologists is proposed.

Keywords: digital competence, technology, educational psychologist, pedagogical criteria, educational platforms.

Introduction

The XXI century is a time full of changes in comparison with the previous centuries. The pace of change in the present moment is faster than in the past. In this regard, each time has its specifics, so it is not for nothing that this time is called the time of digital technology. This is because digital technologies are being introduced into all the actions necessary for human life, and thus our standard of living is being simplified. The digital environment is moving us from one social environment to another (Kamali, Alpat, & Bozkurt, 2024). Digital competence is the ability of an individual to use information and communication technologies (ICT) in an effective, creative and ethical way. It covers all aspects, from searching for the necessary information on the internet, analysing it and identifying reliable sources, using digital devices and programs, creating media content, organising communication and cooperation, and compliance with digital security and ethical standards. Digital competence plays an important role in modern society, as it is necessary for education, work, building social relationships, and personal and professional development. The level of digital skills directly affects a person's success in a modern information environment.

The emergence of digital information exchange is becoming increasingly important in modern educational conditions (Talgatov et al., 2024). A wide range of tools available to all stakeholders in the field of Education provides unlimited resources for the synthesis, analysis and processing of information

(Mutarah et al., 2024). On the other hand, the proliferation of the internet and digital sources creates a series of security-related problems. Open access to various media requires the creation of a rational and coordinated system for students on the internet. Accordingly, teachers should teach students to distinguish reliable sources from unreliable ones, critically evaluate information, and use it to solve problems and problems. A modern teacher must be an experienced user of digital tools and platforms, and know the use of electronic resources for educational purposes and their application in their practice. In this context, there is an urgent need for teachers to have appropriate digital competencies. Insufficient resource base and low level of digital literacy hinder the effective education of today's youth. Fallon (2020) provides teachers with a digital teacher competency system that demonstrates the key skills needed to thrive in a technology-driven environment. For educational psychologists, this structure is very important because it includes aspects that directly affect their learning experience and psychological support. Integrating technology into educational institutions can increase student engagement and improve therapeutic outcomes. The European System of Digital Competencies for Teachers (DigCompEdu) further emphasises the need to align teacher competencies with 21st-century challenges (Kaena & Redecker, 2019). This alignment is crucial for educational psychologists, as they are tasked with educating students not only academically, but also emotionally and socially in the digital world.

An important obstacle to achieving digital competence among educational psychologists is the insufficient integration of ICT training into primary teacher education (ITE). Gudmundsdottir and Hatlevik (2018) highlight the alarming gap in the professional digital competence of newly qualified teachers, which poses challenges for those involved in psychological education. Lack of confidence in using ICT tools limits their ability to meaningfully interact with students in a digital learning environment. The results of Instefjord and Munte (2016, 2017) show that teacher educators often lack the digital competencies needed to model effective practices for their students. This creates a cycle in which future educational psychologists are insufficiently prepared to teach and support students in a technology-rich context. In addition, the limited attention to digital tools in curricula undermines the willingness of educational psychologists to address the psychological aspects of learning in a digital environment. The implications of digital competence go far beyond technological skills. The study by Sanchez-Cruzado et al. (2021) highlights that educational psychologists should have the appropriate digital skills not only to convey content. This shift requires the development of a robust learning plan to enhance the digital competence of educational psychologists, enabling them to implement innovative educational models that meet the unique needs of their students. This shift requires the development of a robust learning plan to enhance the digital competence of pedagogy-psychologists, enabling them to implement innovative educational models that meet the unique needs of their students. There is a lack of digital competence, especially in content creation and collaboration, that seriously prevents educational psychologists from innovating in their teaching practice. The direct link between pre-ICT training and effective communication highlights the need for targeted professional development (Lazaro-Cantabrana et al., 2019).

One of the main approaches to the formation of digital competence is the integration of technologies into the educational process. This may include: the use of multimedia tools, the introduction of presentations, videos and interactive tasks into the educational process. Project activities: organisation of group projects in which students can use digital tools to work together and present results. The development of digital competence goes hand in hand with the development of other skills, and some aspects that have been identified as important for a university teacher in the 21st century are being developed by current educational needs. In particular, in the approach to work, special attention is paid to the development of creativity and innovation. Creative thinking is very important for the development of innovative and innovative teaching methods. Teachers who encourage creativity teach their students to think outside the box and find alternatives, which helps create a stimulating learning environment and develop the problem-solving skills necessary in life.

The main factor determining the work of a teacher of the XXI century is the ability to self-learn and self-expression. This skill allows teachers to adapt their experience to the changing needs of students, thereby improving the quality of education. The critical aspect ability to think critically, is especially important. In conditions of working with large amounts of data, especially taking into account digitalisation, the critical thinking of teachers determines the ability to analyse the information used in their work. The modern educational landscape is saturated with new technologies, pedagogical theories and various

approaches to teaching. Teachers must be able to critically evaluate this information, distinguish facts from pseudoscientific theories, and choose the best teaching methods for their students.

The digital competence of an educational psychologist plays an important role in the process of modern education and psychological services. It provides search, and evaluation of scientific articles, research and methodological materials using digital resources effectively, mastering modern technologies for organizing online classes and webinars, effective communication with students, parents and colleagues in a digital environment, preparation of psychological knowledge, training and information materials in digital format, protection of personal and student data, prevention of cyberbullying, includes compliance with copyright in the use of digital content and compliance with ethical standards in the provision of online psychological assistance. All this makes it possible to improve the quality of professional activities of a teacher-psychologist and provide effective support to students and their parents. It is very important for us as educational psychologists to understand these competencies and how they can be measured and developed in students. For pedagogical psychologists, this is very important because they need to know:

- Effective use of technologies for training: creating and conducting online courses, using distance learning platforms.
- Data assessment and analysis: the ability to work with various digital resources to collect and analyse information about students.
- Creating a safe digital environment: teach students safe behaviour on the internet and build their digital citizenship skills.

In modern society, digital technologies are developing rapidly, which also has a deep impact on the field of education and psychology. The digital competence of educational psychologists is an important component of the modern educational process. Digital competence is necessary for specialists working in the field of education, not only the ability to use information technologies, but also for effective information management, compliance with security measures and effective communication with students. Pedagogical psychologists play a key role in assessing and improving students' digital competence. Their experience in understanding cognitive development and learning processes allows them to develop effective assessment tools adapted to digital skills. Collaborating with teachers and educational psychologists will be able to develop activities and support systems that integrate technology into the curriculum, ensuring that students not only master digital tools better, but can also apply these skills critically and creatively. In the context of digitalisation of the educational sphereeduactional psychologists can use various tools. Including virtual consultations: conducting online sessions with students and their parents, which is especially important in the context of distance learning. Use of programs for psychodiagnostics: Many digital tools allow you to check and diagnose the condition of students. Modern technologies offer new approaches to teaching, including gamification, the introduction of game elements into the educational process, which can increase the motivation of students and improve the assimilation of the material. Adaptive educational platforms: These platforms allow you to adapt the learning process to the individual needs and pace of learning of each student.

The main part

Digital competence is the ability to effectively use information and communication technologies, work with digital data, move safely on the internet, gain knowledge and effectively apply educational methods using electronic means. The aspects that you need to know to use any technology are shown in Table 1.

Table 1. Aspects of digital competence for pedagogical psychologists

Search and evaluation of information	***Assessment of the quality, reliability and availability of information on the internet***
Applicationoftechnologicaltools	Implementation of psychological tests, questionnaires and other methods in digital format
Cybersecurity	Protection of psychological information and compliance with security

	measures on the internet
Onlineplatforms	Effective use of platforms to build relationships with students in the virtual space

Aspects of digital competence:

1. Information competence is the acquisition by a person of the skills of searching, evaluating, analysing, interpreting, using and communicating information. In the course of these processes, the person must take into account not only the correspondence of information to reality, but also its ethical, legal and cultural aspects. Information competence consists of several important components:

- Information search: find the necessary information in databases, libraries, the internet and other resources.
- Assessment of Information: Assessment of the reliability, relevance and quality of information.
- Information processing: analyse, synthesise information and use it according to the intended purpose.
- Disseminate information: share information with other people, communicate and communicate it correctly.

2. Technological literacy is the ability of a person to effectively use modern technologies (computers, mobile devices, software and internet resources). This literacy also includes the skills necessary to process, store, analyse and disseminate information. Components of technological literacy:

- Use of digital devices: be able to use devices such as computers, tablets, and smartphones.
- Mastering software: effective use of Microsoft Office, Google Workspace, graphics programs and other programs.
- Use of internet resources: skills in searching, evaluating information and working on network platforms.
- Cybersecurity: online security measures, data protection and secure storage of personal information.

The importance of technological literacy:

- Education: In the modern educational process, technological literacy increases students' academic success. They can make the most of online resources.
- Professional development: Technological literacy increases competitiveness in the labour market. Employers are looking for professionals with digital skills.
- Application in everyday life: Technologies play an important role in everyday life, in areas such as financial management, communication, entertainment, and health.

3. Communication competence is the ability of a person to establish effective communication, exchange information, form understanding and develop social ties. This skill is realised not only in words but also through body language, intonation of the voice, emotions and context. Components of communication competence:

- Verbal communication: listening, speaking, asking questions and answering skills.
- Written communication: writing emails, messages, and reports.
- Body language: the role of body movements and facial expressions in communication.
- Emotional intelligence: understand the emotions of others and act accordingly.
- Cross-cultural communication: communicate effectively with different cultures.

Importance of communication competence:

- Education: helps students and students to better assimilate information, and develop questioning and analysis skills;

- Professional development: maintain effective communication in the workplace and achieve success in teamwork;

- Social connections: establish good connections in personal life, friendly relationships and professional environments.

4. Critical Thinking is the ability to analyse, evaluate and logically reason information. During this process, a person critically examines his opinions, views and beliefs and makes decisions based on facts and evidence. Components of critical thinking:

- Evaluation of information: checking the reliability, relevance and accuracy of sources.
- Logical reasoning: draw conclusions based on arguments and facts.
- Problem-solving: identify complex problems and search for effective ways to solve them.
- Creative thinking: finding new ideas and solutions, and applying innovative approaches.

The importance of critical thinking:

- Education allows students to understand information more deeply and view it critically;

- Professional development: helps you make the right decisions in the workplace and develop effective strategies;

- Social responsibility: develop the ability to be critical of public issues and news, and to argue one's own opinion.

5. Cybersecurity is a set of measures and strategies aimed at protecting computer systems, networks, programs, and data. Its main purpose is to protect information from unauthorised access, attacks, violations and various cyber threats. Components of cybersecurity:

- Information security: data protection, including encryption, backup and maintaining data integrity.
- Network security: ensure the security of information in the network, and protect against threats in domestic and international networks.
- Software protection: protection against viruses and malware, software crashes.
- Internet security: security issues on websites and online services, phishing attacks and cyberbullying.
- Body Security: restricting physical access, that is, ensuring the physical security of Information Systems.

Importance of cybersecurity:

- Data protection: protection of personal and commercial information, and financial data.
- State security: cyber protection is very important for national security because cyber attacks can pose a threat to the country's infrastructure, economy and citizens.
- Legal liability: Organisations and individuals may be held liable in the event of a violation of cybersecurity norms and laws.

Pedagogical measurements are criteria and indicators used to evaluate, analyze and develop the educational process. They allow you to determine the effectiveness of training, the quality of education, student achievements, the state of the learning environment and other aspects. Aspects such as learning outcomes, teaching methods, organisation of the educational process, student participation, psychological state and assessment system are included in the pedagogical measurements. Pedagogical measurements are an important tool for improving the quality of education, improving the learning process and responding to the needs of students. The evaluation framework, i.e. several established frameworks, provides a basis for evaluating quantitative competencies. The standards of the European Digital Competence Framework (DigComp) and the International Society for Technology in Education (ISTE) describe the basic skills necessary for the effective use of digital technologies. These frameworks serve as a guide for educational psychologists to assess students' abilities in areas such as information literacy, communication and problem-solving through technology. Pedagogical measurements are closely related to the educational psychologist as they determine the effectiveness of the educational process, the development of students and the mechanisms of psychological support. Pedagogical measurements include aspects such as, the quality of teaching methods, the transmission of knowledge, the motivation and interest of students and learning outcomes. The educational psychologist plays an important role in assessing these criteria. It supports the learning process, taking into account the psychological characteristics, personal needs and difficulties of students. The educational psychologist helps students develop emotional and social development, learning barriers, stress management, as well as motivation and self-regulation. In addition, the teacher-psychologist will establish close cooperation with teachers, parents and the school administration to improve pedagogical strategies, improve the learning environment and monitor the psycho-emotional state of students. Thus, pedagogical measurements and

the activity of an educational psychologist contribute to improving the quality of the education system and the integrated development of students.

Digital competence, pedagogical measurements and communication of an educational psychologist play an important role in improving the effectiveness of the educational process. Digital competence allows an educational psychologist to effectively work with students using modern information and communication technologies, provide psychological support and prepare educational materials in digital format. It helps to assess the learning outcomes, motivation and emotional state of students through pedagogical measurements. The educational psychologist implements pedagogical measurements, taking into account the needs of students, using digital resources. For example, it assesses the participation, psychological state, and motivation of students in the online learning process and also offers effective learning strategies. Digital competence, pedagogical measurements and communication of an educational psychologist play an important role in improving the quality and efficiency of the educational process. Digital competence allows the educational psychologist to work effectively with students using modern information and communication technologies. This competence helps to prepare educational materials in digital format, conduct online classes and webinars, as well as organise the educational process on interactive platforms, taking into account the psychological needs of students. Mastering digital technologies allows the educational psychologist to improve the ways of increasing students ' interest, increasing learning motivation and providing psychological support.

When comparing the levels of digital competence of educational psychologists of Kazakhstan and Finland, it is necessary to take into account several important aspects: the structure of the education system, the level of implementation of digital technologies, training methods of specialists and their professional training. In recent years, Kazakhstan has been carrying out several reforms aimed at digitalisation in the field of Education. One of the main goals of digital competence development programs in the country is to improve the quality of education through the introduction of new technologies in schools and universities. The use of digital platforms and resources is actively developing in Kazakhstan. For example, "Bilim Land", "Kundelik.kz", "Mektep.kz" learning platforms such as allow students and teachers to gain digital knowledge. Educational psychologists may face some difficulties in using digital tools, since the level of professional training of specialists in this area is different. Due to the use of new technologies and digital tools, training courses are being organised more and more often, but they are still not uniform and do not cover all regions. In Kazakhstan, special courses and online training programs are being developed to improve the digital competencies of educational psychologists. However, there is an unequal distribution of needs and resources among these specialists.

The Finnish education system is known worldwide, and it is the leader in the direction of digital education. Educational psychologists of this country have a high level of knowledge of digital technologies and widely use them in the educational process. In Finland, digital tools and platforms are increasingly used. For example, there are educational systems among students and teachers that are implemented through electronic textbooks and learning resources, online platforms. It can be said that the digital competence of Finnish educational psychologists is at a high level. The training system of educational psychologist specialists in this country is coordinated with digital means and is based on modern educational technologies. In addition, the inclusion of digital skills in curricula occupies an important place in the Finnish education system. In this country, affordable training and advanced training courses are always organised so that teachers and psychologists can improve their professional skills. These courses are not limited to theoretical knowledge, but are aimed at developing practical application skills. Table 2 carried out a comparative analysis of the extent to which educational psychologists in Kazakhstan and Finland can use digital technology, and these indicators are taken from digital sources.

Table 2. Comparative analysis of the digital education system of Kazakhstan and Finland

Indications	***Kazakhstan***	***Finland***
Digital education system	Emerging systems and platforms	Highly developed, widespread systems
Training of educational psychologists	Uneven, low level in some regions	Digital competence at a high level, continuous improvement of professional

		training
Using digital tools	Mostly, mainly platforms for students	Special tools and techniques for teachers and psychologists
Digital skills enhancement programs	Training and courses are often organised, but do not cover all regions	Continuing education and advanced training courses are common
Level of digital competence	At the average level, in need of improvement	At the highest level, meeting international standards

There are significant differences between the digital competence of educational psychologists of Kazakhstan and Finland. In Finland, digital competence is highly developed, and the education system of this country is recognised at the world level. Although digital competence is also developing in Kazakhstan, there are still several issues related to the professional development of specialists and the effective use of digital tools. Kazakhstan needs additional resources and programs to improve the digital competencies of teachers and psychologists, taking into account the experience of Finland. To develop the digital education system in Kazakhstan, several state programs and reforms have been implemented in recent years. There are several official statistics aimed at increasing the digital competence of Kazakhstan in the field of Education:

- According to the results of 2023, 98% of educational organisations are provided with computers and the internet.
- The activity of the National Testing Centre and digital learning platforms has increased, and more than 4.5 million students and students have used online learning platforms.
- E-learning platforms: Bilimland, introduced in 2020 Mektep.kz ", the number of participants in online learning through platforms such as Bilimland is increasing every year.
- Kazakhstan invested 5 billion tenge in the digital education system in 2022.

In Kazakhstan, more than 10,000 educational psychologists annually take special advanced training courses to train specialists in the field of pedagogy and psychology, but not all participants in this training fully master digital skills. In local regions (especially in rural areas), the number of educational psychologists who have mastered digital educational tools is quite low.

The Finnish education system is highly developed in terms of the use of digital tools. The statistical data are as follows:

- Internet access in all schools in Finland is at 100%. At the end of 2022, all schools and universities will be fully covered by digital education tools.
- Digital learning platforms and mobile educational applications are very common. 80% of students learn through digital tools, and 95% of teachers use these tools in their daily work.
- In Finland, the level of use of online learning platforms for schoolchildren and students is very high, with 95% of high school students using various digital education programs.
- In 2023, more than 20,000 educational psychologists took updated courses in digital education and psychology.
- In Finland, the indicator of the use of" digital counselling "systems in the services of" pedagogical and psychological counselling" increased from 40% to 60%.

According to international OECD research, the digital competence of Finnish educational psychologists is at a high level. In the PISA (Program for International Student Assessment) study, the digital competence of Finnish students was rated as the best in the world level and 92% of teachers use digital tools effectively. According to the 2021 report of the OECD survey of the situation in Kazakhstan, it was found that only 62% of teachers in Kazakhstan can effectively use digital tools. This figure is below the world level and still needs improvement. In comparison with the digital competencies of educational psychologists of Kazakhstan and Finland, one can see the development of the Finnish digital education system and the high level of digital skills of educational psychologists. Even though some reforms and programs to improve digital competence are being implemented in Kazakhstan, it is still at a developing

level. Kazakhstan needs to expand and systematically implement digital competence programs, taking into account the experience of Finland.

Pedagogical measurements are criteria and indicators for assessing various aspects of the educational process (Setiawan et al., 2024). Among them are learning outcomes, the effectiveness of teaching methods, student participation, psychological state and assessment system. The educational psychologist, using these criteria, assesses the learning progress, emotional state and social integration of students. This assessment allows us to improve pedagogical strategies, respond to the individual needs of students and improve the overall quality of the educational process. The role of an educational psychologist is integrative in the education system. It effectively uses pedagogical criteria, implementing programs aimed at developing the psycho-emotional state of students, stress management skills, and communication skills. In addition, it maintains close cooperation with teachers, parents and school administration, thus helping to improve the conditions of the learning environment and meet the psychological needs of students. Thus, digital competence, pedagogical measurements and the activities of an educational psychologist are closely interconnected, and they work together to improve the educational process, ensure the development and well-being of students. Digital competence will improve the quality of professional activity of an educational psychologist and contribute to the formation of an integrated model of the educational process. To effectively assess digital competence, teacher psychologists can use various tools and techniques. Rubrics: The creation of detailed rubrics with specific criteria for evaluating digital projects helps to provide clear expectations and consistent assessments. Questionnaires and tests, that is, self-assessment tools, allow students to assess their level of comfort when using technology and determine the directions of growth. Performance-based assessments, including tasks that require students to demonstrate their ability to use digital tools in real conditions, allow them to evaluate their competencies in practice.

Materials and methods

The plan for the use of digital tools in 5 areas of the educational psychologist, based on Table 3, is aimed at the effective implementation of the professional activities of the psychologist. These areas include: diagnosis, psychological support, training, research, and advocacy.

Table 3. Digital tools

Online platforms	Google Classroom, Microsoft Teams, Zoom
Psychological tests and questionnaires	Socrative, SurveyMonkey, Google Forms
Data analysis tools	Excel, SPSS, R
Content creation tools	Canva, Prezi, PowerPoint
Communication tools	WhatsApp, Telegram, Slack
Electronic libraries and resources	ResearchGate, Google Scholar, PubMed
Meditation and relaxation apps	Calm, Headspace
Educational games and interactive platforms	Kahoot!, Quizlet, ClassDojo

In the first part of the plan, the psychologist will be able to use digital questionnaires and tests in the field of diagnostics. Through platforms such as Google Forms or Socratic, it creates questionnaires that assess the psychological state of students. The results are statistically processed using Excel or SPSS programs to determine the needs of students. The second direction is psychological support. The psychologist teaches students stress management techniques using meditation and relaxation apps such as Calm or Headspace organises group meetings to provide emotional support using Zoom or Microsoft Teams platforms to conduct online sessions. The third direction is training. The psychologist develops interactive educational materials through Canva or PowerPoint, where he organises training and webinars to teach psychological knowledge and skills. Kahoot! or using Quizlet platforms, it conducts game-type tests for students to test their knowledge. The fourth direction is research. The psychologist collects scientific articles from resources such as ResearchGate and Google Scholar to conduct research and analyses the

results through questionnaires and tests on psychological topics. The fifth direction is information and propaganda work. The psychologist publishes information materials on social networks and the school website, posts about psychological consultations and trainings, and creates content aimed at improving psychological literacy among parents and students. He also conducts webinars and online seminars and provides students and parents with information about psychological services. Thus, through the effective use of digital tools, the educational psychologist will be able to improve their work in different areas and provide high-quality psychological support to students and their parents.

In addition, there are different methods of pedagogical measurements. The method of pedagogical measurements is an important tool for the effective assessment and development of the educational process. This method allows you to improve the work of an educational psychologist and evaluate the psychological and educational achievements of students.

The method of pedagogical measurements has several components:

1. Assessment of learning outcomes: the use of formative and summative assessment methods to determine the knowledge, skills and competencies of students. This includes methods such as tests, control work, portfolio and mutual assessment.

2. Psychological diagnostics: the use of standardised tests and questionnaires to assess the emotional and psychological state of students, the level of motivation, and social skills. For example, tools that determine stress levels, self-esteem or social integration.

3. Receiving feedback: improving the educational process by receiving feedback from students and parents, and teachers. To do this, organise surveys, interviews or focus groups.

4. Multifactorial analysis: to conduct a comprehensive analysis, taking into account various factors (teaching methods, teaching materials, students ' interests) to assess the effectiveness of the educational process.

5. Monitoring and evaluation: constant monitoring of the educational process, systematic compilation and analysis of results. Development of special indicators and criteria for monitoring the dynamics of students ' development.

6. Strategic Planning: Development of strategic plans for improving the educational process based on pedagogical criteria. Review of training programs, psychological support measures, and teaching methods.

This method should be used in the professional activities of an educational psychologist to improve the quality of the educational process, improve the psycho-emotional state of students and eliminate barriers to learning. The effective use of the method of pedagogical measurements contributes to improving the overall quality of the education system. Pedagogical methods are a system of approaches and approaches used by teachers and pedagogical psychologists in the process of teaching and upbringing. They aim to develop students ' knowledge, skills, values and social skills. The main types of pedagogical methods are the following: verbal methods, where information is provided through lectures, conversations, explanations and discussions; practical methods, which allow students to practice and develop skills, such as practical activities, laboratory experiments and games; visual methods, where information is visualized through images, schemes, graphs and video content; interactive methods, establishing active communication between students, organizing group work, role-playing games and discussions; game methods, allowing interesting and easy perception of knowledge through the introduction of game elements; research methods, conducting project work and research projects to develop students ' research skills; control methods, monitoring and evaluation of the educational process of students, testing and Pedagogical methods are selected depending on the goals of learning, age characteristics of students, interests and learning styles. Their effectiveness plays an important role in improving the quality of the educational process, motivation and participation of students.

Pedagogical methods: blended learning combines traditional classroom learning with online learning capabilities, providing a flexible environment for Skill Development. This approach allows students to use digital tools, taking advantage of personal communication with teachers and peers. Blended learning combines traditional and online methods, opening up possibilities of which:

- Develop independence: Students learn to plan their time and choose the most appropriate sources of information for themselves.
- Creating a dynamic educational environment: using different learning formats helps to attract students ' attention and makes the process more interactive.

Project-based learning encourages students to participate in project-based learning that integrates technology, promotes the involvement and practical application of digital skills. Projects that require research, collaboration, and presentation using digital platforms help students develop competencies in critical contexts. Project activities can include: the creation of digital projects, that is, the development of websites, videos or blogs on topics related to psychology and pedagogy. Collaboration with other disciplines: Projects in which students from different specialities work together help develop interdisciplinary skills and broaden horizons.

Research Discussions

Collaborative learning technology can encourage collaborative learning when students work together on tasks using digital tools (Begimbetova et al., 2024). This method not only increases the level of digital competence, but also develops important skills such as communication, teamwork and adaptation (Kassymova et al., 2024). Although there are many opportunities to increase digital competence, there are several issues that need to be addressed:

- Equality and accessibility: The digital gap remains an important issue, as not all students have equal access to technology and the internet. Teacher psychologists should advocate for providing equal resources so that all students can develop their digital skills.
- Teacher training: Continuous professional development is essential for teachers to be aware of new technologies and pedagogical practices. Pedagogical psychologists can help with this by providing training and resources.
- Student engagement: It can be difficult to motivate students to improve their digital skills. It's a critical factor in academic success and can significantly influence motivation, learning outcomes, and retention.

Digital competence educational programs that are to increase the digital literacy of educational psychologists, it is necessary to develop special educational programs. Such programs should include: the use of basic digital tools: Microsoft Office, Google Suite, Zoom, Skype, etc, methods of psychological testing: online tests, questionnaires, collection and processing of information. Working on a digital platform: conducting classes in virtual classrooms, building relationships with students. Training and seminars play an important role in improving the digital literacy of educational psychologists. They may include: practical exercises, practical classes on the use of digital tools. Innovations and innovations: introduction to new digital technologies, opportunities for their application in psychological practice. Online courses and webinars are an effective way to expand the knowledge of educational psychologists. They are: the ability to study remotely, removing time and place restrictions. Access to many resources: get experience from different professionals. The exchange of experience between experienced psychologists and young professionals is an effective way to develop digital literacy. Partnership programs: mentoring: experienced psychologists lead young professionals. Teamwork: exchange of experience through Team Projects and tasks.

Digital competence is not limited to technical skills, but should also be aimed at the development of emotional intelligence by educational psychologists. Emotional intelligence is the ability to recognise, understand and manage one's own emotions, as well as feel and interact with other people's emotions. Stress management is important in the process of using digital tools. Educational psychologists need to master the techniques of relieving stress and overcoming negative emotions when working with digital technologies. Digital literacy also includes communication skills. Educational psychologists should improve their communication skills to convey information in a clear, accessible and reliable way. Several strategies can be implemented to effectively develop students' digital competencies. Integration into the curriculum, that is, integrating digital competencies into different disciplines instead of treating them as separate modules, ensures that students understand the importance of these skills in their academic and future professional lives. Involving families in the digital learning process can contribute to developing students ' skills at home. Educational psychologists can organise workshops to help parents understand and participate in their children's digital education. Creating reliable feedback systems will allow students to receive constructive recommendations for the development of their digital skills. Regular checks and certificates help students monitor their progress and set achievable goals. Given the rapid development of technology, future educational psychologists should be ready to constantly update their knowledge and skills. This is flexibility and adaptability: the ability to quickly master new technologies and approaches at

work. Continuous learning: assumes participation in courses and seminars to maintain the relevance of their knowledge.

Conclusion

The development of digital competence of educational psychologists is an important factor in improving the effectiveness of the education system. These specialists need to be able to effectively use digital tools, maintain information security and establish professional contacts with students. The organisation of educational programs, trainings and seminars, online courses and webinars to improve digital literacy, the development of partnerships and coaching are important steps towards improving the professional qualifications of educational psychologists. In the future, digital literacy will help educational psychologists achieve new opportunities and achievements in their professional activities, which, in turn, will allow them to provide high-quality psychological support to students. The development of digital competence is an important aspect of modern education. The formation of digital competence in future educational psychologists is an important task from the point of view of modern educational requirements. The use of different techniques and approaches, such as integrating technology into the learning process, learning through experience, and developing critical thinking, can help train professionals who can work effectively in the digital world. The successful implementation of these initiatives requires active cooperation of all participants in the educational process, including students, teachers and the administration of educational institutions. In the future, it is necessary to constantly study and adapt pedagogical experience to keep up with technological progress and the ever-changing educational landscape. At the same time, the formation of digital competence of educational psychologists is a complex but necessary process that requires an integrated approach. It is important not only to teach students digital skills, but also to develop their critical thinking, ethical standards and readiness for sustainable learning. In this way, they will be able to successfully overcome the challenges that modern educational spaces offer.

CRediT author statement: **Kassymova G.K.**: Conceptualisation, Supervision, Methodology, Validation. **Markhmadova Zh.K.**: Data curation, Software, Writing draft preparation. **Hasyim A.M.**: Visualisation, Proof-reading, Editing.

Cite this article: Markhmadova, Zh.K., Kassymova, G.K., Hasyim, A.M. (2025). Developing Digital Competence Among Educational Psychologists: Pedagogical Measurements and Comparative Analysis. Materials of International Scientific-Practical Internet Conference "Challenges of Science". Issue VIII, pp. 34-45. https://doi.org/10.31643/2025.04

References

Begimbetova, G.A., Retnawati, H., Ndayizeye, O., Flindt, N., Kassymova, G.K. (2024). A Bibliometric Review on Exploring Digital Literacy Assessment Dynamics in Education. Materials of International Scientific-Practical Internet Conference "Challenges of Science". Issue VII, pp. 26-37. https://doi.org/10.31643/2024.04

Sánchez-Cruzado, C., Santiago Campión, R., & Sánchez-Compaña, M. T. (2021). Teacher Digital Literacy: The Indisputable Challenge after COVID-19. S*ustainability*, 13(4), 1858. https://doi.org/10.3390/su13041858

European Commission (2020). Digital Education Action Plan 2021-2027: Resetting education for the digital age. European Commission Strategic Report on Education and Digitalisation. Retrieved on 18 March 2025 from: [ec.europa.eu] (https://ec.europa.eu/education/education-in-the-eu/digital-education-action-plan_en)

European Commission. (2017). Digital Competence Framework for Citizens. Retrieved on 01 May 2025 from [ec.europa.eu] (https://ec.europa.eu/jrc/en/digcomp/digital-competence-framework)

Fallon, H. (2020). From digital literacy to digital competence: the digital teacher competence (TDC) framework. *Research and development of educational technologies*, 68, 2449-2472. http://doi.org/10.1007/s11423-020-09767-4

Finland Ministry of Education and Culture (2022). Digital Education and Teacher Training in Finland. Ministry of Education and Culture of Finland. Retrieved on 11 May 2025 from: [minedu.fi/en] (https://minedu.fi/en)

Finnish National Agency for Education (2021). Digital Competence and Teacher Training in Finland. Finnish National Agency for Education. Retrieved on 09 May 2025 from: [oph.fi] (https://www.oph.fi/)

Gudmundsdottir, G., Hatlevik, O. (2018). Professional digital competence of new qualified teachers: impact on Teacher Education. *European Journal of Teacher Education*, 41, 214-231. http://doi.org/10.1080/02619768.2017.1416085

Instefjord, E., & Munte, E. (2016). Pre-service teacher training for technology integration: an analysis of the emphasis on digital competence in teacher education programs. *European Journal of Teacher Education*, 39, 77-93. http://doi.org/10.1080/02619768.2015.1100602

Instefjord, E., & Munte, E. (2017). Digitally competent teacher training: a study of the integration of professional digital competence in teacher education. *Teaching and Teacher Education*, 67, 37-45. http://doi.org/10.1016/J.TATE.2017.05.016

International Society for Technology in Education (ISTE). (2020). ISTE Standards for Students. Retrieved on 02 April 2025 from [iste.org] (https://www.iste.org/standards/for-students)

José Luis Lázaro Cantabrana, Mireia Usart Rodríguez & Mercè Gisbert Cervera (2019). Assessment of digital teacher competence: developing a tool for measuring teacher knowledge before Service. *Journal of new approaches in educational research*. Volume 8, pp. 73–78. http://doi.org/10.7821/NAER.2019.1.370

Kaena, F., Redecker, Ch. (2019). Aligning the teacher Competence Framework with the tasks of the 21st century: a rationale for the European Digital Competence Framework for educators (Digcompedu). *European Journal of Education*. http://doi.org/10.1111/EJED.12345

Kamali, J., Alpat, M.F. & Bozkurt, A. (2024). AI ethics as a complex and multifaceted challenge: decoding educators' AI ethics alignment through the lens of activity theory. *Int J Educ Technol High Educ*., 21, 62. https://doi.org/10.1186/s41239-024-00496-9

Kassymova, G.K., Nursa'ban, M., Suleimen, S.B., Rifqiyah, F., Sultan, J. (2024). Evaluating Student Self-Management, Interpersonal Skills, and Academic Behaviors. Materials of International Scientific-Practical Internet Conference "Challenges of Science". Issue VII, pp. 38-45. https://doi.org/10.31643/2024.05

Mutarah, R., Azman, M. N. A., Kassymova, G. K., Kenzhaliyev, B. K. (2024). Android-Based Interactive Application Development in the Subject of Design and Technology for the Topic of Manufacturing Technology. AIP Conf. Proc. 2750, 040065.

OECD (2021). "PISA 2021: Programme for International Student Assessment – Digital Competencies." Organisation for Economic Co-operation and Development (OECD). Retrieved on 15 May 2025 from [oecd.org/pisa] (https://www.oecd.org/pisa/)

OECD. (2019). Preparing Our Youth for an Inclusive and Sustainable World: The OECD PISA Global Competence Framework. Retrieved on 05 May 2025 from [oecd.org] (https://www.oecd.org/education/Global-Competence-Framework.pdf)

Setiawan, A., Kassymova, G. K., Mbazumutima, V., & Agustyani, A. D. (2024). Differential Item Functioning of the region-based national examination equipment. *REID (Research and Evaluation in Education),* 10(1). https://doi.org/10.21831/reid.v10i1.73270

Talgatov, Y., Kassymova, G.K., Nurtanto, M. (2024). AI in the Classroom: A Boon or a Threat to Pedagogical Practices? Materials of International Scientific-Practical Internet Conference "Challenges of Science". Issue VII, pp. 128-134. https://doi.org/10.31643/2024.19

Issue VIII, 22 November 2025
e-ISSN 2707-9481 Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University, Almaty, Kazakhstan
ISBN978-601-323-547-9 https://doi.org/10.31643/2025.05

Natalia V. Yakovleva
D. Banzarov Buryat State University, Department of Sports Disciplines, Ulan-Ude, Republic of Buryatia, Russian Federation; e-mail: yakovleva088@yandex.ru; https://orcid.org/0009-0009-5516-4225

Soni Nopembri
Faculty of Sport and Health Sciences Universitas Negeri Yogyakarta, Indonesia
email: soni_nopembri@uny.ac.id
https://orcid.org/0000-0002-9094-6451

Rita S. Lyzhenkova
East Siberian Branch of the Russian State University of Justice, Department of Humanities and Socio-Economic Disciplines, Irkutsk Region, Irkutsk, Russian Federation; e-mail: tina051@yandex.ru
https://orcid.org/0000-0003-3993-2019

Mariam R. Arpentieva
Financial University under the Government of the Russian Federation, Faculty of Social Sciences and Mass Communications, Institute of Humanitarian Technologies and Social Engineering, Faculty "High School of Management", Institute of Management Research and Consulting, Moscow, Russian Federation
e-mail: mariam_rav@mail.ru
https://orcid.org/0000-0003-3249-4941

Gulzhaina K. Kassymova
Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan
email: g.kassymova@satbayev.university
ORCID ID: https://orcid.org/0000-0001-7004-3864

Motivation for Independent Physical Education Classes in Students of Modern Universities

Abstract: The relevance of the article lies in the need to develop an integrative approach and a model of motivation for the independence of physical education classes among students. The purpose of this article is to conduct a systematic analysis of the motivation for independent physical education classes among students from various professional training areas, and to develop and test recommendations and programs for promoting independent physical education classes among students. The authors formulated an integrative model of motivation for the independence of physical education classes among students and showed the types of motivation. The essence of motivation for independent physical education classes among students is revealed, which consists in the peculiarities of formation, functioning, development and destruction of needs and desires of students about physical education classes and, more broadly, health preservation. Approaches to the study of motivation for independent classes, motives are classified, recommendations are offered, and the most productive directions of research on the problem are highlighted. It is proven that modern students of different professional groups do not have a harmonious and sufficiently multi-level and multi-faceted motivation for independent physical education classes.

Keywords: motivation for independent classes, physical education, types of motives for independent physical education classes, competencies, needs of students, desires of students.

Introduction

The problems of motivating modern schoolchildren and students to engage in independent physical education are among the most pressing in the context of the problems of prevention and correction of health disorders and health preservation. They are especially pressing in student age - the age associated with active self-education, the potential presence of necessary competencies in the field of health preservation, as well as numerous health disorders accumulated by many of them by this age. In the context of intensive transformations of general and professional education, the formation and development of a culture of health preservation and physical education as its most important component is

one of the most important tasks of the education system. Physical education is an important component of the professional training of students, which is formed and developed without fail as part of the general training program for any specialist throughout the entire period of study and education at the university. The importance of physical training is associated with the formation and development of physical culture in a person as a component of their general life (social, personal) and professional competencies. Despite the obviousness of the problem under consideration, the presence of a sufficiently large number of research and applied works in the studied area (for example, the studies of V.V. Sevast'yanova, E.A. Stebletsov and V.I. Voropaev, V.A. Koloshkina and N.A. Dvarak, I.S. Galich, V.D. Ivanova, I.V. Zherebtsova, P.A. Istmatov, O.V. Ivakhina, E.Yu. Kozenko, N.V. Savkina, I.T. Khairullin, etc.), the problem of motivating students' independent physical education classes retains its significance and novelty: despite the existing efforts in this area, a systematic understanding of how motives for independent classes at student age arise, develop, improve, or, on the contrary, are blocked and destroyed, has not been formed. This can be seen even in the example of publications of the last ten years, included in such large library databases as RINTS, Cyberleninka, etc. In our study, we turned to the analysis of the most relevant publications to the topic of our study, posted in these Russian libraries. Their analysis shows that domestic and foreign models of the studied aspect of modern students' activity consider the problem of motivation for physical education and sports more about content than methods. M.A. Lozovaya and colleagues, S.A. Marchuk, and many other modern researchers emphasise the importance of systematisation and unification of formalised-educational and independent physical education, health and sports activities of students, the importance of forming and developing a systemic understanding of preserving and strengthening health (Lozovaya, Zotin, & Petrova, 2019; Marchuk, 2016). Another important point is to take into account the place of physical education as a system of competencies, as well as the independence of its classes by future specialists in the context of the peculiarities of educational and professional work. These studies (of a comparative type) were practically not carried out purposefully. Meanwhile, it is obvious that for specialists of different professional groups the relevance and significance, content and forms of physical education and sports classes are in many ways different: for example, for students studying in the profiles of "physical education", "medicine", as well as students undergoing training in the field of "socio-humanitarian" and "engineering and technical" professions).

The purpose of the study is a systematic analysis of the motivation for the independence of physical education classes among students of different areas of professional training, the development and testing of recommendations and programs for motivating the independence of physical education classes among students.

The objectives of the study include 1) theoretical tasks related to the theoretical analysis and synthesis of the problems of motivating the independence of physical education classes among students; 2) development and implementation of a program for the empirical study of the motivation for the independence of physical education classes among students of different areas of professional training, 3) creation and testing of the author's model and program for motivating the independence of physical education classes among students. In our study, we proceed from the assumption that the motivation for independent physical education classes among students should be aimed at harmonizing the processes of training and education of future specialists, ensuring the effectiveness and productivity of these processes in the context of (re)training specialists for independent health preservation during the university and subsequent periods of professional formation and development. The development of motivation for independent physical education classes is associated with the specifics of the programs for the training and education of students at the university: their substantive and structural features. Physical education classes can be an important means of optimizing and harmonising the preparation of future specialists for independent health preservation at different stages of their professional path.

Materials and methods

The object of the study is the motivation for independent physical education classes among students.

The subject of the study is the processes and results, types and stages of motivation for independent physical education classes among students.

The methodological basis for studying the motivation for independent physical education classes among students was formed by several approaches: systemic (A.A. Verbitskiy, G.P. Shchedrovitskiy, etc.), health-preserving (L.B. Dykhan, O.M. Zheleznyakova, G.K. Zaitsev, M.M. Potashnik, N.K. Smirnov, etc.),

individually oriented (K. Rogers, V.V. Serikov, I.S. Yakimanskaya, etc.), competence-based (A.A. Verbitskiy, E.F. Zeer, I.A. Zimnyaya, A.V. Khutorskoy, etc.), and activity-based (A.N. Leontyev, L.S. Rubinstein, etc.). Based on these approaches, a competence-activity-based approach is formed, the essence of which in this study comes down to understanding that independence in physical education classes, like any other activity, is a necessary characteristic of the activity; independence of physical education classes of future specialists can be considered as a component of the systemic stage of development of health-preserving competence.

The central concept of the work within the framework of this understanding is the term "motivation of independence of physical education classes of students". The independence of physical education classes of students is considered by us as an important component of educational and professional independence, creating conditions for high-quality, optimal formation and development of a future specialist. Motivation, as is known, is a set of factors (motives) determining the behaviour of an individual and aimed at satisfying their needs, including in the field of physical education and sports. This includes motives-desires (indirectly related to human needs) and motives-needs (true needs), the consequence of which is a stable interest in physical education classes as a component of health preservation in professional and other types of activities.

Research methods

The work implements the author's model for studying the motivation for independent physical education classes, the basis of which is the survey method and the qualitative-quantitative method of analysis (content analysis) of the data obtained during the survey (Mayring, 2021). Mathematical methods for processing the latter included primary and secondary statistical processing of the research data using the Excel Online program.

The work was carried out during 2020-2025 based on one of the largest universities in Irkutsk and Russia (Irkutsk State Transport University).

The reliability and validity of the results obtained were ensured by:

- compliance of the basic methodological principles of studying the motivation of students' independent physical education classes with the purpose and subject of the study;
- representativeness of the sample size and significance of the experimental data in the study of students' motivation for independent physical education classes;
- Use of research methods adequate to the objectives of studying the motivation of students' independent physical education classes;
- statistical analysis of data obtained from the responses of participants in the study of motivation for independent physical education classes of students;
- an integrated approach and systemic analysis of the motivation for independent physical education classes of students.

Main results and their discussion

Health preservation is considered by almost all scientists and practitioners in the field of pedagogy as a means of increasing the effectiveness and productivity of teaching and upbringing students, their academic performance and ability to learn, the effectiveness of mastering general cultural, professional ("hard") and "soft" competencies (Mayring, 2021; Golovnykh and Naumova, 1980), as well as the overall success of a person as an individual, partner and professional in the modern world (Katany, 2018; Golubchikova et al., 2021). However, although health and successful mastering of the educational program of the university are interdependent, many students subjectively ignore this connection until they have significant health problems and do not face intense distress, for example, academic failure, etc. due to illness or other problems leading to the emergence of borderline or pathological disorders in the area of physical and mental well-being. Their competencies in this area are often fragmented and passive. Therefore, it is not surprising that researchers have repeatedly noted the importance of developing systemic, multi-component educational programs and manuals, designing educational results for students in the area of independent physical education as a component of health preservation based on competency-activity and other integrative and activating approaches (Golubchikova et al., 2021), their inclusion/consideration in education standards (Gun & Zotov, 2018; Ilmaliyev et al., 2022). Potentially, the range of methods, techniques, models and approaches to the formation and development of motivation for

physical education as a component of health preservation is very large, some of the formats and combinations will be more optimal and effective than others, including in the context of the substantive content of health preservation programs. Turning to physical education in the process of university training of a specialist is the most important channel for the formation and development of motivation for the independence of health-preserving activities of a student as a whole, the formation and development of a holistic culture of health preservation, which he will be able to transfer to everyday professional life. The key issue here is the relationship and structure of fundamental and practical competencies transferred and formed / improved in the course of various approaches, models, techniques and methods of teaching students. In order to competently and effectively solve the issues of selection, implementation and improvement of education in this area, a significant part of the activity of the university teacher and other specialists supporting the educational process, working with health-preserving tasks should be devoted to meta-educational activity: organizing and stimulating the motivation of future specialists to form and improve relevant and related competencies.

The most appropriate strategy can be considered an adaptive-developmental strategy of health preservation and motivation for independence in physical education (Arpentyeva, 2015). In contrast to the adaptive or corrective strategy, it not only does not limit the development and life of the student with fears and risks of losing health and the need to compensate for losses and defects in functioning and development, but, on the contrary, focuses on achievements, inclusion in activities, self-actualization and self-realization, which helps to rebuild the psychophysiological functions of a person as a whole, not only compensate for possible existing defects and developmental delays, prevent a decrease in functional capabilities, but bring a person to a new level of "health development". The central focus of the problems of motivation for physical education and health preservation of future specialists in their professional training is, therefore, the problem of its independence, conditions and means of its stimulation and development, forms of education, methods and techniques that must be used to encourage and strengthen students in independent formation (health building), maintenance / preservation (health saving) and improvement of a healthy lifestyle (HLS) (Emelyanova, Lukyanceva & Berezovskaya, 2016; Lycheva, 2022; Pyastolova, 2020). However, the existing practice of caring for the health of students in the country's universities today is such that students act more as consumers, recipients of health-preserving services, and not subjects of health preservation. Health achieved as a result of external management, therefore, does not seem to be an individual, intrinsic value, and, therefore, is easily devalued and "forgotten" as soon as this or that health-preserving program, event or form of externally controlled health activity is completed. The overall effect of such "health preservation" is therefore often not great. Teachers and researchers see the solution to this problem in supporting the motivation for independent health preservation beyond the educational situation and educational activity of students as fully functioning, holistic individuals from birth to the end of a person's life (Litovchenko et al., 2021).

Educational programs for health preservation that stimulate the motivation for independent activities are especially important in the context of the integration of general and additional education, in the context of a decline in the interest of young people and the population as a whole in health, in a healthy lifestyle, and the replacement of the desire for development with the desire to consume goods, etc. Modern researchers believe that it is necessary to create and strengthen such an educational process in a university, as a result of which independent and university-organized physical education classes acquire personal meaning, a persistent individual interest in them and in the acquisition of competencies in the field of physical education and health preservation in general arises, and external given motives for activity are transformed into internal needs of the individual (Litovchenko et al., 2021; Galich et al., 2014). It is important to note that if at the early stages of education and upbringing of children, adolescents, young men and women, attention is paid mainly to the acquisition of general cultural competencies within the framework of certain standards and norms of training, then at the level of professional education, at the university, the processes and phenomena of managing the educational activity of future specialists by teachers and other mentors and the students themselves, reflection and transformation of the processes and results of training in the context of students' independent acquisition of certain competencies and groups of competencies to varying degrees, taking into account the specifics of these competencies and their acquisition during professional (re)training come to the forefront organized by the university and independent studies of students. It is especially important to take into account that modern education requires the development of not only subject-object, but also subject-subject relations between the

teacher and the student. One of the most important aspects of the formation and development of motivation for independence in physical education as a component of health preservation is associated with. Therefore, with the problem of self-government in education: student self-government, readiness and ability to preserve health in the educational process of the university are an important factor in health preservation. The teacher should act as an assistant to the student. It is necessary to help students learn to reflect on their successes, processes and results of (self)education in the field of physical education and other areas, including through the use of various resources of educational environments available to them (Galich et al., 2014; Allen, 2020; Rohde et al., 2023). A necessary condition for this is independence as an active role of the student in the educational process, the readiness and ability of students of a modern university to independently organize and implement training in basic competencies in the context of various conceptual models (Weindorf-Sysoeva, Gryaznova, Shitova, 2020; etc.). For example,

1) M.A. Lozovaya and colleagues, many other researchers emphasize the importance of an integrative model for the formation of a conscious, reflexive attitude of students to their health and the health of those around them, including:

• acquisition of knowledge and skills in the field of health preservation and specific physical education;

• use by students of effective technologies for teaching students and the application of methods of sportization and individualization of the physical education process at the university as a whole;

• the need for personal participation of each student in health and preventive measures of the university and other organizations;

• the formation of a motivational and value-based attitude to their health and a healthy lifestyle in students;

• development of motivation of students for independent preservation and strengthening of their own and public health throughout their lives, self-improvement is the target task of university education (Kapalygina et al., 2017; Zimnyaya & Mukhina, 2016);

2) a model for the formation and development of health-preserving competence of university students, based on the structure of this competence, including its value-semantic, behavioral, emotional-volitional and cognitive components.

Competence as awareness and activity as motivation of students on health-preserving issues are considered as factors of professional success of a university graduate. It is noted that the formation and development of motivation and health-preserving competences in students occurs, first of all, in the context of realizing the recreational and developmental potential of physical education (Kostarev, 2017; etc.).

Both of these models are equally important for us: integration is the main condition for the effective formation and development of motivation for independent physical education as a component of a student's care for his or her health. In general, relying on the integrating modern approaches and concepts, practices and technologies of the model of pedagogical and psychological support for physical education and sports, we can note the following points:

1) the formation and development of students' motivation and competencies in the field of independent physical education as a component of health preservation should be aimed at understanding the essence and functions of numerous modes of health care: preventive and developmental, recreational / restorative and corrective, adaptive and competitive, labor / educational and play / leisure;

2) the training of specialists should include both practice and theory, fundamental knowledge and skills in the field of independent physical education as a component of health preservation. The theory and practice of physical health and physical education should serve the task of forming and strengthening the motivation for independent physical education.

Considering this problem, in addition to numerous factors and conditions for the formation, functioning, development, destruction of the motivation for independent physical education, an important point is the distinction between different types of motivation. Researchers distinguish: external/extrinsic and internal/intrinsic motivation, positive/stimulating, constructive and negative/destructive, anti-motivation, stable and unstable motivation. External motivation, according to experts, is associated with an orientation toward external stimuli (rewards, punishments, etc.). Internal motivation is associated with the individual himself, his concern for his health and physical culture and sports as a means and process of

increasing the effectiveness of his own life. However, any motivation is conditioned internally, although it depends on external factors and stimuli (current or from the past or future of a person).

The study of motives that determine the characteristics (intensity and regularity, (goal) orientation, etc.) of independent physical education and sports activities among students and the identification of factors that facilitate and limit them shows that the leading motives for independent physical exercise and sports are:

A) individual:

1) psychological, aimed at strengthening self-acceptance, self-respect and self-understanding, etc.;

2) motives for achieving goals and striving for self-improvement, including within the framework of physical education and sports;

B) health:

3) health motives aimed at strengthening and maintaining one's health, disease prevention;

4) close to them are professional and activity motives aimed at ensuring and improving performance, preventing and overcoming (dis)stress in educational and work activities;

B) broad social:

5) image/aesthetic, associated with the desire to change/improve appearance, improve the impression made on other people;

6) close to them are cultural motives - motives of "fashion", generally accepted standards, for example, a healthy lifestyle, etc.;

D) narrow social:

7) interactive motives associated with the need for communication and interaction, classes in groups/clubs "by interests";

8) motives of winning, competition, and competition, especially characteristic of students keen on sports (Fassakhova & Dobrynin, 2020; etc.).

The main idea of the study is that the motivation for independent physical education classes among students is a systemic phenomenon in nature and an important component of professional training. It requires the use of a combination of different approaches to its effective and productive formation and strengthening, ensuring successful functioning. Effective motivation can be implemented using a holistic model that combines various, to varying degrees, specialized methods and techniques, conditions and forms of education that stimulate the formation and development of students' scientific-theoretical, methodological-applied and value-semantic competencies in the field of physical education as a component of health preservation.

Hypothesis. In our study, we proceed from the hypothesis that students of different professional groups rely on different motives for independent physical education classes and have different levels of formation of motivation for independence and the health-preservation competencies that ensure them:

1) Unformed motivation for independence in physical education classes is associated with the level of formation of basic competencies and general methodological literacy, in which students have partially formed motives for independence and carry out relatively disordered physical activity. The leading motives for this group of students are narrowly social and broad social motives for independent physical education classes; 2) the formed motivation for independent physical education classes is associated with the level of development of health preservation and its directed reflection, in which students have a formed system of motives for physical education classes and are consistent and regular in implementing health preservation programs. The leading ones for this group of students are narrowly social and health-improving motives for independent physical education classes.

3) a highly formed motivation for independent physical education classes is associated with the level of health preservation management, with which the independence of physical education classes as a component of health preservation is associated, the desire to include physical education classes in the context of practices of caring for other, in addition to physical, components of health (spiritual, psychological). The leading ones for this group of students are psychological and health-improving motives for independent physical education classes. An empirical study of the motivation for independent physical education classes. For this study, 145 people were selected in the pilot and 120 people in the main part of the study. The main study involved 4 groups of different specialities, 30 respondents each (the classic number of respondents/document texts or document sets for content analysis is 30 people/texts/document sets), a total of 120 students of the Irkutsk State Transport University:

Group I – students of the departments of computer technology (bachelor's degree), information security (bachelor's degree), train traffic control system (specialist's degree);

Group II – students of the departments of economics at the enterprise (bachelor's degree), economic security (bachelor's degree), customs affairs/economic policy of the state (specialist's degree);

Group III – students of the departments of management at the enterprise (bachelor's degree), personnel management (bachelor's degree), quality management (bachelor's degree);

Group IV – students of the departments of railway operation (bachelor's degree), railway rolling stock (specialist's degree), railway construction (specialist's degree).

The age and gender composition of the students was largely homogeneous (bachelor's and specialist's degree students of the 2nd and 3rd years, more than 90% of respondents were girls). Physical education classes were held in all groups according to similar programs, specific contents and procedures (methods), as well as goals and formats of teaching for each of the groups of programs were not created.

As can be seen from this list, specialists with special competencies in the field of health preservation (trainers / physical education and sports teachers, medical workers/doctors, clinical psychologists and psychiatrists, social workers / social and medical workers) did not participate in the study, which somewhat limited its context and the completeness of the comparative analysis. However, this problem can be solved in the future, based on the study we conducted.

In the process of qualitative analysis of the research data, several subgroups of respondents were identified according to the criterion of motivation for independent physical education and sports (the presence and regularity of independent physical education and sports and health preservation):

1) demotivated, passive respondents who do not practice regular independent physical education and sports and health preservation in general (16.7%, 20 people);

2) motivated, active respondents who practice regular physical education and sports and health preservation in general (76.7%, 92 people);

3) value-motivated, competent respondents who practice regular physical education and sports and have long-term health preservation programs (6.7%, 8 people).

The distribution of respondents by groups and subgroups is as follows (Table 1):

Table 1. The ratio of the distribution of respondents by groups and subgroups at the beginning of the study

	Group I - "IT specialists"	Group II "economists"	Group III - "managers"	Group IV - "transport workers"
Passive	5	5	4	6
Active	21	23	25	23
Competent	4	2	1	1
Total	30	30	30	30

Note: compiled by the authors based on the results of the study

The study groups of respondents we surveyed, identified by an external criterion ("speciality", professional affiliation), differ from each other insignificantly. The greatest differences were demonstrated by the group "managers" and "IT specialists": among "managers" more students are demonstrating an active position about health preservation and health management (highly motivated), among "IT specialists" there are more "competent" (motivated), "transport workers" showed slightly greater passivity and demotivation compared to other groups (differences are insignificant at the 0.05 level). Among economists, the most noticeable differences are associated with a greater representation of "competent", motivated students. The semantic structure of ideas about the independence of physical education classes in these groups looks as follows:

1) Although modern education, containing independent learning as one of the three main components, is naturally intended and capable of stimulating independence and developing the desire for it and the ability of students to be independent, the forced nature of such "independence" (deprivation of the opportunity to receive support, advice, etc.) from teachers and other students, the general limited development of a person placed in conditions of more or less complete loneliness, prompt some students

to ask the question of how independence and isolation differ, many students record moments of isolation and "abandonment", "being of no use to anyone" (8.3%, 10 people);

2) Demotivated, passive students, solving in addition to health problems, a host of other, more subjectively significant problems, note problems of employment/overload, lack of time, space and other external resources (equipment, etc.). This group of students systematically underestimates and considers internal resources of health-preservation, including the formation/development of the quality of independence, in an extremely local way.

The procedure of the empirical study included work with the author's methods:

development, testing and improvement of the "Big Questionnaire of Health-Preservation" - the author's modification of the projective method of "Unfinished Sentences", collection of primary data using the questionnaire, its completion by 120 respondents;

qualitative and quantitative analysis of responses, content analysis, primary and secondary statistical data processing (counting the occurrence of subcategories in different groups and subgroups of respondents, comparative study of frequencies of occurrence in different groups and subgroups, assessment of the reliability of differences),

interpretation of the obtained data, identification of levels of independence in health preservation and typical ways of responding / understanding/attitudes towards phenomena, methods, conditions, functions, resources and anti-resources of students' health preservation, development and testing of recommendations for improving the programs and improved programs "Fundamentals of Physical Fitness".

During the development, testing and improvement of the questionnaire, the following were assessed (Zarochentsev K. D., Khudyakov A. I., 2005, p. 68, etc.): ecological validity, external validity, internal validity, operational validity, including construct validity. Construct validity of the developed content analysis methodology was ensured by the correspondence of the system of groups of categories, categories, subcategories and their referents to 1) theoretical postulates of research and data from existing studies of health preservation in the educational process; 2) compliance with the research hypotheses formulated based on theoretical assumptions; 3) empirically identified and correlated with theoretical models of health preservation scales (subcategories) of the study of the phenomenon under study.

"The Large Questionnaire of Health Preservation" was also included in the multi-stage training procedure, which assumed detailed work on individual (home) completion of the questionnaire, group (classroom) reflection of the process and results of filling, as well as subsequent independent (home) work aimed at clarifying the answers to the questions. The texts of the answers were analysed using the content analysis method, compared with each other as a whole and for individual groups and subgroups of respondents. It was assumed that many students do not have significant motivation for health preservation and reflection on health preservation, as well as motivation for learning in general, and do not have many of the competencies (knowledge and skills) necessary for correct understanding of the questions of the methodology, in particular, reflexive and metacognitive competencies.

The Large Questionnaire of Health Preservation (R.S. Lyzhenkova, 2022) is an original methodology; it is part of the curriculum for training specialists for independent physical education and health preservation. It is based on the structuring theoretical model of motivation for the independence of health-preserving activities of university students in the process of blended learning, substantiated by us in the course of a theoretical analysis of the problem, which includes a number of components and questions clarifying the formation and development of a particular component. The text of the questionnaire was largely traditional: open questions were offered devoted to various aspects of motivation for independence in physical education and health preservation of students at 3 levels (a) the level of individual exercises, b) the level of exercise cycles and other accompanying methods, c) the level of health preservation programs):

• Competence/content component of motivation for independence in physical education:

What do you need to know and be able to do to independently select, implement and evaluate the results of applying a particular health preservation method, to form, implement and evaluate the results of a program or individual health preservation route?

• process-activity component of motivation for independence in physical education:

Can you independently select, apply and evaluate the implementation of a particular method, health preservation program, for example, exercises for training a particular functional system of the body; build, implement and evaluate a health preservation program, including a training session or a program of classes?

• value-semantic component of motivation for independent physical education classes:

List the main values and goals of health preservation, including physical education and sports that guide your choice, implementation and evaluation of the effectiveness of health-preserving exercises and programs?

• The organisational and methodological component of motivation for independent physical education classes:

What organisational and other external resources do you need to have to independently choose, implement and evaluate the result of using a particular health-preserving technique or program?

• criteria-evaluation component of motivation for independent physical education classes:

What are the criteria for evaluating the effectiveness of using a particular technique, group of techniques or an entire health-preserving program?

Respondents could answer questions from a particular group directly, in the course of answering a question devoted to a specific topic, or as part of answers to other questions, "incidentally". The presence or absence of indications of a particular subcategory was recorded (0 - no, 1 - yes). The total result for the sample could thus range from 0 to 120 units, for individual groups, from 0 to 30 units, for subgroups, and from 0 to a number equal to the number of respondents belonging to a specific subgroup.

The study was implemented as part of the program for the formation and development of independence in the health-preserving activity of university students.

The differences between the 4 studied educational and professional groups of respondents were insignificant; the differences are in the insignificance zone for all 5 components of motivation for independence in health-preserving, tEmp = 1.3 ÷ 1.7 for $p \leq 0.05$ (tCrit. = 1.97). The differences between the subgroups of respondents, differing in the level of motivation for independent health-preserving in general and in different components, tEmp = 3.9 ÷ tEmp = 2.7 ($p \leq 0.01$), that is, they are significant, especially for value-semantic and competence-content indicators. Therefore, the results will be described according to the second criterion. Before describing the main results obtained, we will introduce the following symbols: PG is a subgroup of demotivated students with a passive attitude towards health preservation, AG is a subgroup of motivated students with an active attitude towards health preservation; KG is a subgroup of highly motivated students with a competent attitude towards health preservation. Tables 2–5 below summarise the frequencies of subcategories in different subgroups and the sample.

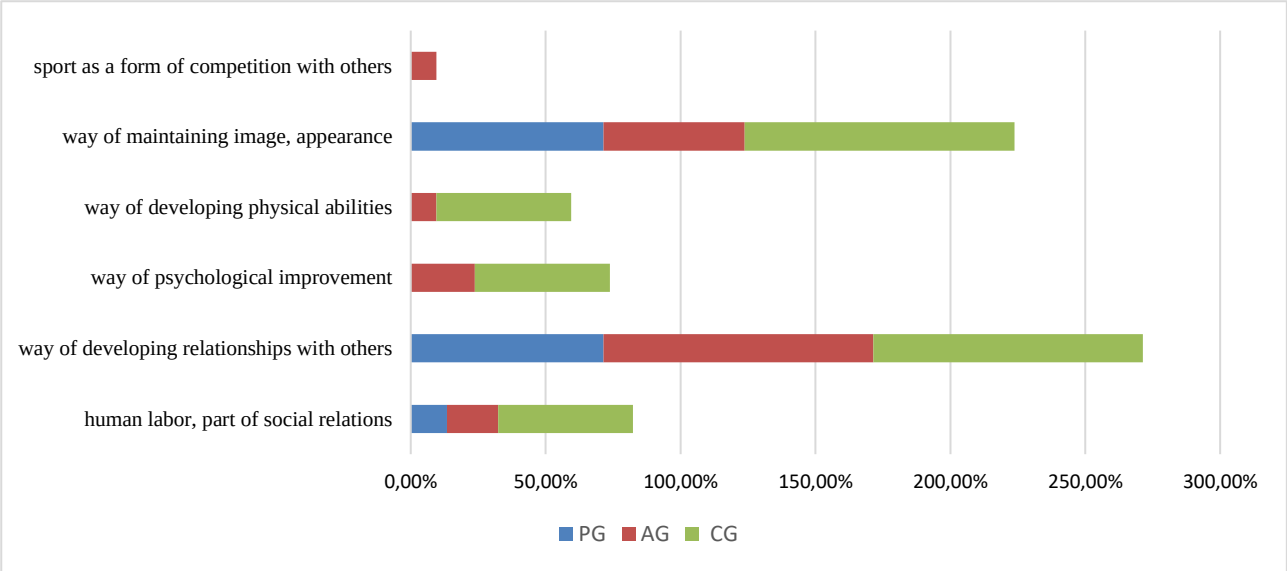


Figure 1. The content component of motivation for independent physical education classes (Developed by the authors based on empirical research)

The diagram in Figure 1 shows that the ideas of different groups of respondents about physical education and sports are significantly different.

The greatest contribution to the concept of "physical culture and sport" as a whole in the sample is made by the subcategories/scales of "area of social activity" and "development of relationships with

others" and "maintaining appearance", less - "work, an important part of life" and "a way of psychological improvement" and, to a lesser extent, "development of physical abilities": the respondents perceive physical culture and sport in general in a rather utilitarian, limited way, their life prospects (development tasks) are little connected with physical culture and sport, broad and narrow social motives dominate.

For the subgroup of respondents with a passive attitude to health-preserving activity, it is typical to turn to the scales (subcategories) of maintaining appearance and statements of the existence of physical culture and sport as a type of social activity (external, formal aspects - extrinsic motivation).

For the subgroup with an active attitude to health-preserving activity, it is also typical to have an idea of the psychological functions of physical culture and sport (internal, more subjective aspects appear). There is also an attempt to separate sports and physical education based on the criterion of help/harm to health and cooperation/competition.

For the subgroup of competent respondents, it is also typical to understand physical education and sports as ways of development, improvement (physical and psychological), and intrinsic motivation.

In general, this suggests that the most independent, active and competent respondents have a more holistic, systemic understanding of physical education and sports as a practice of preserving and developing their internal and external physical and psychological resources.

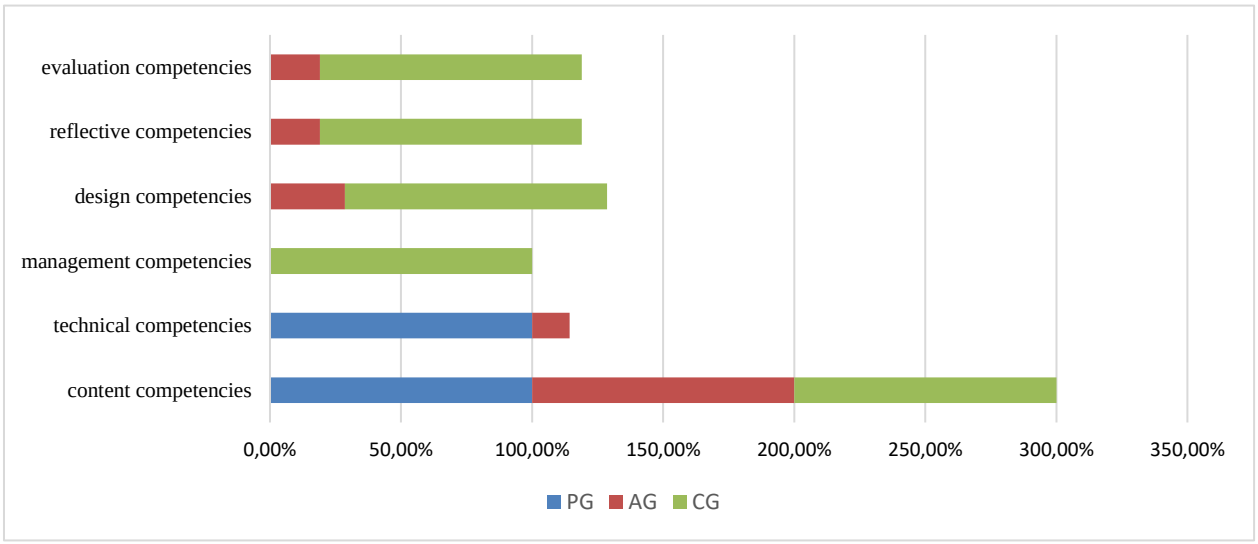


Figure 2. The procedural component of motivating independence in physical education classes (Developed by the authors based on empirical research)

The diagram in Figure 2 shows that the ideas of different groups of respondents about the procedural aspects of the components of motivation for independence in physical education classes are significantly different.

The subgroup of respondents with a passive attitude to health-preserving activity is characterized by an appeal to scales (subcategories) of substantive and technical competencies (external, executive aspects of health-preserving), which suggests that this subgroup of respondents is at the initial stage of competence development: they need to know "what and how to do" (including each exercise/method separately), including in the context of receiving help from a trainer/teacher, Internet resources and classmates. This is the "emerging motivation for independence in health-preserving". The subgroup with an active attitude to health-preserving activity is also characterized by attention to the competencies of reflection, assessment and design, which suggests that they are at a more advanced stage of independent health-preserving, when they try not only to understand what and how to do, but also how to evaluate and how to build a set/system of exercises, and also to reflect on the activities to be able to improve the results obtained. This is the "developing motivation for independence in health-preserving".

For the subgroup of competent respondents, attention is also paid to the competencies of reflection, assessment and design, as well as management, this suggests that they are at the next stage of independent health-saving, "management (independent) health-saving", when they not only understand

and can build systems of health-saving actions, but are also able to reflect, design and manage health-saving. This is "controlled motivation for independence of health-saving".

In general, this suggests that the most independent, active and competent respondents have a more complete set of competencies of health-saving, that three levels of health-saving can be distinguished, at each of which their types of competencies are formed and developed: "forming motivation for independence of health-saving", competencies of a substantive and technical type are formed (understanding of what and how can and should be done, including to "not harm" the body). 2) the intermediate level - "developing motivation for independence in health preservation" - to the understanding of what and how can and should be done (including to achieve the set goals), is added the understanding of how it is possible and necessary to evaluate the implementation of methods / exercises and their sets, how to develop and reflect on the implementation of such sets of methods, the leading competencies here are the competencies of assessment and design;

1) the final level - the level of "controlled motivation for independence in health preservation", associated with the formation of competencies of reflection and management.

Naturally, some respondents record the existence of other levels, including those associated with professional competencies in this area, but, as a rule, at this structure of levels / stages, for all respondents, the matter ends: realizing the presence of other, significantly greater opportunities, they, nevertheless, do not associate their development with independent activity, including educational and professional. This suggests that further development of motivation and independence itself is difficult, the educational system of a modern Russian university is not capable of supporting students' motivation and activity in this area in other classroom and extracurricular activities/events.

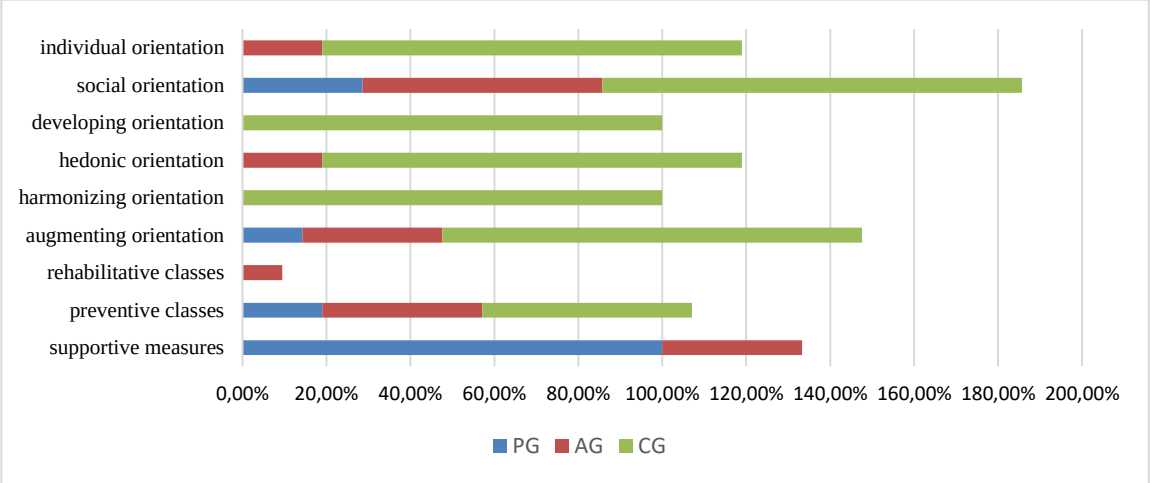


Figure 3. Value-semantic component of motivation for independence in physical education (Developed by the authors based on an empirical study)

The diagram in Figure 3 shows that for the sample as a whole, preventive and supportive selection orientations, social and augmenting (improving) orientations are significant at the beginning. Harmonising, rehabilitating, developing, and individual orientations are the least significant.

For subgroups of respondents with a passive and active attitude towards health-preserving activity, supportive and social orientations, as well as augmenting and preventive ones, are typical. For the subgroup of competent respondents and respondents with a negative, critical attitude towards blended learning, the developmental and harmonising, hedonistic, preventive and augmenting, individual and social orientations are important. All this suggests that the orientation towards development and individualisation of selection is characteristic of active, competent and striving to receive a quality education. Students who are less interested in it and more passive are satisfied with supportive and preventive selection criteria and/or do not take selection seriously at all, since they have not developed and do not comply with either a health-preservation regime, a route or a program. For competent respondents, the values of serving by example and independence, discipline and education of responsibility, passion and efficiency, development and adaptation are important. Here, an understanding of the social significance of

health, the importance of spreading a healthy lifestyle, self-improvement and the pleasure of health preservation is formed. In our opinion, it is especially important to highlight the values of serving by example, unlocking, and transcending the egoistic motives of health preservation in competent respondents. This is one of the ways to solve the dilemma of confronting social norms of life-affirmation / levelling the value of health and life, which modern people face in the consumerist community in general and in the commercialised education system in particular.

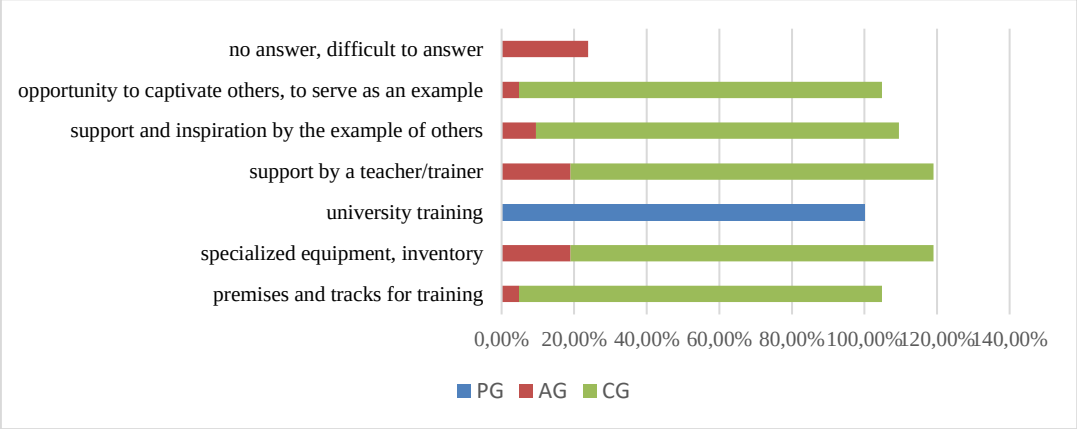


Figure 4. Organisational and methodological component of motivating independence in physical education classes (Developed by the authors based on an empirical study)

The diagram in Figure 4 shows that motivation is largely related to external conditions, educational features. This is fertile ground for activating health preservation and developing independence in health preservation.

Among respondents with a passive attitude towards health-preserving activity, 100% of the subgroup notes university training as a "panacea", and preferably in the classroom, strengthening exercises and fitness, relaxation exercises and strength training are most often mentioned - the most common stereotypical types of physical activity. For active respondents, support, availability of equipment and inspiration by example are also important: a traditional educational situation that develops the functional capabilities of the body and ensures relaxation. For competent respondents and respondents who have a negative, critical attitude towards blended learning, premises/tracks, equipment, teacher support, as well as "exchange of inspirations" are important: support and provision of support and serving as an example for those involved in each other. The most significant for them are complex types of exercises, including within the framework of holistic health-preserving programs, classes with special equipment, strength exercises and relaxation.

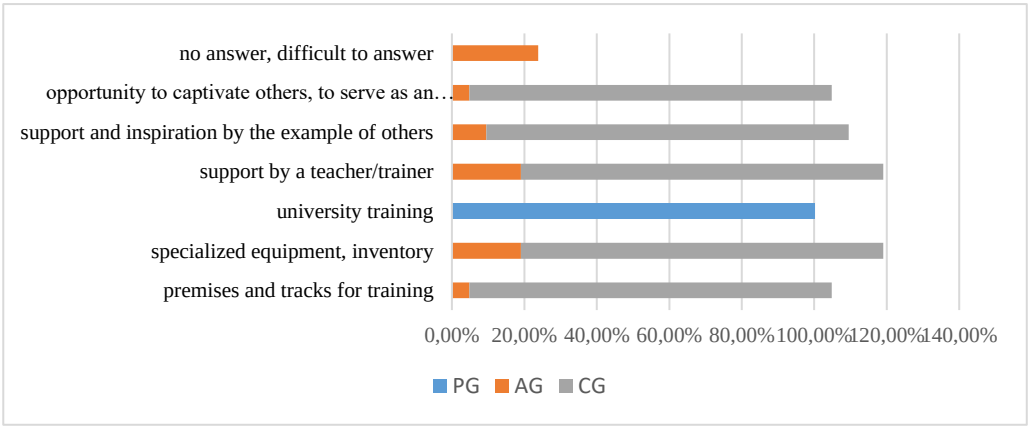


Figure 5. Evaluation component of motivating independence in physical education classes (Developed by the authors based on the empirical study)

The diagram in Figure 5 shows that among respondents with a passive attitude to health-preserving activity, the most frequently mentioned are the absence of losses and expenses, development of mobility, improvement of the body condition and the emergence of a healthy lifestyle, as well as satisfaction with classes and the effectiveness of training.

For active respondents, self-satisfaction, improvement of the body condition and development of flexibility and mobility, the effectiveness of training and the absence of excessive costs and wear, and the development of reflection are also important. For competent respondents, the absence of losses and expenses, development of mobility, as well as satisfaction with classes and the support of the trainer, self-satisfaction, and the quality of training, and its effectiveness are important.

Thus, respondents demonstrate two types of attitudes to classes:

1) a passive-consumer attitude to classes that should not be burdensome, but, at the same time, allow you to achieve health. This group of respondents can be related to those who believe in the "magic of pills" and quick, easy ways to solve health problems, without trying to make their efforts; these are dependent students.

2) an active and creative attitude to classes, a comprehensive assessment of the process and results of classes, distributed responsibility as an understanding that the result of each person's efforts depends on them and their environment: internal and external resources.

As conditions for the latter, as the survey results show, systematicity, persistence, experience and orientation in one's potential, methodological competence, and self-control competencies are important. However, the ratio of the frequency of mentioning the importance of competence and openness of information (more often) and purposefulness and systematicity of classes (much, 3 times in the sample) indicates crisis trends: disorientation in choosing the direction of further development. Respondents strive to be open, know and can do a lot, do a lot, but strive for little.

In general, it is clear that the "growth points" to which the work of teachers and educational process support services of the university should be addressed are different:

- advertise a healthy lifestyle, health care, stimulate the transition to a healthy lifestyle, to health preservation;
- support reflection, comprehension and rethinking of one's own experience and the choice from the palette of available methods and directions of the most "developing", correction of the desire to limit development to the "suitable" and "easy", joint research work that allows comparing the "pros" and "cons" of adaptive and non-adaptive (supradaptive) strategies of health-preserving activity;
- Informing and researching the paths (prospects) of development within the non-adaptive (supradaptive) strategy of health preservation, as well as the explicit and implicit consequences of abandoning them.

Conclusion

Having analysed the hypothesis of the study, we can conclude that it was confirmed. The current format of university education in the area of motivation for independent physical education classes is not effective. The main condition for success is targeted work in the area of formation and development of motivation (readiness) and ability (competencies) for independent health preservation. In addition to teachers, academic health preservation services can and should take part in such work. Based on the obtained results, we developed a model for the formation and development of motivation for independent physical education classes and health-preserving activity of university students, various points of which act as principles and recommendations for optimising the educational process of the university. Within the framework of the model, conditions, levels, types of motives and several motivation components are integrated:

1. Competence/content component of motivation for independence in health preservation: motivations and competencies in health preservation, physical education, individual route of health preservation, level of independence and own resources of activity;

2. Process-activity component of motivation for independence in health preservation: functions/significance and difficulties of activity in the field of physical education and health; features of selection and integration of methods and implementation of health preservation programs;

3. Value-semantic component of motivation for independence in health preservation: significance, values and conditions of health preservation; motives for independence in different conditions of education;

4. Organisational-methodological component of motivation for independence in health preservation: organisational and external resources of health preservation; functions and methods of university training in the field of health preservation;

5. criteria-evaluation component of motivation for independence in health preservation: criteria for the effectiveness of methods/training/health preservation programs/health preservation classes and programs; conditions for independence in health preservation.

The prospects of the study are related to a comparative study of 1) different training options; 2) students of different specializations, career and professional orientations at different stages of training; 3) the creation, testing, improvement and implementation of model programs to support the motivation for independence in health preservation of future specialists at the university in the context of different conditions, the implementation of academic health preservation services.

CRediT author statement: **N.V. Yakovleva**: Conceptualisation, Supervision, Methodology, Validation, Writing draft preparation. **R.S. Lyzhenkova & M.R. Arpentieva**: Data curation, Software, Writing draft preparation. **S. Nopembri**: Visualisation, Proof-reading. **G.K. Kassymova**: Editing.

Cite this article: Yakovleva, N.V., Lyzhenkova, R.S., Nopembri, S., Arpentieva, M.R., Kassymova, G.K. (2025). Motivation for Independent Physical Education Classes in Students of Modern Universities. Materials of International Scientific-Practical Internet Conference "Challenges of Science". Issue VIII, pp. 46-60. https://doi.org/10.31643/2025.05

References

Allen, M. (2020). *E-learning.* Moscow: Alpina Publisher. 200 p. (In Russian)

Arpentyeva, M.R. (2015). Content analysis: psycholinguistic analysis of texts. In: Barbako, O.M., Zobnin, Yu.A. (Eds.*) Mathematical methods and models in management, economics and sociology.* Tyumen: Tyumen State Oil and Gas University. Issue 9, pp. 13-26. (In Russian)

Emelyanova, G.I., Lukyanceva, T.N., Berezovskaya, V.A. (2016). Implementation of the health-preserving system in the institution of additional education. *Educational environment today: development strategies.* No. 1 (5), pp. 302-304. (In Russian)

Fassakhova, T.A., Dobrynin I.M. (2023). Motivation for independent physical education among university students // Current issues of sports psychology and pedagogy. Vol. 3. No.4, pp. 45–52. (In Russian)

Galich, I.S., Slepova, L.N., Hairova, T.N, Dizhonova, L.B. (2014). Personal motivation of students for physical training and sports. *International Journal of Experimental Education*, no. 7-2, pp. 94-95.

Golovnykh, M.V., Naumova N.N. (1980). Problems of implementing students' health preservation in the conditions of a Soviet university: the experience of the Bratsk Industrial Institute. *Proceedings of Bratsk State University. Series: Humanities and social sciences.* 2017. No. 1, pp. 7-11. (In Russian)

Golubchikova, M.G., Lyzhenkova, R.S., Byshlyago, A.A., Korobchenko, A.I., Arpentyeva, M.R. (2021). Towards a theory of educational and professional independence. *Professional education in Russia and abroad.* No. 1 (41), pp. 24-33. (In Russian)

Gun, G.E., Zotov, I.V. (2018). Health protection of schoolchildren in educational activities within the framework of the Federal State Educational Standard. *Successful practices of implementing the Federal State Educational Standard of General Education.* St. Petersburg, pp. 131-143. (In Russian)

Ilmaliyev, Z.B., Patihan, T., Tursunbekov, D.M., ... Sansyzbayeva, D.B., Kassymova, G.K. (2022). Motivating factors of innovative research activities and barriers to R&D in Kazakhstan. Cakrawala Pendidikan, 41(3), 619-629. https://doi.org/10.21831/cp.v41i3.47704

Kapalygina I.I. (2017). Conceptual models of health-preserving schoolchildren in the conditions of the information and educational space. *The phenomenon of man. Collection of works of the International scientific and practical conference. Podolsk, April 15-20*. Moscow, Podolsk: Moscow Regional Humanitarian Institute, 2017, pp. 108-114. (In Russian)

Katany, I.A. (2018). Motivation and purposefulness of the organization, content of independent physical exercises of various orientations. *International Journal of Humanities and Natural Sciences.* No. 9, pp. 25-29. (In Russian)

Kostarev, A.Yu., Sirlibaev, M.K. (2017). Pedagogical conditions for the formation of students' health competence. *Scientific notes of P.F. Lesgaft University*. No. 9 (151), pp. 145-150. (In Russian)

Litovchenko, O.G., Litvinova, N.S., Koshkarova, N.I., Tostanovskiy, A.V. (2021). Students' lifestyle as a health-preserving factor. *Educational Bulletin Consciousness.* Vol. 23. No. 11, pp. 20-29. (In Russian)

Lozovaya, M.A., Zotin, V.V., & Petrova, S.S. (2019). Formation of effective health-preserving competencies in students using modern pedagogy methods. *Problems of modern pedagogical education*. No. 64-3. Pp. 154-157. (In Russian)

Lycheva, E. (2022). Application of new methods and techniques for health care as a way to a healthy lifestyle. *Student.* 2022. No. 2-4 (172), pp. 96-97.

Marchuk, S.A. (2016). Model for the formation of health-preserving competence in students of a railway university. *Modern science-intensive technologies*. No. 12-1. pP. 161-165. (In Russian)

Markova, A. K., Matis, T. A., Orlov, A. B. (2015). *Formation of the motivation of learning*. Moscow, Akademiya Publ.; 191 p. (In Russian)

Mayring, Ph. (2021). *Qualitative Content Analysis*. New York: SAGE Publications Ltd. 240 p.

Pyastolova, N.B. (2020). Healthy way of life: health building, health saving. *Physical Culture. Sport. Tourism. Motor Recreation.* Vol. 5. No. 2, pp. 121-127.

Rohde, N., Flindt, N., Rietz, C., & K. Kassymova, G. (2023). How e-learning programs can be more individualized with artificial intelligence – a theoretical approach from a pedagogical point of view. Muallim Journal of Social Sciences and Humanities, 7(3), 1-17. https://doi.org/10.33306/mjssh/240

Weindorf-Sysoeva, M.E., Gryaznova, T.S., Shitova, V.A. (2020). *Distance learning methods*.Moscow: Yurait Publishing House, 2020.194 p.

Zimnyaya, I.S., Mukhina, S.A. (2016). The essence, content and structure of the health-preserving educational environment of the university // Bulletin of the Mari State University. Vol. 10. No. 4 (24), pp. 16-21. (In Russian)

Issue VIII, 22 November 2025
e-ISSN 2707-9481 Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University, Almaty, Kazakhstan
ISBN978-601-323-547-9 https://doi.org/10.31643/2025.06

Dinara Kh. Altybayeva
Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan
E-mail: dinara.altybayeva.88@mail.ru
ORCID ID: https://orcid.org/0000-0002-2132-0076

Maral A. Dyussebekova
Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan
E-mail: m.dyussebekova@satbayev.university
ORCID ID: https://orcid.org/0000-0002-4359-9784

Bagdaulet K. Kenzhaliyev
Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan. E-mail: bagdaulet_k@mail.ru
ORCID ID: https://orcid.org/0000-0003-1474-8354

Ahmad Gemeal
Central Metallurgical Research & Development Institute, Egypt; Al-Farabi Kazakh National University, Kazakhstan.
E-mail: agemeal@cmrdi.sci.eg
Gemil.Akhmad@kaznu.kz
ORCID ID: https://orcid.org/0000-0001-6663-2623

Study of the Ion Dissociation Process during the Reduction of Metal Oxides

Abstract: In the present work, an attempt was made to experimentally confirm the possibility of ion dissociation of a metal oxide as one of the stages of the reduction process. Additionally, a solid, nonvolatile reducing agent was employed to investigate the feasibility of a dissociative reduction mechanism. A common feature of all the experiments was the use of a non-contact reduction technique. This experimental approach makes it possible to investigate individual processes occurring on the surfaces of the reductant and the oxide. An essential requirement in this case is the use of low-volatility oxides and reducing agents.

Keywords: ion dissociation; reduction of metal oxides; iron oxide; copper oxide; gas-phase ionization.

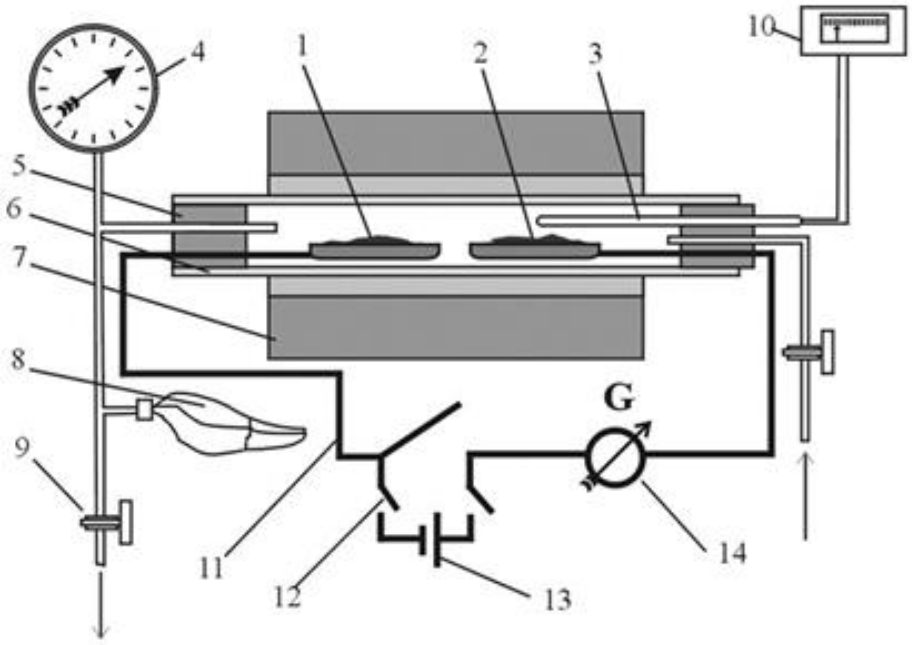
Introduction

The reduction of metal oxides plays a key role in metallurgy, solid-state chemistry, and functional materials technology. Despite the extensive study of the thermodynamic and kinetic aspects of these processes, their atomic-level mechanisms often remain the subject of scientific debate (El-Geassy et al., 2013; Yuan et al., 2021). One possible reduction pathway involves ion dissociation of oxides, leading to the formation of charged species that participate in oxygen transfer between the oxide and the reducing agent. However, experimental verification of this mechanism is challenging due to the difficulty of isolating and detecting ion fluxes generated directly within the reaction zone (Geld, 1957; Zhang et al., 2016).

In recent years, non-contact research methods have attracted increasing attention, as they eliminate the influence of electrical connections and external charge carriers on experimental outcomes (Hammam et al., 2022). These methods create conditions under which the recorded electrical signals can be directly correlated with the reduction process itself, including potential oxygen ionization during oxide lattice dissociation. An important feature of such experiments is the requirement to use low-volatility oxides and reducing agents, which prevents masking effects associated with gas-phase reaction products (Kenzhaliyev et al., 2022).

Research methods

A special experimental setup (Figure 1) was designed to investigate the possibility of ion dissociation of iron and copper oxides.



1 – oxide sample; 2 – reductant sample; 3 – thermocouple; 4 – manometer; 5 – stoppers; 6 – alumina tube; 7 – heating furnace; 8 – expansion vessel; 9 – valve; 10 – recording device; 11–14 – elements of the external electric circuit

Figure 1. Set up for recording ion currents during the reduction of oxides using a non-contact method

The setup consisted of an alumina tube, sealed at both ends with rubber stoppers, placed in a furnace heated up to 1200 °C. Inside the tube, within the heating zone, two iron crucibles were positioned 5 mm apart. Each crucible was connected to an iron electrode passing through a rubber stopper to the outside of the alumina tube. The pressure and composition of the gas phase could be adjusted via tubes embedded in the rubber stoppers. The temperature inside the tube was measured using a platinum thermocouple. One of the crucibles contained iron oxide, while the other contained metallic titanium in the form of shavings. The ends of the iron electrodes were connected by a copper wire to a potentiometer. In some experiments, a direct current (DC) power source was included in the resulting electrical circuit. A vacuum could be created inside the tube using a vacuum pump after preliminary purging with an inert gas (argon).

Before the main experiments, "blank" tests were conducted on the setup. The interior of the alumina tube was filled with argon, and no samples were placed in the iron crucibles. The furnace was heated to the experimental temperature of 1200 °C. No current or voltage was detected in the external electrical circuit. Similar tests were carried out after evacuating the alumina tube, and again, no readings were observed on the potentiometer.

Subsequently, a series of experiments was performed with identical iron oxide samples in both crucibles. Similar experiments were conducted with titanium and titanium dioxide samples. In these cases, no potentiometer readings were observed either. All series of blank experiments described above were repeated with a 50 V DC power source connected to the external circuit. Under these conditions, an electric current became noticeable in the system at a temperature of 600 °C under atmospheric argon pressure, reaching 2-4 μA. As the temperature increased to 1000 °C, the current gradually rose to 2 mA. When the system was evacuated to a pressure of 10^3 Pa, the current decreased by roughly a factor of ten, but still increased with rising temperature. The magnitude of the current was the same for both direct and reverse connections of the DC power source.

Results and discussions

The preliminary experiments demonstrated that in the electrical system without samples or with identical samples under the conditions described above, no electromotive force (voltage) or current was observed between the iron electrodes. It was determined that at temperatures of 600 °C and above, the gas phase inside the alumina tube becomes sufficiently ionized to conduct an electric current with the parameters described earlier.

The main series of experiments was conducted with iron oxide in one crucible and titanium shavings in the other, the latter taken in a tenfold excess relative to the amount required for complete oxidation of the iron oxide. Under these conditions, at temperatures above 500 °C, a voltage of 0.2-1.0 mV appeared in the external circuit. No current was recorded. During a 15-minute hold at this temperature, no changes in the electrical parameters were observed. Changes in the system pressure, whether increased or decreased, caused the voltage to drop to zero; however, 1.5-2.0 minutes after stabilization of the pressure, the voltage gradually returned to the value it had prior to the pressure change.

Further temperature increase led to a rise in both voltage and current. The maximum voltage of 35 mV and current of 40 μA were obtained at 1200 °C, both under vacuum and at atmospheric pressure. It should be noted that the electrical parameters, especially at temperatures between 500-700 °C, were unstable. However, there was a general trend of increasing current between the iron oxide and titanium samples with rising temperature (Figure 2). At temperatures of 700 °C and above, the iron oxide sample acted as the positive pole, while the titanium sample acted as the negative pole.

Reversed polarity was observed in some experiments during sharp pressure fluctuations in the gas phase at temperatures below 700 °C. At higher temperatures, changes in pressure caused a significant drop in voltage, followed by a gradual recovery to a value close to that before the pressure change. The time required for the voltage to return to its original value varied between 5 minutes (at 1100-1200 °C) and 20 minutes (Figure 3).

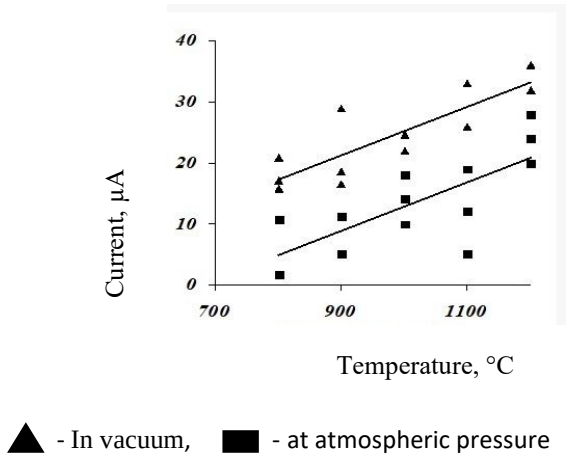


Figure 2. Variation of the current between the iron oxide and the reductant samples as a function of temperature

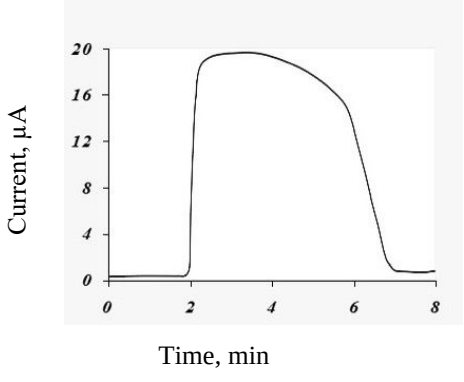


Figure 3. Variation of the current between the oxide and the reductant over time

It should be emphasized that voltage and current decreased with both increasing and decreasing pressure. The magnitude of the change in current and voltage with pressure varied across experiments and sometimes dropped to zero.

Clearly, the emf between the samples only occurs when the processes of iron oxide reduction by titanium occur simultaneously and ceases when the iron oxide is completely reduced to metal.

Similar experiments were conducted with cuprous oxide. However, due to the relatively high rate of cuprous oxide reduction, the process was completed within a few minutes (3-5), and stable electrical parameters were not recorded. The current varied from 1 to 28 microamps, and the voltage from 1-2 to 30 millivolts.

A series of experiments was subsequently conducted with a DC power source connected to the electrical circuit. The connection was made in two ways: in the first, the negative pole was connected to a sample of iron oxide, and the positive pole to titanium filings (direct connection); in the second, the opposite was true (reverse connection).

The iron oxide-titanium system in this case represented a source of direct current emf, connected to the overall electrical circuit.

In all these experiments, the rate of iron oxide reduction was virtually identical to the rate previously recorded in experiments without a direct current source.

The experiments conducted allow us to conclude that during the reduction of copper oxide by metallic titanium, a potential difference arises between the oxide and the titanium. Assuming that the partial pressure of negatively charged oxygen ions above the oxide is proportional to the equilibrium partial pressure of oxygen above it, the occurrence of this potential difference can be explained as follows. In this case, the partial pressure of ionized oxygen above iron oxide should be greater than that above the titanium dioxide coating the titanium surface. When iron and titanium oxide samples are combined, the positive charge on the iron oxide sample is greater because it releases a greater number of negatively charged oxygen ions into the gas phase. Thus, a potential difference arises between the iron and titanium oxide samples, with iron oxide having a positive charge and titanium having a negative charge. This potential difference was recorded in the experiments described above. When an external electrical circuit is closed, an electric current is observed, disrupting the equilibrium in the iron oxide-titanium-oxygen ion gas-phase system. The system attempts to restore equilibrium by further releasing oxygen ions from the iron oxide and reacting with titanium. Thus, in the external electrical circuit, charge transfer from titanium to iron oxide is accomplished by electrons, while in the internal circuit, charge transfer from iron oxide to titanium is accomplished by negatively charged oxygen ions. The current in this system is too low for the mass transfer of ionized oxygen to make a significant contribution to the overall rate of iron oxide reduction.

The conducted studies experimentally confirmed the possibility of ionic dissociation of iron oxide with the release of negatively charged oxygen ions into the gas phase during its reduction with metallic titanium using a contactless method. During the reduction of iron oxide with metallic titanium, conditions were created for an electrochemical reduction mechanism through the exchange of oxygen ions and electrons between the oxide and the reducing agent. However, due to its poor mass transfer characteristics, this mechanism cannot significantly contribute to the overall rate of iron oxide reduction.

Thus, most of the views expressed in the literature on the mechanism of metal oxide reduction are not at all contradictory. They all describe a single process of metal oxide reduction, the mechanism of which significantly depends on the combined influence of many different factors, many of which can already be listed. These include the physicochemical properties of the oxides being reduced, the reducing agents used, and their reaction products, temperature, gas phase pressure, oxygen partial pressure in the system, and other factors influencing the conditions for internal and external diffusion. The key stages of metal oxide reduction and the contribution of each mechanism to the overall reduction process depend on the balance of these factors.

The reduction of metal oxides from liquid slags with carbon can occur through direct interaction. This mechanism is called direct reduction; it is similar to the process of metal cementation from aqueous solutions and can be accompanied by the exchange of oxygen ions and electrons between the metal oxide and the reducing agent. X-ray observation of the reduction of iron oxide with solid carbon showed that direct

reduction occurs only during the initial phase of their interaction. The carbon is then coated with a gas film, which disrupts the contact between the carbon and the slag, and the direct reduction process virtually ceases. The process then continues similarly to the reduction of solid oxides involving the gas phase.

The presented material on the mechanism of the process of reduction of metal oxides and its critical analysis showed that, despite numerous studies conducted in this area, there is no consensus on the mechanism of reduction yet, however, the general trend in the development of ideas on the mechanism of reduction of metal oxides indicates a convergence of previously existing ideas and the need to create a unified theory of the process.

Conclusion

The possibility of reduction processes accompanied by the release of oxygen into the gas phase has been experimentally confirmed.

The experimental results also confirmed the possibility of ion dissociation of iron oxide with the release of negatively charged oxygen ions into the gas phase during its reduction by metallic titanium using a non-contact method.

It was established that the reduction process can proceed via different mechanisms depending on the external conditions, as well as the properties of the oxides and the reducing agents used.

Acknowledgement. This work was supported by the Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University in Almaty, the Republic of Kazakhstan, and the Ministry of Education and Science of the Republic of Kazakhstan, grant numbers AP26101273.

Cite this article: Alybayeva, D.Kh., Kenzhaliyev, B.K., Dyussebekova, M.A., Gemeal, A. (2025). Study of the Ion Dissociation Process during the Reduction of Metal Oxides. Materials of International Scientific-Practical Internet Conference "Challenges of Science". Issue VII, pp. 61-65. https://doi.org/10.31643/2025.06

References

El-Geassy, A. A., Halim, K. A., Bahgat, M., Mousa, E. A., El-Shereafy, E. E., & El-Tawil, A. A. (2013). Carbothermic reduction of Fe2O3/C compacts: Comparative approach to kinetics and mechanism. Ironmaking & Steelmaking, 40(7), 534-544. https://doi.org/10.1179/1743281212Y.0000000076

Geld, P.V. (1957). The role of the gas phase in the reduction of oxides by solid carbon. Chemistry and technology of rare elements. TR. Institute of Chemistry, UFAN USSR. Sverdlovsk. Issue 8. – pp. 8-14.

Hammam, A., Nasr, M. I., El-Sadek, M. H., Omran, M., Ahmed, A., Li, Y., Xiong, Y., & Yu, Y. (2022). Comparative Study on the Isothermal Reduction Kinetics of Iron Oxide Pellet Fines with Carbon-Bearing Materials. Sustainability, 14(14), 8647. https://doi.org/10.3390/su14148647

Kenzhaliyev, B. K., Kvyatkovskiy, S. A., Dyussebekova, M. A., Semenova, A. S., & Nurhadiyanto, D. (2022). Analysis of existing technologies for depletion of dump slags of autogenous melting. Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex use of mineral resources, 323(4), 23-29. https://doi.org/10.31643/2022/6445.36

Yuan, X., Luo, F., Liu, S., Zhang, M., & Zhou, D. (2021). Comparative study on the kinetics of the isothermal reduction of iron ore composite pellets using coke, charcoal, and biomass as reducing agents. Metals, 11(2), 340. https://doi.org/10.3390/met11020340

Zhang, Y. L., Guo, W. M., Liu, Y., & Jia, X. L. (2016). Reduction mechanism of Fe_2O_3-Cr_2O_3-NiO system by carbon. Journal of Central South University, 23(6), 1318-1325. https://doi.org/10.1007/s11771-016-3182-1

Issue VIII, 22 November 2025
e-ISSN 2707-9481 Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University, Almaty, Kazakhstan
ISBN978-601-323-547-9 https://doi.org/10.31643/2025.07

Sergey Trebukhov
Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan
E-mail: s.trebukhov@satbayev.university
ORCID ID: https://orcid.org/0000-0001-9708-0307

Alina Nitsenko
Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan
E-mail: nitc@inbox.ru
ORCID ID: https://orcid.org/0000-0001-6753-0936

Bagdaulet Kenzhaliyev
Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan
E-mail: bagdaulet_k@satbayev.university
ORCID ID: https://orcid.org/0000-0003-1474-8354

Xenia Linnik
Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan
E-mail: xenija_linnik@mail.ru
ORCID ID: https://orcid.org/0000-0002-0683-1409

Valeriy Volodin
Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan
E-mail: volodinv_n@mail.ru
ORCID ID: https://orcid.org/0000-0003-0116-1423

Alexey Trebukhov
Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan
E-mail: yexala88@mail.ru

Extraction of selenium from substandard non-ferrous metallurgical feedstock

Abstract: In this paper, an innovative process for the extraction of selenium from substandard selenium-containing raw materials obtained at copper smelters is proposed. The process has been tested on an enlarged scale under the developer's conditions and implemented on an industrial scale for the first time in the Republic of Kazakhstan. The implementation of this development has enabled the Republic of Kazakhstan to transition from a country reliant on raw materials to a new level: a country producing high-tech products in demand on all global metal markets. This work was awarded a high Government award in 2025 – the Al-Farabi Prize in Science and Technology.

Keywords: selenium, refining, rough selenium, vacuum distillation, introduction, impurities, purification.

Introduction

The use of selenium by humankind has a history spanning more than one hundred and thirty years (Kudryavtsev, 1961). Selenium has found extensive applications in radio electronics, phototechnology, metallurgy, the rubber industry, organic synthesis, and glass production (Analytical review, 2018). Selenium with a main-component content of no less than 99.5%, corresponding to grade ST1 (GOST 10298-2018, 2018), is in particularly high industrial demand and is primarily intended for export.

According to USGS estimates (U.S. Geological Survey, 2019), global selenium consumption is distributed as follows: 40% in metallurgy (including manganese production), 25% in glass manufacturing, 10% in agriculture, 10% in the production of chemicals and pigments, 10% in the electronics industry, and 5% in other sectors. The main sources of selenium production include the roasting of waste from sulfuric acid plants, pulp-and-paper mills, and the processing of anode slimes from copper electrorefining plants (Kudryavtsev, 1961). The selenium dioxide (SeO_2) generated in these processes is reduced with sulfur dioxide (SO_2) to elemental selenium, which is then upgraded to commercial-grade material by recrystallization, vacuum distillation, hydride-based purification, and other methods (Volodin & Trebukhov, 2017).

The high reactivity of selenium complicates its purification from most impurities. To address this issue, various technological schemes and industrial equipment have been developed to improve both the quality and the quantity of produced technical selenium (Kenzhaliev et al., 2018).

The Republic of Kazakhstan is one of the world's major regions possessing significant reserves of rare and rare-earth metals (Rakishev, 2016). With the growing production of solar cells, laser systems, LED lamps, and photodetectors, selenium has become a strategically important raw material. The primary producers of technical selenium in Kazakhstan are Kazakhmys Corporation LLP and Kazzinc LLP. However, these major metallurgical enterprises obtain selenium in non-commercial form as a by-product of their primary operations; its value is nearly an order of magnitude lower than that of commercial-grade selenium, which plays a critical role in the semiconductor and high-tech industries (Kenzhaliev et al., 2018; Dodonov, 2011).

Current global economic conditions demand the production of high-value products with significant added value. The collapse in global copper prices (Naumov & Naumova, 2010) contributed to the establishment in 2022 of a selenium refining unit at the production site of Kazakhmys Progress LLP (Balkhash, Republic of Kazakhstan), processing crude selenium produced at the Balkhash Smelting Plant of Kazakhmys Smelting LLP.

The main part of the research

The Laboratory of Vacuum Processes of the "Institute of Metallurgy and Ore Beneficiation" JSC at Satbayev University (Almaty, Republic of Kazakhstan) has developed a vacuum-distillation technology for crude selenium refining using vapor filtration (Innovation Patent No. 28695, 2013; Innovative patent No. 27273, 2012; Patent No. 37275, 2023).

The Republic of Kazakhstan is one of the world's largest producers of technical-grade selenium, a material exhibiting semiconductor and optical properties. These unique characteristics have enabled selenium to be widely used in the production of semiconductors and solar cells, driving a growing global demand for high-purity selenium. At the facilities of Kazakhmys Smelting LLP, using a technology developed by the JSC "Institute of Metallurgy and Ore Beneficiation" of Satbayev University, the first industrial-scale production of refined selenium from crude selenium feedstock has been established in Kazakhstan (Kazakhmys, 2025).

The production capacity is 70 t/year, with the potential to increase throughput to 140 t/year. The process is environmentally clean (carried out in sealed equipment that prevents toxic emissions), reagent-free (based on the physical properties of selenium), and allows the recovery of up to 2 kg of gold and up to 60 kg of silver annually that were previously lost during the sale of crude selenium (Table 1).

Table 1. The dynamics of global selenium prices over the years:

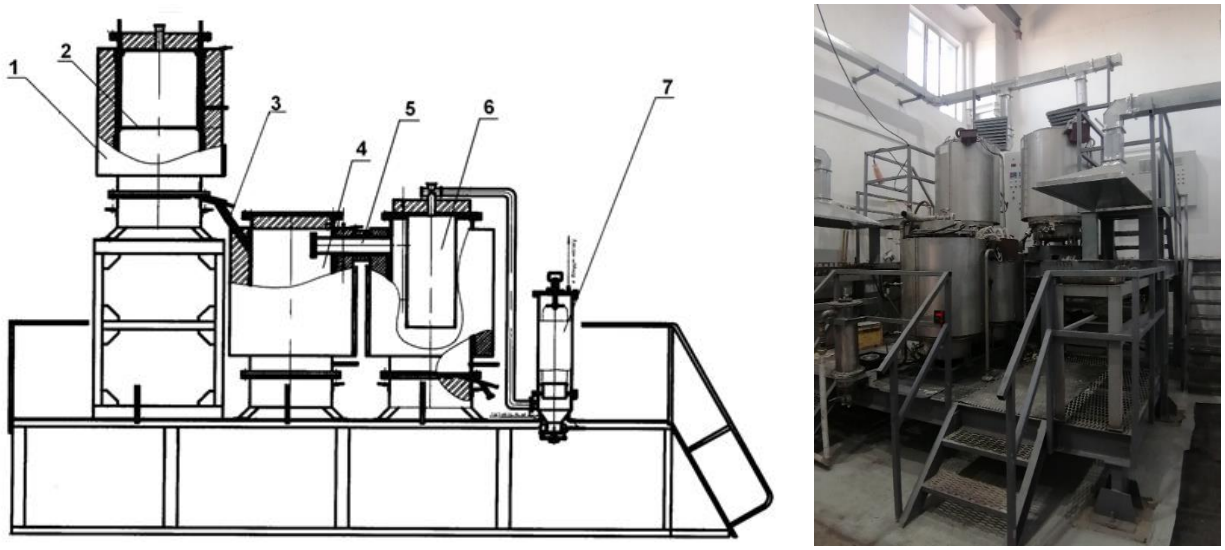
Year	2004	2006	2010	2014	2017	2024
Price in USD per kg	4.0	42.0	165.0	85.0	60.0	38.0

The present work provides the results of technological trials of this process and equipment.

The bulk density of dried crude selenium is 1.7 g/cm³ without tapping and 2.12 g/cm³ with tapping; the angle of repose is 47°. X-ray fluorescence analysis using an Axios PANalytical wavelength-dispersive spectrometer determined the following elemental composition, wt. %: 89.511 Se; 2.032 O; 1.594 S; 0.766 Mg; 0.759 Na; 1.684 Pb; 0.311 Al; 1.011 Te; 1.595 Cl; 0.101 Ag; 0.109 Si; 0.199 Sb; 0.131 Cu; 0.112 Fe; 0.003 P; 0.082 As. X-ray diffraction analysis performed on a D8 Advance (BRUKER) diffractometer with Co radiation identified the following major phases in the crude selenium: Se (Selenium); $AsSe_9Cu_{0,05}$ (Copper Arsenic Selenide); CSe_2 (Carbon Selenide).

The technological scheme for producing commercial-grade selenium at Kazakhmys Progress LLP includes preliminary washing of crude selenium to neutral pH to remove residual acidity, followed by drying in a vacuum oven at 95-105 ℃ and a residual pressure of 40.0 kPa until the moisture content falls below 3%. The material is then fed into a melting furnace, where residual moisture is removed, and the material undergoes zone refining (seigeration) with melt filtration through a metal mesh at 460-480 ℃ under atmospheric pressure. The remelted crude selenium is delivered via heated pipelines to the evaporator of the vacuum distillation unit. Distillation is conducted at 440-460 ℃ in the evaporator and 160-180 ℃ in the

condenser under a residual pressure of 0.13-0.4 kPa with continuous vacuum pumping. The refined selenium is cast into molds at atmospheric pressure, producing ingots weighing 4.8-5.5 kg. The dry distillation residue, enriched in precious metals, is returned to the head of the process for treatment in the Kaldo furnace. The figure shows the apparatus chain of the vacuum distillation unit and a photograph of the industrial selenium-refining area.



a) b)

a) Circuit diagram of the apparatus: 1 - intake melting furnace; 2 - "false bottom" in the furnace; 3 - heated pipeline; 4 - evaporator; 5 - steam line; 6 - condenser; 7 - bag filter; b) - photo of the production site.

Figure 1. Circuit diagram of a vacuum distillation unit for refining rough selenium and a photograph of the production site of Kazakhmys Progress LLP for refining rough selenium in Balkhash

To determine the content of the main and impurity elements, a sample of remelted selenium taken after the melting furnace was analyzed by X-ray fluorescence. The composition, wt. %, was: 95.611 Se; 1.639 O; 0.371 S; 0.238 Mg; 0.296 Na; 0.465 Pb; 0.077 Al; 0.621 Te; 0.516 Cl; 0.011 Ag; 0.071 Si; 0.032 Sb; 0.021 Cu; 0.031 Fe. The yield of remelted, filtered selenium was ~74%, while slag constituted ~24%. The material balance discrepancy of - 0.35% is attributed to the relatively constant quantity of selenium retained as skull (garnisage) on the bottom of the melting furnace. Selenium distribution across the process products was as follows: 79.9% of selenium transferred into the melt (and subsequently into the vacuum distillation unit), and 16.4% remained in the slag.

The silver content in products after seigeration was determined by XRF analysis and amounted to: 0.393 wt. % in slag and 0.011 wt. % in remelted selenium. Thus, 91.76% of the silver contained in crude selenium was transferred into the slag.

As a result of vacuum distillation of the remelted crude selenium, a metal containing 99.54% of the main component was obtained, corresponding to grade ST1 according to GOST 10298–2018 [3], suitable for export. XRF analysis of the refined selenium ingots showed the following composition, wt. %: 99.543 Se; 0.217 O; 0.003 S; 0.003 Pb; 0.021 Mg; 0.007 Ni; 0.005 Al; 0.122 Te; 0.005 Cl; 0.003 Si; 0.031 Sb; 0.033 Cr; 0.002 Cu; 0.005 Fe. The yield of refined selenium was 96.07%. Selenium recovery to the raffinate was 98.96%. No selenium was detected in the particulate residue after distillation, whereas the silver content in this residue was 2.05 wt. %.

Additional recovery of selenium from melting-furnace slags through vacuum distillation increases its overall extraction to 94.1%. However, this significantly increases energy consumption and, consequently, processing costs. Therefore, melting-furnace slags, which constitute ~20% of the output and contain considerable amounts of precious metals, are fed to the head of the process - the Kaldo furnace - for further selenium extraction. This technological approach ensures more stable operation of vacuum equipment and reduces losses of selenium and noble metals across the range of intermediate products formed during the processing of commercial-grade crude selenium (secondary sublimates and residues).

Conclusions

The industrial-scale implementation of this work has enabled the Republic of Kazakhstan to produce refined selenium with a purity exceeding 99.9%, which is in high demand across global metal markets. In early 2025, more than 100 tonnes of refined selenium were exported. At present, efforts are underway to produce ultra-high-purity selenium with a purity level above 99.99%.

Acknowledgement. This work was supported by the Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University in Almaty, the Republic of Kazakhstan / Ministry of Education and Science of the Republic of Kazakhstan, grant numbers AP32723179.

Cite this article: Trebukhov S., Kenzhaliyev B., Volodin V., Nitsenko A., Linnik X., Trebukhov A. (2025). Extraction of selenium from substandard non-ferrous metallurgical feedstock. Materials of International Scientific-Practical Internet Conference "Challenges of Science". Issue VIII, pp. 66-69. https://doi.org/10.31643/2025.07

References

Analytical review. (2018). *The global and Russian selenium and tellurium market 2018* (2nd ed.). MetalResearch, International Metallurgical Research Group. https://www.metalresearch.ru/pdf/World_Rus_Se_Te_mark.pdf *(In Russ.)*

Dodonov, V. Y. (2011). *The global crisis and trends in economic development of Kazakhstan*. Kazakh Institute for Strategic Studies under the President of the Republic of Kazakhstan. https://www.readcube.com/articles/10.2139/ssrn.2322826 *(In Russ.)*

GOST 10298-2018. (2018). *Selenium technical: Technical specifications* (Introduced February 1, 2019). https://internet-law.ru/gosts/gost/69856/ *(In Russ.)*

Kazakhmys. (2025, February 5). *Kazakhmys has shipped the first batch of technical selenium* [Press release]. https://www.kazakhmys.kz/ru/news/item-otgruzka-tex-selena *(In Russ.)*

Kenzhaliev, B. K., Trebukhov, S. A., Volodin, V. N., Trebukhov, A. A., & Tuleutai, F. H. (2018). Extraction of selenium from industrial products of metallurgical production. *Kompleksnoe Ispolzovanie Mineralnogo Syra*, 4(307), 56–64. https://doi.org/10.31643/2018/6445.30 *(In Russ.)*

Kenzhaliev, B. K., Volodin, V. N., Trebukhov, S. A., Ospanov, E. A., & Shakhalov, A. A. (2025). *Method of refining substandard selenium by vacuum distillation and apparatus for its implementation* (Republic of Kazakhstan Patent No. 37275). Institute of Metallurgy and Enrichment. https://gosreestr.kazpatent.kz/Invention/Details?docNumber=388600 *(In Russ.)*

Khrapunov, V. E., Abisheva, Z. S., Marki, I. A., et al. (2013). *Installation for refining rough selenium* (Republic of Kazakhstan Innovation Patent No. 27273). JSC Center for Earth Sciences, Metals and Enrichment. https://gosreestr.kazpatent.kz/Invention/Details?docNumber=198797 *(In Russ.)*

Khrapunov, V. E., Marki, I. A., & Adylkanova, M. A. (2014). *Method for extracting selenium from selenium-containing products* (Republic of Kazakhstan Innovation Patent No. 28695). JSC Center for Earth Sciences, Metallurgy and Enrichment. https://gosreestr.kazpatent.kz/Invention/Details?docNumber=219432 *(In Russ.)*

Kudryavtsev, A. A. (1961). *Chemistry and technology of selenium and tellurium*. Vysshaya Shkola. https://www.studmed.ru/kudryavcev-aa-himiya-i-tehnologiya-selena-i-tellura_7ff23b035ad.html *(In Russ.)*

Naumov, A. V., & Naumova, M. A. (2010). Global selenium and tellurium markets: Their condition, the crisis and its consequences. *Non-Ferrous Metals*, (11), 6–10. https://www.rudmet.ru/journal/431/article/3606/ *(In Russ.)*

Rakishev, B. R. (2016). Restructuring of products of the mining and metallurgical complex of Kazakhstan. *Mining Information and Analytical Bulletin*, (12), 293–305. https://www.giab-online.ru/files/Data/2016/12/293_305_12_2016.pdf *(In Russ.)*

U.S. Geological Survey. (2019). *Mineral commodity summaries 2019* (pp. 146–147). https://doi.org/10.3133/70202434

Volodin, V. N., & Trebukhov, S. A. (2017). *Distillation processes of selenium extraction and refining*. Tengri Ltd. https://doi.org/10.31643/2016-2019.002 *(In Russ.)*

Issue VIII, 22 November 2025
e-ISSN 2707-9481 Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University, Almaty, Kazakhstan
ISBN978-601-323-547-9 https://doi.org/10.31643/2025.08

Baishibekov Arman
Institute of Metallurgy and Ore Beneficiation JSC,
Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan
E-mail: a.baishibekov@satbayev.university
ORCID ID: https://orcid.org/0000-0003-3704-9425

Toylanbai Gulnara
Institute of Metallurgy and Ore Beneficiation JSC,
Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan
E-mail: g.toilanbay@satbayev.university
ORCID ID: https://orcid.org/0000-0001-5926-6610

Rhenium and Rare Dispersed Elements: Resource Base, Hydrometallurgical Extraction Pathways, and Advanced Polymer-Based Sorption Technologies

Abstract: Rhenium and some trace elements are different from other metals. Their importance comes from the fact that they are used in high-temperature alloys, optoelectronic devices, catalytic systems, and energy technologies. Because they are rare in nature and are often found in small amounts in copper, molybdenum, zinc, and aluminum ores, it is hard to extract them. This depends on how the metallurgical industry works and how much money it makes. This, along with the fact that the quality of the ore is getting worse, has brought to light a wider range of raw materials, such as off-gases, metallurgical dust, coal waste, and spent catalysts. Hydrometallurgical methods are the main ways to extract minerals. They include different combinations of leaching, ion exchange, solvent extraction, and sorption. Polymeric materials, particularly interpolymer hydrogel systems made of polymethacrylic acid and poly-4-vinylpyridine, have become useful for binding perrhenates and trivalent lanthanide ions in the last few years. This is because the interactions between the polymers are controlled and work together in the polymer matrix. These improvements make it possible to extract a wider range of raw materials and open up new ways to selectively extract metals at very low concentrations. This review summarizes information about the geological and anthropogenic resource base, the most common ways to get rhenium and trace elements, and the latest technological advances in processing these materials.

Keywords: rhenium; rare elements; hydrometallurgical extraction; technogenic raw materials; sorption; interpolymer hydrogel systems; ion exchangers; poly (methacrylic acid); poly (4-vinylpyridine); polymer–polymer complexes; sorbent materials; critical metals; resource recovery; microwave-assisted leaching.

Introduction

Rhenium, along with the metals categorized as "rare dispersed" elements — gallium, germanium, indium, selenium, tellurium, and thallium — comprises a set of resources valued primarily for their particular technological uses rather than the quantity of their extraction. They don't usually form distinct mineral assemblages as other non-ferrous metals do. Instead, they are found in small amounts spread out throughout the lattices of sulfides, silicates, oxides, and substances made from coal. The processing of copper, molybdenum, zinc, and aluminum is mostly what makes them available. This means that changes in the production of these main metals have a direct effect on the stability of supply chains (European Commission, 2023).

Rhenium is the one that is most limited in terms of where it can be found and how it can be used. It is mostly found in molybdenite, where it replaces molybdenum in a very small amount, with an average crustal abundance of about one part per billion. Thus, the roasting of molybdenum concentrates, and, in some cases, catalytic processes are closely related to industrial recovery. High levels of rhenium have been found in different porphyry copper-molybdenum systems, such as deposits in Chile, the United States, Kazakhstan, and Armenia (Werner et al., 2023; Wang et al, 2021). The stability of the perrhenate ion (ReO_4^-) in different oxidizing environments is an important reason why hydrometallurgical methods are so popular in modern industry.

The conditions for other distributed elements are just as complicated. Gallium is often extracted from bauxite liquors, germanium from sphalerite or coal-related substances, and selenium and tellurium from anode slimes produced during copper electrorefining. They have many uses, such as supporting III–V semiconductor technologies, broadband optical fibers, transparent conductive coatings, and thermoelectric modules (European Commission, 2023). The production of renewable energy systems and modern electronics is not keeping up with the rising demand for them.

A lot of problems that won't go away are making it hard for them to get better. This includes very small amounts in most feedstocks, chemical affinity for main elements that limits selectivity, and the instability of certain oxidation states, especially in phases that contain germanium and tellurium. As a result, industrial wastes like smelter dust, used catalysts, coal fly ash, and zinc production recycling liquors have become interesting as possible feedstocks that can be used to make primary ores (Joo & Kinas, 2012; Arroyo et al, 2009; Haghighi et al., 2018; Kim et al., 2015).

Hydrometallurgical methods are still the most important part of modern processing systems. Gallium and germanium are often leached under conditions of chloride or fluoride; indium needs a very precise pH range; and rhenium in the form of ReO_4^- is best for ion-exchange and sorption techniques. New technologies like ionic solutions, membrane separation, and microwave activation have made it easier to work with complicated or low-quality materials (Prusty et al., 2021).

Mineralogical position and global distribution of rhenium and trace elements

Rhenium and trace elements have a very uneven distribution, which is what makes them different from most metals. Rhenium is mostly found in molybdenite, where it can be found in amounts of hundreds of grams per ton. In most copper-molybdenum porphyry deposits, the amount of rhenium in molybdenite ranges from 0.5 to 30 g/t, and in bulk ore, it is less than 1 g/t. Because of this low abundance, there aren't many deposits that can be thought of as economically important. Gallium and germanium have similar problems. They are usually found in bauxite, sphalerite, and coal deposits, but they don't often form their own mineral formations. Because these elements are spread out, they need to be processed in a way that combines recovery with the production of major industrial metals. For instance, gallium is taken from bauxite during Bayer processing, germanium is taken from zinc sulfide concentrates and coal fly ash, and tellurium is taken from anode slimes during copper electrorefining. Because of this interdependence, the supply of dispersed elements is at risk of changes in base metal production and the limits of current refinery processes.

Secondary and technogenic materials as an emerging resource base

The decline in ore grades and the growing difficulty of mining operations have made people more interested in secondary technogenic sources. Metallurgical off-gases, dusts, sludges, spent catalysts, and waste materials from the copper, molybdenum, and zinc industries often have dispersed elements in higher amounts than natural ores. For example, the amount of rhenium in flue dusts or roaster gases can be hundreds of parts per million (ppm), which makes secondary extraction possible. Spent platinum–rhenium catalysts from the petrochemical industry are some of the best secondary sources because they can contain up to several percent rhenium.

Processing technogenic materials has a number of benefits. For example, the material is often already in a fine-grained or oxidized state, which makes leaching easier. Also, there is less waste, which is good for the environment, and the overall energy footprint is lower than mining virgin ores. As demand around the world grows, secondary resources are likely to become a big part of the supply chain for rhenium and dispersed elements.

Hydrometallurgical pathways for the recovery of rhenium and dispersed elements

Hydrometallurgy is the main way to get rhenium and other trace elements back because the ionic states in solution make it possible to control dissolution and separation very precisely. The speciation of these metals under different redox conditions affects the effectiveness of leaching regimes and the planning of future purification processes.

Acidic leaching is still widely used for germanium, gallium, and indium because solutions based on chloride and sulfate make it easier to make soluble compounds. Acidic conditions make it easier to extract rhenium, especially when the element is in oxidized residues, which helps it dissolve (Mahmoudi et al., 2021).

Alkaline leaching works better for metals that are amphoteric or have stable anionic forms, like gallium and tellurium. These situations often improve selectivity by stopping other drugs from working.

Oxidative leaching is very important for getting rhenium out of the ground. Strong oxidizing agents like nitric acid, hydrogen peroxide, or the oxidizing environment created during roasting help change rhenium compounds into perrhenate ion, which is important for the next steps in the separation process.

New technologies and advanced methods for extraction processes

• Ion exchange methods work well for ReO_4^-. These allow for selective extraction using anion exchange resins or specially designed polymer sorbents, as well as solvent extraction for indium, gallium, and Germanium using organophosphorus extractants (Redlinger et al., 2015).

• Ways to make GeO_2 by precipitation;

• Sorption on functionalized polymers with a strong attraction to perrhenate and similar oxyanions;

• Membrane and electrochemical methods are useful because they can lower energy costs and make processes work better together.

New ways of extracting things and new technologies for extraction methods

Over the past ten years, there has been a shift toward more environmentally friendly extraction methods that make it easier to work with more complex feedstocks. Many areas of technology need special attention:

- Ionic liquids and deep eutectic solvents provide controlled solvation conditions and reduced volatility;
- Microwave-assisted leaching is used to speed up dissolution and change how different phases interact;
- Bioleaching of germanium and gallium from coal and zinc processing waste, aided by microbial activity that increases metal mobility;
- Nanostructured sorbents, hybrid polymer-inorganic composites, and novel ion-exchange systems; Employed a combination of hydrometallurgical processes to enhance selectivity and reduce waste.

All of these methods are different from pyrometallurgical methods, which use a lot of power. They are also adaptable and can process various feedstocks at low temperatures.

Interpolymer hydrogel systems and remotely activated ion exchangers are two of the most active areas of research right now. Compared to regular resins, they offer a completely new way to choose. Polymethacrylic acid (PMAA) and poly-4-vinylpyridine (P4VP) are two types of polymer networks that work together in a controlled way to make these materials. When you touch or activate the hydrogels from a distance, they change shape a lot. This rearrangement changes the density and accessibility of ionogenic groups, how the material swells, and creates a microenvironment that makes it easier for oxyanions and multivalent cations to bind. Jumadilov and his team found that systems based on PMAA/P4VP absorb cerium, europium, scandium, and lanthanum better. The polymers interact at the polymer-polymer interface (Jumadilov et al., 2022; Jumadilov & Imangazy, 2023; Suleimenova et al., 2025). Interpolymer systems may demonstrate an atypically high affinity for yttrium, a phenomenon termed "anomalous" sorption, linked to alterations in the internal structure of the polymer network (Jumadilov et al., 2023; Dyussembayeva et al., 2024). Interpolymer systems, such as polyacrylic acid and poly-4-vinylpyridine, exhibit significant potential for rhenium extraction due to their enhanced selectivity for the perrhenate ion (ReO_4^-) in the presence of other anions, a frequent occurrence in industrial solutions (Jumadilov et al, 2024).

These results show that interpolymer systems are a type of sorbent that can be easily changed and is flexible. They can change the chemical environment at the molecular level, which lets them get rhenium and rare elements from both primary and secondary sources in dilute and complex media. Adding them to commercial hydrometallurgical flowsheets in the future will make extraction more efficient and promote more eco-friendly methods.

Proposed new section: results from recent experimental studies

In addition to the broader developments outlined above, recent experimental investigations have provided new insights into the selective extraction of rhenium and dispersed elements from complex, low-grade solutions (Baishibekov et al., 2025). This study aimed to see how well interpolymer hydrogel systems

and remotely operated ion exchangers worked in settings that were similar to technogenic process streams. Special attention in recent studies has been given to solutions containing competing oxyanions and multivalent cations, as such species often reduce the selectivity of conventional sorbents. Experimental observations demonstrate that modifications to microenvironmental polarity and swelling characteristics of poly (methacrylic acid): poly (4-vinylpyridine) interpolymer networks can significantly affect their ion-binding interactions. Researchers found that this tunability changed both the ability to absorb ions and the order in which they bind when there were several trace components present at the same time. Enhanced stabilization of perrhenate within the tailored interpolymer matrix resulted in consistently higher distribution coefficients compared with conventional anion-exchange resins. Comparable behavior was observed for lanthanide and yttrium ions, suggesting that the underlying mechanisms are linked to cooperative conformational adjustments within the polymer network.

These findings represent an early stage in the development of such materials but highlight their potential as adaptable platforms for metal-ion separation. Their capacity to function effectively in the presence of diverse impurity ions is particularly relevant for industrial environments, where feed compositions fluctuate, and target metals are often present at trace levels.

Conclusion

As technology-driven industries continue to expand, the strategic importance of rhenium and dispersed trace elements becomes increasingly evident. Their distinctive chemical and physical characteristics support a wide range of applications, including high-temperature superalloys, catalytic systems, optoelectronic components, and renewable-energy technologies. Despite this significance, the extraction of these metals remains challenging due to their low natural abundances, dispersed mineralogical occurrences, and dependence on by-product recovery from major base-metal operations.

Recent advances point to a gradual shift toward hydrometallurgical methods that prioritize selectivity and reduce environmental impact. Progress in solvent extraction, solid-phase sorption, ionic-liquid systems, and alternative leaching strategies has broadened the possibilities for treating primary ores as well as secondary, technogenic materials. The diversification of resource bases through the use of recycled and industrial residues is becoming increasingly important as global demand continues to rise.

Sustained development of integrated and adaptable recovery processes will be essential to ensuring the long-term availability of rhenium and dispersed trace elements in a rapidly evolving technological landscape.

Cite this article as: Baishibekov, A., Toylanbai, G. (2025). Rhenium and Rare Dispersed Elements: Resource Base, Hydrometallurgical Extraction Pathways, and Advanced Polymer-Based Sorption Technologies. Materials of International Scientific-Practical Internet Conference "Challenges of Science". Issue VIII, 2025, pp. 70-74 https://doi.org/10.31643/2025.08

References

Arroyo, F., Fernández-Pereira C., Olivares, J., Coca, C. (2009). Hydrometallurgical Recovery of Germanium from Coal Gasification Fly Ash: Pilot Plant Scale Evaluation. Ind. Eng. Chem. Res., 48, 7, 3573–3579. https://doi.org/10.1021/ie800730h

Baishibekov, A.; Fischer, D.; Jumadilov, T.; Temirova, S.; Yulusov, S.;Altaibayev, B.; Karim, D. (2025). Structural, Sorption, and Regeneration Properties of Poly(methacrylic acid): Poly(4-vinylpyridine) Interpolymer Systems for the Recovery of Rhenium and Molybdenum. Polymers. 17, 3054. https://doi.org/10.3390/polym17223054

Dyussembayeva, G., Jumadilov, T., Mukataeva, Z., Suleimenova, M., Grazulevicius, J. (2024). Characteristics of mutual activation of an intergel system based on hydrogel polymethacrylic acid and poly-4-vinylpyridine. Chemical Journal of Kazakhstan. 2(86), 94–104. https://doi.org/10.51580/2024-2.2710-1185.25

European Commission. (2023). Critical Raw Materials Report. Publications Office of the European Union. ISBN 978-92-68-07237-9. https://doi.org/10.2873/725585

Haghighi, H.K., Irannajad, M., Fortuny, A., Sastre, A.M. (2018). Recovery of Germanium from leach solutions of fly ash using solvent extraction with various extractants, Hydrometallurgy, 175, 164-169. https://doi.org/10.1016/j.hydromet.2017.11.006.

Imangazy, A., Jumadilov, T., Khimersen, Kh., Bayshibekov, A. (2023). Enhanced sorption of europium and scandium ions from nitrate solutions by remotely activated ion exchangers. Polymers. 15(5), 1194. https://doi.org/10.3390/polym15051194

Joo, S-H, Kim, Y-U., Kang, J-G., Kumar, J. R., Yoon, H-S., Parhi, P. K., Shin, Sh. M. (2012). Recovery of Rhenium and Molybdenum from Molybdenite Roasting Dust Leaching Solution by Ion Exchange Resins. Materials Transactions. 53, 2034-2037. https://doi.org/10.2320/matertrans.M2012208

Jumadilov, T.K., Malimbayeva, Z., Yskak, L., Zhuzbayeva, A., et al. (2022). Comparative characteristics of polymethacrylic acid hydrogel sorption activity in relation to lanthanum ions in different intergel systems. Chemistry & Chemical Technology. 16(3), 418–431. https://doi.org/10.23939/chcht16.03.418

Jumadilov, T., Totkhuskyzy, B., Imangazy, A., Gražulevičius, J. (2023). Anomalous sorption of yttrium ions by the mutual activated hydrogels in the interpolymer system of poly(methacrylic acid) and poly(4-vinylpyridine). Chemistry & Chemical Technology. 17(1), 52–59. https://doi.org/10.23939/chcht17.01.052

Jumadilov, T., Utesheva, A., Grazulevicius, J., Imangazy, A. (2023). Selective sorption of cerium ions from uranium-containing solutions by remotely activated ion exchangers. Polymers. 15(4), 816. https://doi.org/10.3390/polym15040816

Jumadilov, T.K., Baishibekov, A.M., Fischer, D.E. (2024). Investigation of the efficiency of rhenium ion sorption using ion-exchange resins polyacrylic acid:poly-4-vinylpyridine in various ratios. Chemical Journal of Kazakhstan. 3, 36–44. https://doi.org/10.51580/2024-3.2710-1185.31

Kim, H-S., Park, J.S., Seo, S., Tran. T., Kim, M.J. (2015). Recovery of rhenium from a molybdenite roaster fume as high purity ammonium perrhenate. Hydrometallurgy, 156, 158-164. https://doi.org/10.1016/j.hydromet.2015.06.008

Kinas, S., Jermakowicz-Bartkowiak, D., Pohl, P., Dzimitrowicz, A., Cyganowski, P. (2024). On the path of recovering platinum-group metals and rhenium: A review on the recent advances in secondary-source and waste materials processing. Hydrometallurgy. 223, 106222. https://doi.org/10.1016/j.hydromet.2023.106222

Mahmoudi, A., Shakibania, S., Mokmeli, M., Rashchi, F., Karimi, H.Y. (2021). Selective Separation and Recovery of Tellurium from Copper Anode Slime Using Acidic Leaching and Precipitation with Cuprous Ion. J. Sustain. Metall. 7, 1886–1898. https://doi.org/10.1007/s40831-021-00462-z

Prusty, S., Pradhan, S., Mishra, S. (2021). Ionic liquid as an emerging alternative for the separation and recovery of Nd, Sm and Eu using solvent extraction technique-A review. Sustainable Chemistry and Pharmacy. 21, 100434. https://doi.org/10.1016/j.scp.2021.100434

Redlinger, M., Eggert, R., Woodhouse, M. (2015). Evaluating the availability of gallium, indium, and tellurium from recycled photovoltaic modules. Solar Energy Materials and Solar Cells. 138, 58-71. https://doi.org/10.1016/j.solmat.2015.02.027

Suleimenova, M., Jumadilov, T., Gražulevičius, J.V. (2025). Electrochemical and conformational properties of polyacrylic acid and poly-2-methyl-5-vinylpyridine hydrogels during their remote interaction in aqueous environment. Chemical Journal of Kazakhstan. 2024–4, Article 48. https://doi.org/10.51580/2024-4.2710-1185.48

Wang, X., Zeng, F., Deng, F., Bian, J., Pan, Zh. (2021). Rhenium in Chinese coals, a review. Arab J Geosci 14, 1411. https://doi.org/10.1007/s12517-021-07793-x

Werner, T.T., Mudd, G.M., Jowitt, S.M., Huston, D. (2023). Rhenium mineral resources: A global assessment. Resources Policy. 82, 103441. https://doi.org/10.1016/j.resourpol.2023.103441

Issue VIII, 22 November 2025
e-ISSN 2707-9481 Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University, Almaty, Kazakhstan
ISBN978-601-323-547-9 https://doi.org/10.31643/2025.09

Arailym Mukangaliyeva
Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan
E-mail: a.mukangaliyeva@satbayev.university
ORCID ID: https://orcid.org/0000-0001-7032-1764

Sergey Trebukhov
Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan
E-mail: s.trebukhov@satbayev.university
ORCID ID: https://orcid.org/0000-0001-9708-0307

Valeriy Volodin
Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan
E-mail: volodinv_n@mail.ru
ORCID ID: https://orcid.org/0000-0003-0116-1423

Alina Nitsenko
Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan
E-mail: alina.nitsenko@gmail.com.
ORCID ID: https://orcid.org/0000-0001-6753-0936

Xenia Linnik
Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan
E-mail: xenija_linnik@mail.ru
ORCID ID: https://orcid.org/0000-0002-0683-1409

Thermal Decomposition of Mg_2Sn in Vacuum

Abstract: Vacuum distillation of magnesium is considered one of the practical approaches for processing secondary biodegradable alloys of the Mg–Sn system. The process relies on the difference in the partial vapor pressures of magnesium and tin; however, its accurate description requires an understanding of the thermal behavior of the intermetallic Mg_2Sn phase. In the present work, dimagnesium stannide was synthesized, containing 97.8% of the Mg_2Sn phase and 2.8% Sn. The obtained specimen was used to further investigate the decomposition and possible dissociative evaporation of Mg_2Sn to refine the process parameters of magnesium distillation.

Keywords: biodegradable alloy, dimagnesium stannide, magnesium, tin, dissociation, vacuum, dissociation pressure.

Introduction

Magnesium alloys have long attracted the attention of researchers in the fields of materials science, physical chemistry, and metallurgy due to their lightweight, high strength-to-weight ratio, and unique reactivity profiles, which determine their behavior in various environments (Ablakatov et al., 2023). These properties are attributed to magnesium's position in the periodic table as an alkaline earth metal with a low density of approximately 1.74 g/cm³ and a hexagonal close-packed crystal structure, which influences its mechanical properties and alloying potential (Volodin et al., 2024 & Li et al., 2023). In recent decades, the focus has shifted to their biomedical applications, where magnesium-based biodegradable materials offer a novel approach to implants and devices (Chen et al., 2021 & Tamay et al., 2021). Traditionally, metals such as titanium or stainless steel have been used for implants, often requiring secondary procedures for their removal from the body (Wang et al., 2022). In contrast, magnesium alloys naturally degrade in the body, synchronizing with the healing process and minimizing long–term complications (Gan et al.,2021 & Frank et al., 2008).

However, the high reactivity of magnesium with atmospheric gases and its flammability pose safety risks during manufacturing and processing, often requiring inert atmospheres or specialized equipment to prevent oxidation or combustion (Han et al.,2023). Recycling, especially from secondary sources such as used medical implants or industrial waste, remains insufficiently studied despite its environmental, economic, and resource saving importance (Guangling et al., 2007). Traditional remelting can introduce impurities or degrade properties, while the presence of alloying elements complicates separation. This gap is critical for the development of a closed-loop system for biomaterial use, where effective recycling could reduce dependence on primary production and decrease the carbon footprint–recycling magnesium requires only about 5% of the energy needed for primary production (Lipeng et al., 2024)

A promising approach to solving these problems in biodegradable alloys containing tin is vacuum distillation. The method is based on the difference in the partial pressures of the components, which allows selective extraction of the target element followed by its condensation. In the Mg–Sn system, the high volatility of magnesium enables the recycling of magnesium–tin alloys. However, the thermodynamic behavior of the intermetallic phase Mg_2Sn remains insufficiently studied. The compound melts congruently at 770 °C, but data on its behavior at the liquid–vapor boundary and the possibility of its transition into the gas phase without decomposition are lacking. This is critical for correctly constructing the phase diagram, taking into account the evaporation region, and for assessing the risk of magnesium distillate contamination with tin during the potential evaporation of Mg_2Sn.

In light of this, our study aims to experimentally determine the thermal behavior of dimagnesium stannide (Mg_2Sn) upon heating in a vacuum to establish its stability or decomposition in the gas phase and to subsequently optimize the distillation recycling strategy for alloys.

The main part of the research

The object of the study was the synthesized crystalline dimagnesium stannide (Mg_2Sn). Tin with a purity of 99.99 wt.% and magnesium with a purity of 99.99 wt.% (subjected to double distillation) were used as the starting components for the synthesis. For the preparation of the alloy, magnesium and tin were taken in amounts of 23.50 wt.% and 76.50 wt.%, respectively. The synthesis was carried out in an argon atmosphere at a pressure of 500 kPa and a temperature of 1100 °C. The excess pressure was required to prevent the evaporation of magnesium.

X-ray diffraction analysis revealed the presence of a single-phase dimagnesium stannide (97.8 %) in the synthesized sample, along with a small amount of unreacted tin (2.8 %).

The thermal behavior of Mg_2Sn was studied during heating at a constant rate using an apparatus with continuous sample weighing under varying constant gas-phase pressures. During the experiment, it was determined that, upon the decomposition of dimagnesium stannide, elemental magnesium is released and evaporates, which is recorded by the weighing system. Tin, on the other hand, does not evaporate up to 1000 °C due to its low vapor pressure. The temperature at which the sample starts losing mass at this pressure was considered the decomposition temperature of Mg_2Sn.

As a result of a series of experiments, the temperatures for the intense evaporation of the volatile component were determined in the pressure range from 0.13 to 40.00 kPa. The obtained data allowed the development of an approximation equation for the temperature dependence of the dissociation pressure of dimagnesium stannide: $\ln p^D\,[\text{Pa}] = 26{,}695 - 21250 \times T^{-1}$

The dissociation temperature at atmospheric pressure was found to be 1401 K (1128 °C). The enthalpy of dissociative evaporation of magnesium was estimated to be 176.7 ± 16.5 kJ/mol, and the entropy was 126.1 ± 11.8 J/(mol·K).

It was established that during dissociative evaporation, Mg_2Sn decomposes into the metals Mg and Sn, as confirmed by the experiment at 850 °C and 0.67 kPa.

Based on the established decomposition behavior, a series of experiments was conducted on the distillation processing of the synthetic Mg–Sn alloy containing the Mg_2Sn phase and magnesium oxidation products. The material was heated at 800 °C and 0.67 kPa for 1 hour to obtain distillates. Two products were obtained: a magnesium condensate with a silvery color (Figure 1a) and a powdery residue with small spherical granules (Figure 1b). The presence of spherical granules indicates the coalescence of tin droplets after magnesium evaporation from the alloy. Overall, the obtained morphological and analytical data are consistent with the dissociative evaporation mechanism of Mg_2Sn that we have established.

X–ray diffraction analysis showed the following phase composition of the condensate: 91.6 % Mg, 1.52 % Mg_2Sn, and 6.95 % SiO_2. X–ray fluorescence analysis revealed magnesium content of 95.35 %, tin content of 0.25 %, and silicon content of 4.84 %. The presence of Mg_2Sn is explained by the entrainment of the original alloy by the magnesium vapor flow during dissociation, while the presence of SiO_2 is attributed to sample contamination during removal from the condenser surface.

a) b)

Figure 1. Magnesium condensate (a) and residue after distillation with spherical tin granules (b)

Conclusions

Thus, the vacuum thermal evaporation of magnesium from dimagnesium stannide confirms the dissociation of the compound into its elements. The dissociation pressure at the melting temperature (770.5 °C = 1043.5 K) is 560 ± 52 Pa (4.2 ± 0.4 mm Hg), which is consistent with the data from the vacuum thermal process. The vapor pressure of pure magnesium at this temperature is estimated to be 258 Pa, illustrating the simultaneous decomposition of the stannide and evaporation of elemental magnesium under the experimental conditions. During vacuum distillation of the Mg–Sn alloy at pressures above 0.67 kPa, the vapor phase primarily consists of elemental magnesium.

Acknowledgement. This work was supported by the Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University in Almaty, the Republic of Kazakhstan / Ministry of Education and Science of the Republic of Kazakhstan, grant numbers AP26196623.

Cite this article: Mukangaliyeva A., Volodin V., Trebukhov S., Nitsenko A., Linnik X. (2025). Thermal Decomposition of Mg_2Sn in Vacuum. Materials of International Scientific-Practical Internet Conference "Challenges of Science". Issue VIII, pp. 75-78. https://doi.org/10.31643/2025.09

References

Ablakatov, I. K., Ismailov, M. B., Mustafa, L. M., & Sanin, A. F. (2023). Investigation of the technology of introducing Li, Mg, and Zr alloys into aluminum alloy. *Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources*, *327*(4), 32–40. https://doi.org/10.31643/2023/6445.37

Chen, H., Yuan, B., Zhao, R., Yang, X., Xiao, Z., Aurora, A., Iulia, B., Zhu, X., Iulian, A., & Zhang, X. (2021). Evaluation on the corrosion resistance, antibacterial property, and osteogenic activity of biodegradable Mg–Ca and Mg–Ca–Zn–Ag alloys. *Journal of Magnesium and Alloys*, *10*(12), 3380–3396. https://doi.org/10.1016/j.jma.2021.05.013

Gan, L., Qu, W.-Y., Luo, M., Cheng, L., Guo, C., Li, X.-G., Xu, Z., Hu, X.-G., Li, D.-Q., Lu, H.-X., & Zhu, Q. (2021). Semi-solid processing of aluminum and magnesium alloys: Status, opportunity, and challenge in China. *Transactions of Nonferrous Metals Society of China*, *31*(11), 3255–3280. https://doi.org/10.1016/S1003-6326(21)65729-1

Han, Y., Zhou, J., & Zhang, L. (2023). Research progress on biodegradable magnesium alloys for medical applications. *Journal of Magnesium and Alloys*, *11*(3), 789–812. https://doi.org/10.1016/j.jma.2023.02.005

Li, R., Wang, L., Yang, B., Xu, B., Liang, D., Wang, F., & Tian, Y. (2023). Magnesium alloy scrap vacuum gasification–directional condensation to purify magnesium. *Metals*, *13*(4), 675. https://doi.org/10.3390/met13040675

Song, G. (2007). Control of biodegradation of biocompatible magnesium alloys. *Corrosion Science*, *49*(4), 1696–1701. https://doi.org/10.1016/j.corsci.2007.01.001

Tamay, D., Gokyer, S., Schmidt, J., Vlădescu, A., Huri, Y., Hasırcı, V., & Hasırcı, N. (2021). Corrosion resistance and cytocompatibility of magnesium–calcium alloys modified with zinc- or gallium-doped calcium phosphate coatings. *ACS Applied Materials & Interfaces*, *14*(1), 104–122. https://doi.org/10.1021/acsami.1c16307

Volodin, V., Kenzhaliyev, B., Trebukhov, S., Nitsenko, A., Linnik, X., & Trebukhov, A. (2024). On the problem of the distillation separation of secondary alloys of magnesium with zinc and magnesium with cadmium. *Metals*, *14*(6), 671. https://doi.org/10.3390/met14060671

Wang, L., Liang, D., Yu, R., Wang, M., Tian, Y., Ma, T., Yang, B., Xu, B., & Jiang, W. (2024). Progress and prospects in magnesium alloy scrap recycling. *Journal of Magnesium and Alloys*, *12*(12), 4828–4867. https://doi.org/10.1016/j.jma.2024.11.031

Wang, T., Xu, Y., Zhang, Q., Li, G., Guo, Y., Lian, J., Zhang, Z., & Ren, L. (2022). Enhancing the antibacterial properties of magnesium alloys with copper-doped anhydrous calcium phosphate nanoparticles embedded into the polycaprolactone coating for medical implants. *ACS Applied Nano Materials*, *5*(12), 18965–18976. https://doi.org/10.1021/acsanm.2c04778

Witte, F., Hort, N., Vogt, C., Cohen, S., Kainer, K. U., Willumeit, R., & Feyerabend, F. (2008). Degradable biomaterials based on magnesium corrosion. *Current Opinion in Solid State and Materials Science*, *12*(5–6), 63–72. https://doi.org/10.1016/j.cossms.2009.04.001

Issue VIII, 22 November 2025
e-ISSN 2707-9481 Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University, Almaty, Kazakhstan
ISBN978-601-323-547-9 https://doi.org/10.31643/2025.10

Yernazar Kanaly
"Kazmekhanobr" State Scientific Production Association of Industrial Ecology,
Almaty 050036, Kazakhstan
E-mail: ametoz@mail.ru
ORCID ID: https://orcid.org/0000-0002-8168-2626

Bauyrzhan Surimbayev
"Kazmekhanobr" State Scientific Production Association of Industrial Ecology,
Almaty 050036, Kazakhstan
E-mail: surimbaev@gmail.com
ORCID ID: https://orcid.org/0000-0002-3988-8444

Lyudmila Bolotova
"Kazmekhanobr" State Scientific Production Association of Industrial Ecology,
Almaty 050036, Kazakhstan
E-mail: l_bolotova@yahoo.com
ORCID ID: https://orcid.org/0000-0003-0828-9817

Yerlan Yessengarayev
"Kazmekhanobr" State Scientific Production Association of Industrial Ecology,
Almaty 050036, Kazakhstan
E-mail: esengaraev_erlan@mail.ru
ORCID ID: https://orcid.org/0000-0001-8487-7464

Mukhitdin Akzharkenov
"Kazmekhanobr" State Scientific Production Association of Industrial Ecology,
Almaty 050036, Kazakhstan
E-mail: kazatm@mail.ru
ORCID ID: https://orcid.org/0009-0005-1184-7412

Assessment of the Possibility of Using Heap Leaching Technology for Processing Gold-Bearing Ore

Abstract: The article presents the results of technological studies conducted to investigate the material composition and determine the effectiveness of the heap leaching process for gold from a technological sample. These studies included laboratory tests and column tests aimed at assessing the possibilities of extracting gold from oxidized ores.
Keywords: heap leaching, gold-bearing ore, percolation, Portland cement, agglomerated ore, cyanidation, column tests.

Introduction

The heap leaching method is the most cost-effective way to process low-grade ores and industrial waste because it has much lower operating and capital costs than agitation leaching. Despite this, one of the main problems with this method is the presence of fine clay particles in the raw material, which impede the flow of the solution through the heap layer and negatively affect the efficiency of leaching.

For use in heap leaching technology, mineral raw materials must have the following basic characteristics:

- free gold content;
- the ore must have sufficient porosity and permeability;
- absence of metal impurities that compete with gold when dissolved in a cyanide solution and when extracting gold from the productive solution.

The ore's compliance with these parameters ensures the efficiency of the heap leaching process

(Fazlullin 2001), (Karaganova et al., 2002), (Surimbayev et al., 2025).

To conduct an initial assessment of the suitability of raw materials, preliminary tests are carried out on small-scale samples. These studies are usually conducted under agitation leaching conditions on ore samples, which can be achieved in industrial gold ore processing schemes using heap leaching.

The data obtained during the tests make it possible to determine the estimated degree and kinetics of noble metal extraction into cyanide solutions, estimate the consumption of basic reagents, identify possible ore preparation options (including the need for preliminary agglomeration), and select the optimal method for extracting metals from productive solutions. Based on the results of such experiments and taking into account the expected scale of processing, a preliminary conclusion is formed about the possibility and feasibility of using heap leaching technology for this type of raw material (Dementyev et al., 2004).

The paper presents the results of technological studies to determine the possibility of processing oxidized ore from one of the deposits in Kazakhstan using heap leaching technology.

Materials and research methods

The sample of gold-silver-bearing ore consists of weathered siliceous siltstone rocks and a mixture of clayey, gravelly, and crushed material (Figure 1).

Figure 1. Photograph of the initial ore sample

Table 1. Fire assay and chemical analysis results

Component	Content, %	Component	Content, %
Gold, g/t	1.18	Sodium oxide	1.90
Silver, g/t	48.78	Potassium oxide	0.60
Copper	0.0098	Silicon oxide	71.05
Nickel	0.0008	Aluminum oxide	11.00
Zinc	0.0116	Arsenic	0.156
Lead	0.3820	Antimony	0.015
Cobalt	0.0005	Total sulfur	0.37
Total iron	4.40	Sulfate sulfur	0.32
Calcium oxide	1.12	Sulfide sulfur	0.05
Magnesium oxide	0.81	Degree of sulfur oxidation	86.49

Gold and silver represent industrial value in the sample (Table 1), with an average content of 1.18 and 48.78 g/t, respectively, according to assay analysis. The content of competing metals that can interact with cyanide is insignificant: copper and zinc at 0.01%, nickel and cobalt at less than 0.001%. The content of harmful impurities – arsenic and antimony – was 0.156% and 0.015%, respectively. The sample belongs to the low-sulfide type of ore (S sulfide <1%) and, in terms of sulfur oxidation, to the oxidized zone.

Mineralogical studies have revealed the presence of free gold in the form of high-grade gold and electrum, as well as silver in the form of halides. Gold was found in the form of inclusions of various sizes in iron oxides and hydroxides. Phase analysis for gold confirmed the results of mineralogical studies, from which it follows that most of the gold (87.18%) is in free form.

Thus, the chemical composition of the tested ore is favorable for the heap leaching process.

Results and discussions

The ore is physically destructured. Small particles of silt and clay reduce the permeability of the heap, which impedes the flow of the solution and makes the leaching process less effective. For raw materials with a content of fine particles and clay exceeding 15%, preliminary pelletization is required to ensure an acceptable percolation rate (Bolotova et al 2023), (Yessengarayev et al 2018), (Bolotova et al 2020). Sieve analysis results show that crushed ore of various sizes (-50+0 mm, -25+0 mm, and -12+0 mm) contains an increased amount of particles smaller than 2.5 mm, which makes it necessary to evaluate the hydrodynamic characteristics and make a decision on pelletization.

Percolation tests were conducted for crushed ore with sizes of -50 mm, -25 mm, and -12 mm. It was found that non-agglomerated ore with a size of -50 mm meets the requirements of the heap leaching process. Ore with a size of -25 mm and -12 mm does not meet the requirements in terms of the rate of water percolation through the ore layer, which is less than 10 m/h. In this regard, tests were conducted to determine the optimal consumption of Portland cement. According to all regulatory parameters of percolation, the following modes are satisfactory for ore with a size of -25 mm and -12 mm: Portland cement consumption of 4 kg/t; water consumption of 98 – 101 l/t; pellet moisture content of about 10%. Figure 2 shows a photograph of pelletized ore. Thus, ore with a size of less than 25 mm after pelletization is also suitable for the heap leaching process.

-25 mm -12 mm

Figure 2. Agglomerated ore after 72 hours of aging

The initial assessment of ore leaching efficiency is carried out using standard bottle tests on crushed ore with a size of 80 - 90% of the -0.071 mm class. The gold dissolution rates achieved are considered to be the maximum possible, as grinding ensures complete access of gold to the cyanide solution. To assess the applicability of heap leaching technology, an additional bottle test is performed on crushed ore with a size of -2.5 mm. The experiments were carried out in a bottle agitator under the following conditions: ore sample

weight 0.3 kg, solid to liquid ratio (S:L) 1:2, pH 10 - 11, sodium cyanide concentration 0.10%, leaching duration 24 hours. During the leaching process, the sodium cyanide concentration and pH of the medium were monitored, with reagents added as necessary. Based on the results of the bottle test, a diagram of the degree of metal dissolution was constructed, which is shown in Figure 3.

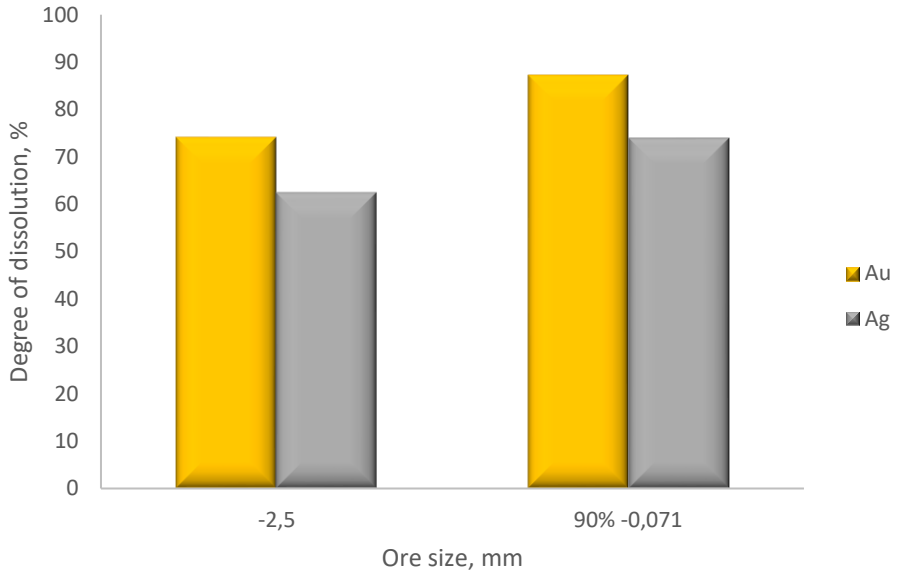


Figure 3. Degree of dissolution of gold and silver from ore based on bottle test results

The data in Figure 3 shows that ore size has a significant impact on the degree of gold dissolution. Thus, the degree of gold dissolution from crushed ore of -2.5 mm was 74%, while from ground ore with a size of 90% of the -0.071 mm class, the degree of gold dissolution increased to 87%. Particularly noteworthy is the high degree of silver dissolution, which is estimated at 62% (size -2.5 mm) and 73% (size 90% class -0.071 mm). As mentioned earlier, the ore belongs to the category of oxidized ores. As a rule, silver in oxidized ores dissolves well in cyanide solutions along with gold.

The copper and zinc content in the cyanide solution is, as expected, low – 2.33 mg/l and 2.05 mg/l, respectively. It is known that during heap leaching, copper accumulates in the productive solution as a result of repeated circulation of solutions. When its concentration exceeds 100 mg/l, special methods must be used to ensure effective gold extraction (Bolotova et al 2018), (Shalgymbayev et al 2024), (Kanaly et al 2024). For the ore being tested, this problem of accumulation of metal impurities in the productive solution will not arise.

The consumption of sodium cyanide for interaction with minerals was 0.84 - 1.02 kg/t.

The final assessment of the applicability of heap leaching technology and process modes is determined by the results of column tests. Column tests of heap leaching of gold were carried out in three columns on crushed non-granular ore with a size of -50 mm and on granular ore with a size of -25 mm and -12 mm in a closed cycle: leaching of gold from ore with alkaline cyanide solutions; sorption of dissolved gold by a sorbent; return of the solution to the leaching cycle after adjusting the sodium cyanide concentration and pH. AM-2B anion exchange resin, known for its high selectivity and efficiency, was used to extract dissolved gold from the leach solutions. It excellently sorbs cyanide complexes of gold from multicomponent solutions containing heavy metal impurities.

During the tests, the operating parameters of the process and reagent consumption were determined. The percolation characteristics of non-agglomerated and agglomerated ore were maintained throughout the process. There was no accumulation of impurity metals in the productive solutions. Gold and silver were effectively extracted with AM-2B resin.

To dissolve the gold, 31 leaching cycles were required for ore with a size of -25 mm and 12 mm, and 44 cycles for ore with a size of -50 mm. The total amount of productive solution obtained was quite large, at

2.34-2.71 m^3/t of ore. The high specific consumption of the leaching solution is due to the slower dissolution of silver.

The consumption of sodium cyanide for leaching gold from coarse ore was 0.58 - 0.67 kg/t.

Based on the data obtained, the gold and silver balance was calculated for heap leaching of gold and silver from ore (Table 2).

Table 2. Metal balance

Naming of indicators	Indicators		
Ore size, mm	-50	-25	-12
Metal extracted with ion exchange resin, g/t of ore:			
Au	0,69	0,81	0,82
Ag	12,87	21,40	24,16
Metal extracted during water washing operations, g/t of ore:			
Au	0,02	0,02	0,02
Ag	0,63	0,45	0,33
Metal content in column leaching tails, g/t:			
Au	0,44	0,39	0,31
Ag	34,04	27,28	21,32
Estimated metal content in the source ore, g/t:			
Au	1,15	1,21	1,15
Ag	47,54	49,12	45,82
Degree of metal dissolution from ore according to balance, %:			
Au	61,50	68,28	72,79
Ag	28,40	44,48	53,46
Expected metal recovery in commercial products, Doré alloy, %:			
Au	55,05	61,11	65,15
Ag	25,42	39,81	47,85

Based on the data obtained, the gold and silver balance was calculated for heap leaching of gold and silver from ore. The maximum degree of dissolution of gold (72.79%) and silver (53.46%) was achieved with an ore size of -12 mm. At a size of -25 mm, the indicators decrease to 68.28% and 44.48%, respectively, and at a size of -50 mm, to 61.50% and 28.40%.

Conclusion

Studies have shown that heap leaching is a highly effective method for processing oxidized ore. For optimal processing of this ore, it is recommended to crush it to a size of -12 mm with preliminary pelletizing. The estimated extraction of gold in the Doré alloy during industrial processing of oxidized ore will be 65.15%, and silver - 47.85%, with an initial content in the ore of 1.15 g/t and 45.80 g/t, respectively.

The results obtained confirm the possibility of effective processing of oxidized ore by heap leaching, which opens up prospects for further industrial application of this method.

CRediT author statement: Ye. Kanaly: Writing – original draft, Data curation, Investigation. **L. Bolotova:** Writing – review & editing, Conceptualization. **B. Surimbayev:** Project administration, Methodology, Conceptualization. **Ye. Yessengarayev:** Validation, Methodology, Investigation. **M. Akzharkenov:** Visualization, Formal analysis, Investigation.

Cite this article: Kanaly Ye., Bolotova L., Surimbayev B., Yessengarayev Ye., Akzharkenov M. (2025). Assessment of the Possibility of Using Heap Leaching Technology for Processing Gold-Bearing Ore. Materials of International Scientific-Practical Internet Conference "Challenges of Science". Issue VIII, pp. 79-84. https://doi.org/10.31643/2025.10

References

Bolotova, L. S., Kanaly, Ye. S., Yessengarayev, Ye. K., Akzharkenov, M. D., Kudryashov, G. A., & Shalgymbaev, S. T. (2020). Change in the nature of oxidized gold-bearing ore with increasing quarry depth. *Geology and Subsurface Protection*, *(3)(76)*, 34–40.

Bolotova, L. S., & Shalgymbaev, S. T. (2018). Ion exchange resins in gold hydrometallurgy. In *Intensification of hydrometallurgical processes for processing natural and man-made raw materials: Technologies and equipment* (pp. 178–180). Proceedings of the International Scientific and Practical Conference. St. Petersburg, Russia: Saint Petersburg State Institute of Technology (Technical University).

Bolotova, L. S., Shalgymbayev, S. T., Raipov, S. K., Surimbayev, B. N., Kanaly, Ye. S., & Kurmanov, Zh. E. (2023). Heap leaching of gold from the destructured oxidized ore of the Belsu deposit, Republic of Kazakhstan. *IOP Conference Series: Earth and Environmental Science, 1254*(1), 012094. https://doi.org/10.1088/1755-1315/1254/1/012094

Dementyev, V. E., Druzhina, G. Ya., & Gudkov, S. S. (2004). *Heap leaching of gold and silver*. Irkutsk, Russia: OJSC "Irgiredmet".

Fazlullin, M. I. (2001). *Heap leaching of precious metals*. Moscow, Russia.

Kanaly, Ye. S., Surimbayev, B. N., Bolotova, L. S., & Shalgymbaev, S. T. (2024). Choice of a sorbent for copper and cobalt sorption from gold-containing heap leaching solutions. *Metallurgist, 67*(9–10), 1457–1465. https://doi.org/10.1007/s11015-024-01638-0

Karaganova, V. V., & Uzhkenova, B. S. (2002). *Gold heap leaching: International experience and development prospects*. Moscow–Almaty.

Shalgymbaev, S. T., Bolotova, L. S., Ibraev, S. Ya., Surimbaev, B. N., Akzharkenov, M. D., & Kanaly, Ye. S. (2024). *Method for extracting copper from cyanide-containing circulating solutions for processing gold-copper ores with regeneration of cyanide and copper* (Republic of Kazakhstan Patent No. 36552). Bulletin No. 2, January 12, 2024.

Surimbayev, B., Akcil, A., Bolotova, L., Yessengarayev, Ye. K., Kanaly, Ye. S., Akzharkenov, M. D., Khumarbekuly, Y., Shalgymbayev, S., Zhumabai, S. Y., & Mambetzhanova, A. M. (2025). Technology development of gold heap leaching in Kazakhstan: An overview. *Mineral Processing & Extractive Metallurgy Review*. https://doi.org/10.1080/08827508.2024.2448786

Yessengarayev, Ye. K., Kanaly, Ye. S., Bolotova, L. S., Baimbetov, B. S., & Akzharkenov, M. D. (2018). The influence of ore preparation methods on heap leaching gold recovery rates. In *Intensification of hydrometallurgical processes for processing natural and technogenic raw materials: Technologies and equipment* (pp. 297–299). Proceedings of the International Scientific and Practical Conference. St. Petersburg, Russia.

Issue VIII, 22 November 2025
e-ISSN 2707-9481 Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University, Almaty, Kazakhstan
ISBN978-601-323-547-9 https://doi.org/10.31643/2025.11

Christian S. Ugwuanyi
Department of Science Education, University of Nigeria
Faculty of Education, University of the Free State,
Bloemfontein, South Africa
e-mail: christian.ugwuanyi@unn.edu.ng
ORCID ID: https://orcid.org/0000-0003-2174-3674

Technology Adoption in Science, Technology, Engineering, and Mathematics Education: Perspectives of the Nigerian University Students

Abstract: Since the emergence of the global pandemic in late 2019, the crave for the shift from the traditional mode of teaching to hybrid or remote mode has been on the increase. This paradigm shift, though not bad but has not been easy for developing countries like Nigeria. The extant literature from the developed countries has shown that the integration of technology in teaching and learning has proved to be effective. However, literature on the perspectives of students on technology adoption in Science, Technology, Engineering, and Mathematics (STEM) Education is scarce in most developing countries, like Nigeria. Thus, adopting a cross-sectional survey research design, this study explored the perspectives of University Students on technology adoption in STEM education. A sample of 90 undergraduates from Nigerian Universities participated in this research. An adopted survey instrument was used for the data collection. This survey measure was properly validated and trial tested with internal consistency reliability indices of (α = .95, .95, and .99) for the three clusters of the it as reported by Oladele et al. (2023). Data were collected through an online survey in which a Google Form link was shared with the students in their respective universities through their WhatsApp platforms. Responses of the participants were properly screened for any missing values before the data analysis. Thereafter, the data were quantitatively analysed applying appropriate statistics. The findings revealed that students had positive perspectives towards the adoption of technology in STEM education. Further, analysis revealed that while students' perspectives did not differ significantly based on their gender, their perspectives differed significantly ($p < .05$) based on their age. However, it was found that STEM students do not have a good experience in using Google Forms for taking assessments, with the school providing the data they use to join classes and technical support during online classes. These findings have both policy and practice implications. Thus, the researcher recommends that the appropriate government authority should prioritise adequate provision of ICT facilities to ensure effective adoption of technology in STEM education.

Keywords: STEM, perception, technology, university

Introduction

STEM education is crucial for advancing technology and economic prosperity in the 21st century, as it equips individuals with critical thinking, problem-solving, and analytical skills needed to tackle complex global challenges (Samuel & Amina, 2025). The progress of STEM education in the Nigerian context has been a major concern of STEM educators, especially in the technology era. Education is changing dramatically due to technological improvements and the knowledge-based global economy (Chukwuemeka et al. 2025). According to Chukwuemeka et al., in Nigeria, the transition from traditional methods of teaching to smart learning technologies is both necessary and challenging. There has been a push for improved teaching methods in Nigerian engineering education, particularly with the advancement of information and telecommunications technology (Oleyede et al., 2017). Thus, in Nigeria, numerous existing government policies recognize developing technology for teaching and learning. For example, the significance of emerging technologies in teaching and learning and advocating for their incorporation into the educational system has

been noted by the National Science, Technology, and Innovation Roadmap (NSTIR) and Technology, and Innovation Policy (NSTIP) (Onanuga & Saka, 2025).

Compared to 40-50 years ago, there has been limited progress in classroom instruction, the use of teaching aids, and laboratory work within the country. While STEM education has gained prominence due to the need for economic transformation, educators have been working to develop integrated pedagogical approaches that can be effectively implemented through instructional programs (Ndiku & Kaluyu, 2020). This shift is largely driven by the dwindling of students' learning outcomes in STEM subjects, which is often attributed to traditional teaching methods, where knowledge is directly transferred from instructor to student. In response, educators are actively exploring ways to seamlessly integrate Artificial Intelligence (AI) into higher education curricula to better prepare students for an AI-driven future (Olatunde-Aiyedun, 2024). As a result, STEM teacher training has evolved to address the modern demands of global education (Abah et al., 2024).

Recent technological advancements have introduced emerging technologies such as augmented reality, learning management systems, handheld devices, smart boards, and virtual tools into classroom teaching (Sosa et al., 2018). Information and Communication Technology (ICT) has fundamentally transformed education, shifting from traditional face-to-face instruction to blended, virtual, and e-learning approaches (Sosa et al., 2018). Moreover, ICT has altered the role of teachers, transitioning them from being the primary knowledge source to becoming facilitators and designers of dynamic learning experiences (Oladele et al., 2021). Technology now not only enhances access to quality education but also broadens educational opportunities. The Fourth Industrial Revolution (4IR) further emphasizes innovation in the classroom through digital and smart technologies (Oladele, 2024).

In this context, Virtual Laboratories (VLs) have revolutionized STEM programs in higher education, with increasing interest in using VLs to focus on integrative approaches that solve real-world problems through technology (Ndunagu et al., 2023). This highlights the potential of technology to reposition STEM education more effectively. However, there remains a gap in understanding the perspectives of university undergraduates regarding the integration of technology in STEM education. Drawing on the Technology Acceptance and Use Theory, this study sought to explore these perspectives and examine students' views on the adoption of technology in STEM education.

Theoretical framing of the study

The Unified Theory of Acceptance and Use of Technology (UTAUT) is a technology acceptance model developed by Venkatesh et al. (2003) to explain users' intentions to adopt information systems and their subsequent usage behaviour. According to the theory, effort expectancy, social influence, performance expectancy, and facilitating conditions are the major constructs that play significant parts in the acceptance of technology use. Performance expectancy, effort expectancy, and social influence are theorised to directly influence behavioural intention, whereas facilitating conditions directly affect actual technology use. In addition, gender, age, among others, are identified as moderating variables that shape the strength of these relationships. UTAUT was developed through the synthesis of eight prominent technology acceptance models and was empirically validated using longitudinal data. The findings revealed that the model accounted for approximately 70% of the variance in behavioural intention and about 50% of the variance in actual system use (Venkatesh et al., 2003). Consequently, this study is anchored on UTAUT to examine university students' perspectives on technology adoption in STEM education.

The applicability of UTAUT has been demonstrated across diverse contexts. For instance, Koivumäki et al. (2007) applied the model to examine the attitudes of 243 users in northern Finland toward mobile services and technology. Their findings indicated that familiarity with devices and user competence significantly influenced perceptions, whereas time spent using the devices did not. Similarly, Eckhardt et al. (2009) employed UTAUT to investigate the influence of workplace referent groups, such as supervisors and colleagues, on technology adoption intentions in 152 German organisations. The study revealed that social influence from workplace referents had a significant effect on information technology adoption.

Further empirical support for the theory was provided by Curtis et al. (2010), who utilised UTAUT to study social media adoption in 409 nonprofit organisations in the United States. Their findings showed that organisations with clearly defined public relations departments were more likely to adopt and use social

media to achieve organisational objectives. The study also revealed gender differences, with women perceiving social media as more useful, while men exhibited greater confidence in active usage. Likewise, Verhoeven et al. (2010) applied UTAUT to examine computer usage frequency among 714 first-year university students in Belgium and found the model effective in explaining variations in computer use and differences in information and communication technology competencies between secondary and tertiary education levels.

More recently, Welch et al. (2020) adopted UTAUT to investigate factors influencing mobile learning adoption among 118 museum professionals in England. Their study demonstrated the suitability of UTAUT in explaining the uptake of mobile learning technologies for just-in-time knowledge development. In addition, Williams et al. (2015) conducted a systematic review of 174 studies that applied UTAUT, further confirming its robustness and widespread applicability across different technological and organisational contexts.

Review of Literature

Many African countries have increasingly emphasized the acquisition of basic ICT competencies within STEM education (Barakabitze et al., 2019). Research indicates that improving the effectiveness of STEM education requires the adoption of learner-centred pedagogical approaches alongside the integration of ICT into STEM teaching and learning processes (Ndiku & Kaluyu, 2020). Rapid advancements in information and communication technologies, coupled with increased internet connectivity, have resulted in a more complex, interconnected, and knowledge-driven global environment. Consequently, innovation in STEM education has become essential for rethinking educational practices to meet the demands of the twenty-first century (Abah et al., 2024). ICT plays a critical role in preparing students for STEM-related careers by fostering innovation, enhancing skills development, and supporting technical problem-solving abilities (Gbeleyi & Olusegun, 2023).

Empirical studies further demonstrate the benefits of specific digital platforms and emerging technologies in STEM education. For instance, Google Classroom has been identified as an innovative tool for enhancing STEM learning among undergraduate students in universities (Oladele et al., 2021). Students have shown readiness to adopt educational applications for learning, utilize immersive technologies, integrate Internet of Things (IoT) tools to align with Fourth Industrial Revolution (4IR) requirements, embrace technological innovations, and engage in lifelong learning (Oladele, 2024). Similarly, the integration of ICT in classroom instruction enables students to participate in interactive learning activities and to access a broader range of knowledge resources (Barakabitze et al., 2019). More recently, the incorporation of Artificial Intelligence (AI) into education has been recognized as ushering in a new era of teaching and learning, with significant implications for STEM education globally (Samuel & Amina, 2025).

In the Nigerian context, Ndunagu et al. (2023) reported that several higher education institutions have adopted remote learning systems and established Learning Management System (LMS) platforms that allow students to access learning materials anytime and anywhere via internet-enabled devices. These virtual learning environments have been found to effectively engage learners, generate valuable data for learning analytics, and offer cost-effective instructional solutions. Similarly, the use of ICT in teaching and learning has been shown to enhance STEAM education and improve students' digital competencies at the secondary school level (Sidi et al., 2022). In line with this, recent studies have emphasized that integrating AI into STEM education is vital for advancing scientific and technological development in Nigeria (State et al., 2025). Evidence also suggests that students in Sub-Saharan Africa have generally reported positive experiences with online STEM education (Oladele et al., 2023), a finding that aligns with earlier studies showing favourable student attitudes toward online learning (Forson & Vuopala, 2019; Kamaruzaman et al., 2021). However, Ndlovu and Meyer (2019) stressed that adequate preparation remains a critical prerequisite for meaningful learning in online environments. Parkes et al. (2015) further observed that although students are generally technology-ready, they still require support in developing higher-order skills such as synthesizing ideas, integrating learning strategies, rationalizing concepts, and collaborating effectively.

Despite these positive developments, notable challenges persist. Studies have shown that STEM pre-service teachers often demonstrate insufficient competence in emerging digital technologies, regardless of their mode of entry into university (Onanuga & Saka, 2025). In addition, the lack of formal technology-embedded teacher training, limited collaborative learning practices, inadequate technical expertise, and

poor internet connectivity continue to hinder the effective implementation of technology-enhanced STEM teaching and learning in Africa (Oladele et al., 2023). Gender disparities have also been reported, with male pre-service teachers exhibiting higher levels of digital competence than their female counterparts (Onanuga & Saka, 2025). However, Oladele et al. (2023) found that aside from gender, variables such as students' age, discipline, and level of study did not significantly influence technology adoption, particularly during the COVID-19 pandemic and the Fourth Industrial Revolution, when free and accessible online platforms became widely available.

Based on the foregoing, it is evident that substantial research has been conducted globally on technology adoption in STEM teaching and learning. Nevertheless, studies within the Nigerian context have paid limited empirical attention to undergraduate students' perspectives on technology adoption in STEM education. This identified gap in the literature motivated the present study. Accordingly, the research addressed the central question: What are university students' perspectives on technology adoption in STEM education?

Methods

Ethical statement

The approval for the conduct of this research was granted by the committee on research ethics of the University of Nigeria. Besides, the consent of the participants was sought through the online survey tool. Thus, the research ensured that the participants were granted freedom of participation and assured them that their responses would be treated with a high level of confidentiality.

Study participants

The participants for this research were 90 undergraduate students purposively sampled from different universities in Nigeria. Purposive sampling was used to ensure that only the respondents from STEM fields were used for the research.

Measure

The measure that was used for data collection for this research was an adapted Technology Adoption for Teaching and Learning Questionnaire (TATLQ) developed by Oladele et al. in 2023. The questionnaire had three sections A and B. The section A sought information on the demographics (gender, age, department) of the students while section B is made of three clusters: A, B and C. Cluster A sought information on the readiness of the students for adoption of technology with 14 items ($\alpha = .95$). Cluster B sought information on the experience of students during online classes with 21 items ($\alpha = .95$), while Cluster C sought information on the quality of online teaching and learning with 12 items ($\alpha = .99$). Despite that Oladele et al.'s research was done in Nigeria, the instrument was properly revalidated and trail tested. The trial-tested version gave the same internal consistency reliability indices as the original version.

Data collection procedure

Data collection for this research was facilitated through an online survey tool. In this case, Google Form Survey items were prepared, and the link was shared with the study participants through their various WhatsApp platforms. This was made possible through the assistance of the professional colleagues of the researcher in various universities across Nigeria.

Data analysis

The data collected through the online survey were screened for possible missing values. The demographic profiles of the participants were analyzed using descriptive statistics of frequency and percentage, and presented with Bar charts. An inferential statistic, such as a t-test of independent samples and ANOVA (analysis of variance), was used to test the hypotheses at 5% probability level, on whether any

of the moderators, like gender and age, had a significant influence on students' perspectives towards technology adoption in STEM education.

Results

Descriptive analysis of the demographic profiles of the students

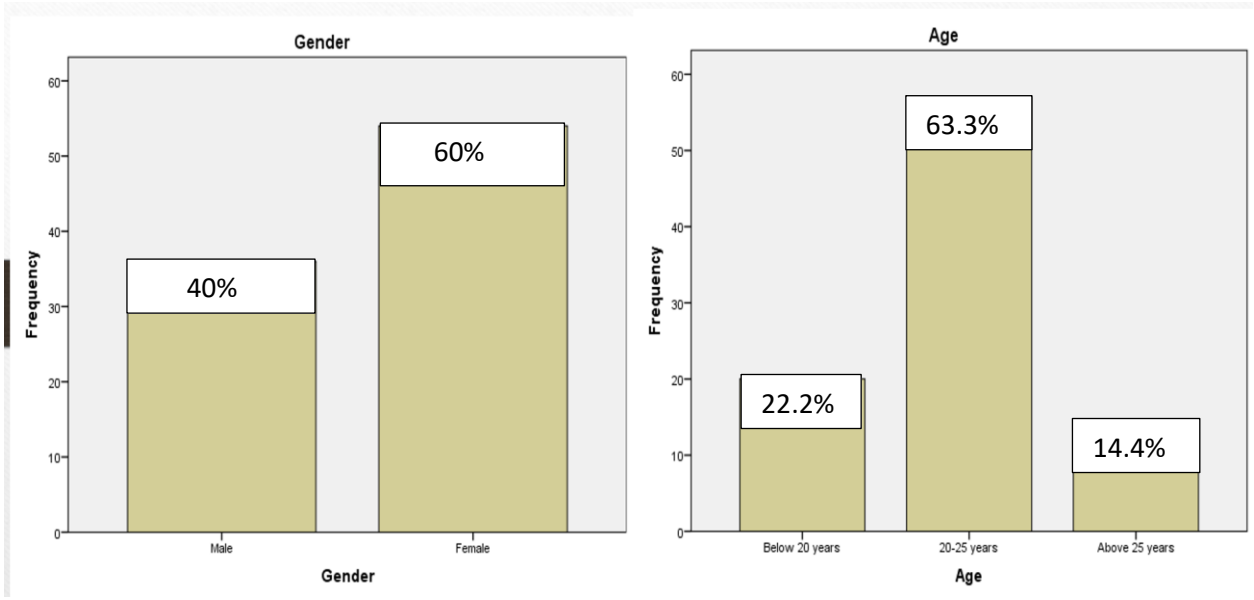


Figure 1. Bar chart showing the gender and age of the participants

Figure 1 shows the gender and age distribution of the purposively selected STEM students from Nigerian Universities. It indicates that 40% of the respondents are male STEM students while 60% are female STEM students. Besides, 22.2% of the respondents are below the age of 20 years, 63.3% are within the ages of 20-25 years, while 14.4% are above 25 years.

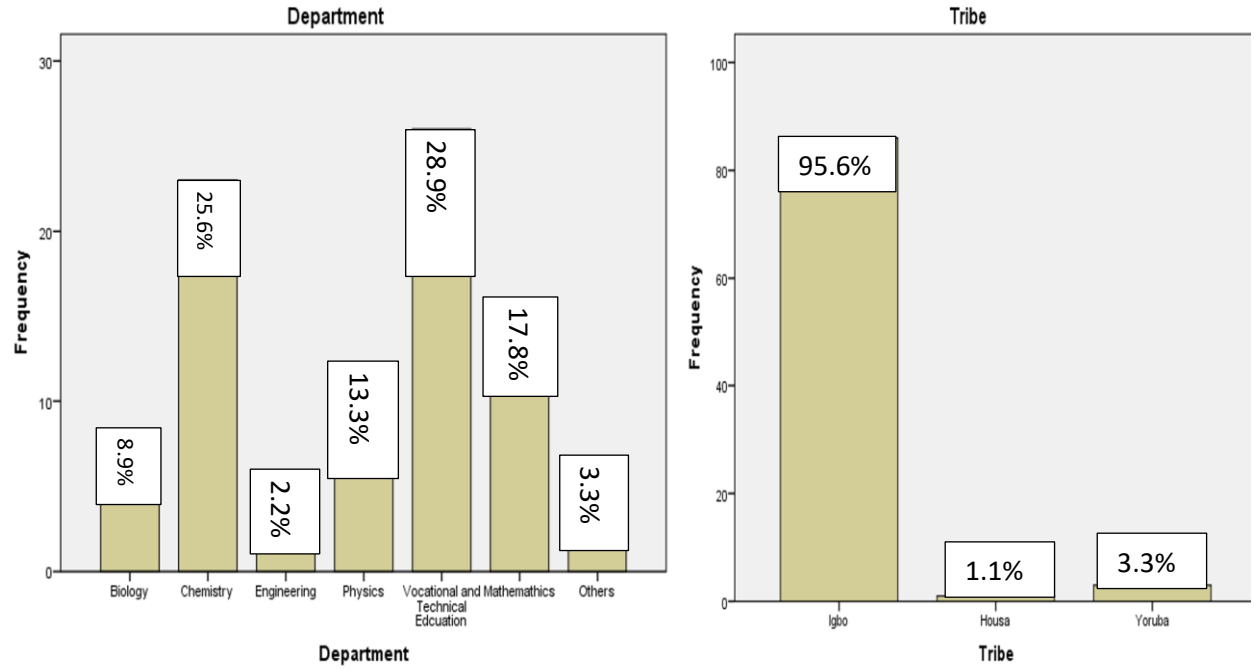


Figure 2. Bar chart showing the department and tribe of the participants

Figure 2 shows that 8.9% of the respondents are from the Biology Department, 25.6% from the Chemistry Department, 2.2% from the Engineering Department, 13.3% from the Physics Department, 28.9% from Vocational and Technical Education, 17.8% from Mathematics Education, while 3.3% are from other STEM Departments. Also, the Figure indicates that 95.6% of the respondents are from the Igbo tribe, 1.1% from the Hausa tribe, and 3.3% from the Yoruba tribe.

Table 1. Mean analysis of the STEM students on their readiness for online teaching and learning

Item Statement	Mean	Std. Deviation	Remark
1. Possession of personal computer	2.77	1.08	Agree
2. Having access to internet supply	3.46	.58	Agree
3. Being able to have power supply uninterrupted	2.30	.81	Disagree
4. I can use online tools like google collaborate	1.72	1.57	Disagree
5. Being able to participate in zoom meetings	2.73	.78	Agree
6. Having functional and accessible email address	3.56	.54	Agree
7. Being conversant in communication using email	2.89	.83	Agree
8. Being able to surf the internet for learning materials	3.18	.58	Agree
9. Possessing varieties of gadgets for adequate participation in online teaching and learning aside	2.48	.66	Disagree
10. Dedicating sufficient time for online teaching and learning participation	2.74	.73	Agree
11. Being prepared for the cost implication of data bundle for easy participation in online teaching and learning	2.57	.71	Agree
12. Being able to use chatbot and other facilities for different platforms	2.76	.71	Agree
13. Being able to use other learning platforms apart form from Zoom or Google meet.	2.67	.84	Agree
14. I perceive online learning online as a good inniative	2.56	1.45	Agree
Overall Mean	38.19	6.57	Agree

Table 1 indicates that STEM students who participated in this study exhibited readiness for the adoption of technology in STEM education in Nigerian universities. However, it was found that STEM students are not ready in terms of having access to an uninterrupted power supply, experience with using google collaboration tools, having gadgets for effective participation in online teaching and learning other than computer. That notwithstanding, the overall mean score of (M = 38.19, SD = 6.57) indicates that the STEM students had positive perspectives on the adoption of technology in STEM education.

Table 2. Mean analysis of the STEM students on their experience with online teaching and learning

Item Statement	Mean	Std. Deviation	Remark
1. Being conversant in the use of WhatsApp	3.62	.51	Agree
2. Being skilled in the use of google forms for assessment purpose	2.43	1.49	Disagree
3. Being capable in the use of google docs for handing in assessments	2.83	.80	Agree
4. Provision of data bundle for students to join online classes by school	2.13	.87	Disagree
5. Providing the data I use to join online classes	3.29	.74	Agree
6. Being able to use functions from different platforms during online class	2.66	.78	Agree
7. Being able to resolve internet issues while engaging in online classes	2.70	.73	Agree
8. Technical supports are provided during online classes	2.47	.77	Disagree
9. During online classes I have access to clear and legible presentations	2.69	.73	Agree
10. Having enough time to take note of important points during online classes	2.72	.72	Agree
11. During online classes I have opportunity to ask questions	2.89	.57	Agree

12. To aid my online learning process, I have access to lecture playbacks	2.85	.72	Agree
13. My learning process has been enhanced through the use of technology	2.73	.78	Agree
14. During online class, lecture information were effectively shared	3.03	.61	Agree
15. To get content to support learning, I was able to surf the internet	3.24	.56	Agree
16. Taking online assessments has been easy for me	3.00	.62	Agree
17. After online assessment, I got feedback timely	2.83	.64	Agree
18. I am able to access lecturer materials directly before and after classes	2.70	.70	Agree
19. Access to lecturer materials before the class was very easy for me	2.75	.64	Agree
20. During online learning, I enjoy educative and informative interactions and discussions with my fellow students	3.06	.61	Agree
21. My self-discipline to work independently improves during online teaching	3.06	.61	Agree
Overall Mean	58.88	10.00	Agree

Table 2 analysis shows that the overall positive experience of the STEM students with online teaching and learning was M = 58.88, SD = 10.00. However, the results equally showed that STEM students do not have a good experience in using Google Forms for taking assessments, with the school providing the data they use to join classes and technical support during online classes.

Table 3. Mean analysis of the STEM students on their assessment of the quality of online teaching and learning

Item Statement	Mean	Std. Deviation	Remark
1. Maintaining a timely lecture schedule	2.92	.75	Good
2. Enhancing access to online lecture slides	2.90	.83	Good
3. Making room for clear presentation of lecture materials	2.95	.79	Good
4. Improving learners' communication skills/ability	2.95	.83	Good
5. Ensuring adequate lesson contents coverage	2.99	.69	Good
6. Enabling adequate revision of lectures before the final examinations	2.92	.82	Good
7. Ensuring the availability of online learning resources to support the class	2.93	.81	Good
8. Using suitable images and backgrounds to ensure engaging lecture presentations	2.92	.83	Good
9. Providing adequate feedback	2.95	.82	Good
10. Making sure that the contents are communicated in simple and clear terms	3.03	.67	Good
11. Providing adequate support for achieving class tasks	3.02	.77	Good
12. Maintaining courteous classroom interaction	2.98	.77	Good
Overall Mean	34.49	8.44	Good

Table 3 indicates that the STEM students' assessment of the online teaching and learning is good, with an overall mean of (M = 34.49, SD = 8.44).

Table 4. Mean analysis of the perspectives of STEM students on the adoption of technology based on gender and age

Gender	n	Mean	Std. Deviation	df	t	p
Male	36	135.44	18.17	88	1.388	.169
Female	54	128.96	23.76			
Age	n	Mean	Std. Deviation	df	F	p
Below 20 years	20	127.20	19.22	2, 87	4.381	.015
20-25 years	57	136.12	18.28			
Above 25 years	13	118.23	32.62			

Table 4 revealed that there is no significant difference in the mean scores with respect to the perspectives of male (M = 135.44, SD = 18.17) and female (M = 128.96, SD = 23.76) STEM students on the adoption of technology in universities, t (88) = 1.388, p = .169.

With respect to age, Table 4 revealed that there is a significant difference in the mean scores with respect to the perspective of STEM students of different age ranges, below 20 years ((M = 127.20, SD = 19.22), 20-25 years (M = 138.12, SD = 18.28) and above 25 years (M = 118.23, SD = 32.62) on the adoption of technology in universities, F (2, 87) = 4.381, p = .015. Thus, the null hypothesis was rejected ($p < .05$).

Table 5. Pairwise comparison test for the significant influence of age on perspectives of STEM students on technology adoption

(I) Age	(J) Age	Mean Difference (I-J)	Std. Error	Sig.
Below 20 years	20-25 years	-8.92	5.47	.269
	Above 25 years	8.97	7.49	.491
20-25 years	Below 20 years	8.92	5.47	.269
	Above 25 years	17.89*	6.46	.025
Above 25 years	Below 20 years	-8.97	7.49	.491
	20-25 years	-17.89*	6.46	.025

Table 5 revealed that the mean difference between STEM students who are within the age range of 20-25 years and above 25 years is the only pair that has a significant p-value. This implies that the mean difference between STEM students who are within the age range of 20-25 years and above 25 years contributed to the significant influence of age on the perspectives of STEM students towards the adoption of technology in STEM education.

Discussion of the Findings

This research was necessitated due to the lack of empirical evidence on the perspectives of students towards the adoption of technology in STEM Education in Nigerian universities. This research has empirically shown that students have positive perspectives towards the adoption of technology in STEM education. This finding was likely this way since students generally have a good attitude towards technology in STEM education because it increases engagement, provides individualized and accessible learning experiences, and prepares them directly for future employment in the digital economy. Key causes for these positive perspectives include the transition from passive to active learning, the availability of real-time feedback, and the ability to visualize complicated scientific or mathematical concepts using immersive tools such as virtual reality (VR) and interactive simulations.

Buttressing this finding, it has been found that to improve STEM education performance, it is necessary to implement innovative learner-friendly pedagogies and embrace ICT integration in STEM subject learning (Ndiku & Kaluyu, 2020). Besides, rapid advances in information and communications technology (ICT), as well as increased internet connectivity, have made today's world more complex, interconnected, and knowledge-driven, and STEM education innovation is critical in rethinking education to cope with the changes of the twenty-first century (Abah et al., 2024). Moreover, it has been revealed that information communication technology is critical for STEM students because it promotes innovation, skill development, and technical problem solving (Gbeleyi & Olusegun, 2023). In line with this, research has shown that Google Classroom provides a new approach to STEM and learning for undergraduate students at universities (Oladele et al., 2021). The above research has shown the great role technology plays in STEM education.

However, it was found that STEM students do not have a good experience in using Google Forms for taking assessments, with the school providing the data they use to join classes and technical support during online classes. This cannot be unconnected to some infrastructural challenges and lack of ICT skills among the students in some of the universities in Nigeria. In line with these findings, it has been found that regardless of how students entered university, STEM pre-service teachers displayed weak skills in new digital

technologies (Onanuga & Saka, 2025). Similarly, the lack of formal technology-embedded teacher training, collaborative learning methodologies, sufficient technical know-how, and internet access are all barriers to implementing digitally enabled STEM teaching and learning in Africa (Oladele et al., 2023). Furthermore, there was a significant gender disparity in digital competencies, with men pre-service teachers outperforming their female counterparts (Onanuga & Saka, 2025). According to Oladele et al., during the COVID-19 outbreak and the Fourth Industrial Revolution (4IR), students' age, discipline, and study level may have been unimportant due to the availability of free technical platforms on the internet.

Finally, it was found that while students' perspectives towards the adoption of technology in STEM education do not differ by gender, they differ significantly based on their age. In line with these findings, Oladele et al. (2023) discovered that, except for gender, none of the tested hypotheses for students' age groups, disciplines, or study levels were rejected. The research findings have given credence to the theory of acceptance and use of technology by demonstrating how the demographics of the participants impact their perceptions of technology adoption. This research, therefore, has made an important contribution to knowledge of STEM education in the Nigerian context, especially with respect to the adoption of technology.

Conclusion and recommendations

The findings showed that students have positive perspectives towards the use of technology in STEM education, owing to their perception that digital tools improve engagement, grasp of complicated topics, and facilitate self-directed learning. Technology was also seen as relevant to future job demands, encouraging collaboration and enhancing confidence in problem-solving activities. Overall, the results demonstrate that, when effectively incorporated, technology catalyzes deeper learning and higher interest in STEM courses, highlighting its crucial role in creating current STEM education. However, inadequate ICT infrastructure was spotted as a limitation to effective technology adoption in STEM education. Based on this, therefore, the researcher recommends that the appropriate government authority should prioritise adequate provision of ICT facilities to universities for effective adoption of technology in STEM education. Also, STEM lecturers should effectively integrate technology in their teaching of STEM courses.

Acknowledgment

I wish to appreciate the management of Abai Kazakh National Pedagogical University, Almaty, particularly the Department of Pedagogy and Psychology, for making it possible for me to share my research findings in the International Scientific-Practical Internet Conference "Challenges of Science" organized by the Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University.

Cite this article: Ugwuanyi, Ch.S. (2025). Technology Adoption in Science, Technology, Engineering, and Mathematics Education: Perspectives of the Nigerian University Students. Materials of International Scientific-Practical Internet Conference "Challenges of Science". Issue VIII, pp. 85-94. https://doi.org/10.31643/2025.11

References

Abah, J. A., Iji, C. O., & Chinaka, T. W. (2024). Preparing Pre-Service STEM Teachers in an Emerging Global Environment. *Discourse and Communication for Sustainable Education*, *15*(2), 62–78. https://doi.org/10.2478/dcse-2024-0016

Barakabitze, A. A., Lazaro, A. W., Ainea, N., Mkwizu, M. H., Maziku, H., Matofali, A. X., Iddi, A., & Sanga, C. (2019). *Transforming African Education Systems in Science , Technology , Engineering , and Mathematics (STEM) Using ICTs : Challenges and Opportunities*. *2019*. https://doi.org/10.1155/2019/6946809

Chukwuemeka, E. J., Dominic, S., Akanbi, K. R., & Aregbesola, B. G. (2025). Transforming from Traditional to Smart Education in Nigeria: Challenges and Opportunities for Learning. *Ilorin Journal of Education*, *46*(1), 48-62.

Curtis, L.; Edwards, C.; Fraser, K. L.; Gudelsky, S.; Holmquist, J.; Thornton, K.; & Sweetser, K. D. (2010). Adoption of social media for public relations by nonprofit organizations. *Public Relations Review, 36* (1), *90*–92. *doi:10.1016/j.pubrev.2009.10.003.S2CID154466947.*

Eckhardt, A.; Laumer, S.; & Weitzel, T. (2009). Who influences whom? Analyzing workplace referents' social influence on IT adoption and non-adoption. *Journal of Information Technology, 24* (1), *11*–24. *doi:10.1057/jit.2008.31. S2CID 42420244.*

Gbeleyi, O. A., & Olusegun, O. P. (2023). *Teaching of STEM Subjects in Africa : Perspectives of Gender , Difficult Topics,*

School Ownership and Recommendation of CTCA. *4*(1), 24–34.

Koivimäki, T.; Ristola, A.; & Kesti, M. (2007). The perceptions towards mobile services: An empirical analysis of the role of use facilitators. *Personal and Ubiquitous Computing, 12 (*1), *67*–75*. doi:10.1007/s00779-006-0128-x. S2CID 6089360.*

Menon, Devadas; Shilpa, K (November 2023). Chatting with ChatGPT: Analyzing the factors influencing users' intention to Use the Open AI's ChatGPT using the UTAUT model*. Heliyon. 9* (11)e20962*. Bibcode:2023Heliy...920962M doi:10.1016/j.heliyon.2023.e20962. ISSN 2405-8440. PMC 10623159 PMID37928033.*

Ndiku, J. M., & Kaluyu, V. (2020). Learner perspective of pedagogy for improved performance in stem subjects: a literature review. *IOSR Journal of Research & Method in Education*, *10*(4), 15-27.

Ndunagu, J. N., Ukhurebor, K. E., & Adesina, A. (2023). Virtual Laboratories for STEM in Nigerian Higher Education: The National Open University of Nigeria Learners' Perspective. *CEUR Workshop Proceedings*, *3393* (Tell), 38–48.

Oloyede, A. A., Ajimotokan, H. A., & Faruk, N. (2017). Embracing the future of engineering education in Nigeria: teaching and learning challenges. *Nigerian Journal of Technology*, *36*(4), 991-1001.

Oladele, J. I. (2024). *Technology Readiness and Implications for Higher Education in Universities in North-Central Nigeria*. *6*, 1–19. https://doi.org/10.38140/ijer-2024.vol6.39

Oladele, J. I., Ayanwale, M. A., & Ndlovu, M. (2023). *SCIENCE & TECHNOLOGY Technology Adoption for STEM Education in Higher Education : Students ' Experience from Selected Sub-Saharan African Countries*. *31*(1), 237–256.

Oladele, J. I., Koledafe, O. S., & Daramola, D. S. (2021). *Journal of Digital Learning and Education Prospects for Online Instructional Delivery Using Google Classrooms : Implications for Higher Education in Sub-Sahara Africa*. *01*(3), 92–108. https://doi.org/10.52562/jdle.v1i3.227

Olatunde-Aiyedun, T. G. (2024). Artificial intelligence (AI) in education: integration of AI into science education curriculum in Nigerian universities. *International Journal of Artificial Intelligence for Digital*, *1*(1).

Onanuga, P. A., & Saka, A. O. (2025). Emerging Digital Technologies: Building Competencies of STEM Pre-Service Teachers. *Journal of Teaching and Learning*, *19*(1), 155–169. https://doi.org/10.22329/jtl.v19i1.8810

Samuel, I. R., & Salisu, A. D. (2025). Shaping the Future of STEM Education in Nigeria through Artificial Intelligence. *Journal of African Innovation and Advanced Studies*.

Sidi, S. B., Gurjiya, A. U., & Umar, A. M. (2022). Challenges and Prospects of Teaching Science. *Technology*, 8(1), 43–50. https://www.ajstme.com.ng

Sosa Neira, E., Salinas Ibáñez, J., & De Benito Crosetti, B. (2018). Factors that facilitate or limit the incorporation of emerging technologies in the classroom. International Online Journal of Education and Teaching (JET), 5(1), 38-59.

Venkatesh, V., Morris, M. G., Davis, G.B., Davis, & F.D. (2003). User acceptance of information technology: Toward a Unified View*. MIS Quarterly. 27* (3), *425*–478*. doi:10.2307/30036540. JSTOR 30036540. S2CID 14435677.*

Venkatesh, V., Thong, J.Y.L., & Xu, X. (2012). Consumer acceptance and use of information technology: Extending the Unified Theory of Acceptance and Use of Technology*. MIS Quarterly. 36* (1), *157*–178. *doi:10.2307/41410412. ISSN 0276-7783. JSTOR 41410412.*

Verhoeven, J. C.; Heerwegh, D.; & De Wit, K. (2010). Information and communication technologies in the life of university freshmen: An analysis of change*. Computers & Education, 55* (1), *53*–66*. doi:10.1016/j.compedu.2009.12.002.*

Welch, R., Alade, T., & Nichol, L. (2020). Using the unified theory of acceptance and use of technology (utaut) model to determine factors affecting mobile learning adoption in the workplace: a study of the science museum group*. International Journal on Computer Science and Information Systems, 15* (1), *85*–98*.*

Issue VIII, 22 November 2025
e-ISSN 2707-9481 Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University, Almaty, Kazakhstan
ISBN978-601-323-547-9 https://doi.org/10.31643/2025.12

Azamat Yessengaziyev
Institute of Metallurgy and Ore Beneficiation JSC,
Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan.
E-mail: a.yessengaziyev@satbayev.university
ORCID ID: https://orcid.org/0000-0002-4989-4119

Bauyrzhan Orynbayev
Laboratory of Metallurgical Processing of Materials,
Aktobe Regional University Named After K. Zhubanov,
Aktobe 030000, Kazakhstan.
E-mail: Bauyrzhan.Orynbayev@stud.satbayev.university
ORCID ID: https://orcid.org/0000-0002-7730-9060

Zaure Karshyga
Institute of Metallurgy and Ore Beneficiation JSC,
Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan.
E-mail: z.karshyga@satbayev.university
ORCID ID: https://orcid.org/0000-0002-3025-7363

Aisha Tastanova
Institute of Metallurgy and Ore Beneficiation JSC,
Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan.
E-mail: aisha.tastanova@stud.satbayev.university
ORCID ID: https://orcid.org/0000-0003-1953-8938

Talgat Arynbayev
Institute of Metallurgy and Ore Beneficiation JSC,
Satbayev University
050010, Shevchenko str., 29/133, Almaty, Kazakhstan
E-mail: arynbayev.talgat@mail.ru
ORCID ID: https://orcid.org/0009-0006-5895-6779

Enhancing the Efficiency of Rare Earth Element Recovery from Phosphogypsum by Counter-Current Hydrochloric Acid Leaching

Abstract. This paper examines a three-stage countercurrent hydrochloric acid leaching of phosphogypsum to enhance the recovery of rare earth elements while simultaneously producing a technologically valuable gypsum product. The phosphogypsum under study has a ΣREE content of 340.53 g/t and consists primarily of $CaSO_4 \cdot 2H_2O$ dihydrate with minor silicate and phosphate impurities. The countercurrent leaching process is shown to ensure efficient reagent distribution and profound destruction of the gypsum matrix. At a solid: liquid ratio of 1:10, the overall recovery of rare earth elements reaches 88%, while at a solid: liquid ratio of 1:4, it is 82.4%, accompanied by a threefold increase in the ΣREE concentration in the productive solutions. X-ray phase analysis of the residue confirmed that complete removal of calcium sulfate from the solid phase is achieved at a solid-liquid ratio of 1:10, while at a solid-liquid ratio of 1:4, some sulfate phases are retained. The precipitate that forms during cooling of the solution is represented by $CaSO_4 \cdot 2H_2O$ and is successfully converted by heat treatment (165°C, 4 h) into the hemihydrate form $CaSO_4 \cdot 0.5H_2O$. The strength of the obtained material (5.1 MPa) corresponds to that of G5 gypsum binder. The obtained results demonstrate the effectiveness of three-stage countercurrent leaching and confirm the possibility of comprehensive processing of phosphogypsum, which ensures the production of productive solutions suitable for further sorption or extraction enrichment of rare earth elements, as well as a gypsum residue that meets the requirements of the construction industry.

Keywords: phosphogypsum, rare earth elements, hydrochloric acid leaching, extraction, gypsum binder, phase composition, solution.

Introduction

Rare earth elements (REEs) are critical metals that support the development of high-tech industries such as the production of permanent magnets, electric motors, batteries, optoelectronics, laser systems, and catalytic materials. Global demand for neodymium, praseodymium, and heavy lanthanides has been increasing annually in recent years, increasing the need to develop a sustainable mineral resource base. Given the limited availability of traditional deposits, interest in man-made sources of rare earth metals is growing, with phosphogypsum considered one of the largest and most promising sources for processing (Cuadros-Muñoz et al., 2024; Leal Filho et al., 2023).

Globally, the annual production volume of phosphogypsum exceeds 200–300 million tons, and total man-made accumulations reach 7–9 billion tons (Mukaba et al., 2021; Mashifana, 2019; Yang et al., 2024). No more than 10–15% of the material is processed, while the bulk is stored in waste dumps, forming environmentally hazardous man-made waste containing fluorine, sulfates, residual phosphates, heavy metals, and natural radionuclides (Maina et al., 2025; Men et al., 2022).

The formation of phosphogypsum occurs during the decomposition of apatite raw materials with sulfuric acid at a temperature of about 80 °C. The chemical processing of $Ca_5(PO_4)_3F$ using H_2SO_4 is known as the extraction method for the production of phosphoric acid and is described by the equation:

$$Ca_5(PO_4)_3F\ (\text{solid, 100\% REE}) + 5H_2SO_4\ (aq) + nH_2O\ (aq) \rightarrow$$
$$H_3PO_4\ (\text{aq, 20–30\% REE}) + CaSO_4{\cdot}nH_2O\ (\text{solid, 70–80\% REE}) + HF\ (aq) \quad (1)$$

During the production of wet-process phosphoric acid, a by-product is calcium sulfate dihydrate ($CaSO_4{\cdot}2H_2O$). Depending on the process conditions – temperature, sulfuric acid concentration, solid-to-liquid ratio, and holding time – other modifications of calcium sulfate may also form: hemihydrate ($CaSO_4{\cdot}0.5H_2O$) or anhydrite ($CaSO_4$). The majority of the rare earth elements contained in the original phosphate raw material accumulate in the resulting solid phases – approximately 70–80%. The remaining 20–30% are converted into wet-process phosphoric acid, being distributed between the liquid and solid phases depending on their chemical forms and solubility (Hammas-Nasri et al., 2016). Gaseous fluorine is also released, which is captured and converted into fluorine-containing products. Technologically, the processing of 1 ton of phosphate raw material requires approximately 0.6 tons of concentrated sulfuric acid, which leads to the formation of approximately 1.2 tons of phosphogypsum (van Selst et al., 1997; Bilal et al., 2023). It is this stoichiometric balance that determines the colossal volumes of annual accumulation of phosphogypsum and its dominant contribution to the global flow of man-made mineral waste.

Typical ΣREE contents in phosphogypsum vary from 200–500 mg/kg for phosphate raw materials to 1500–2500 mg/kg for apatite phosphogypsum (Cánovas et al., 2019; Kurkinen et al., 2021). REE are present both in an isomorphously included state in the crystal lattice of $CaSO_4{\cdot}2H_2O/0.5H_2O$ and in the form of microdispersed phosphate and fluorine-containing phases. The complex phase nature of the inclusions significantly complicates the extraction of REE and requires the use of hydrometallurgical processes aimed at the destruction or rearrangement of the $CaSO_4$ structure and the selective transfer of lanthanides into solution (Kirillov et al., 2021).

Existing studies show that phosphogypsum processing can be carried out using various methods, the most common of which are acid, alkaline and conversion leaching. The processes of phosphogypsum dissolution using HCl, HNO_3, and H_2SO_4, which ensure the destruction of phosphate-fluoride microphases and the transfer of rare earth elements into solution, have been studied in most detail (Lütke et al., 2022; Dong et al., 2025; Guan et al., 2022). In addition to acid methods, alkaline and conversion approaches occupy an important place, where, for example, Na_2CO_3 is used for the preliminary decomposition of $CaSO_4$ and the transfer of the system to a more reactive state, which subsequently increases the efficiency of acidic dissolution (Gasser et al., 2022). Conversion methods based on the conversion of $CaSO_4$ to CaS with subsequent extraction of REE are discussed in detail in Nsaka Ntumba et al., 2023.

The issue of phosphogypsum processing is of particular importance for Kazakhstan. The country's largest man-made phosphogypsum deposits have been created at the Kazphosphate LLC enterprise in the Zhambyl region. According to the state news agency Kazinform (News Agency), in the immediate vicinity of the city of Taraz, there are two operating waste dumps with a total capacity of more than 16 million tons, and the total volume of previously formed deposits exceeds 36 million tons. In addition, a project for the

construction of a third waste dump with a capacity of 20 million tons has been approved. The scale of these accumulations is causing serious concern among the population and environmental organizations, since the long-term storage of phosphogypsum negatively affects groundwater, soil, and the sanitary and hygienic condition of the territory, which has been repeatedly noted by the Ministry of Ecology and the deputy corps.

In the face of increasing environmental pressure, issues of managing phosphogypsum accumulations and returning its components to economic circulation are particularly pressing. Large-scale man-made phosphogypsum waste dumps pose environmental risks, but they also represent a potential source of valuable resources. Of particular interest from the perspective of industrial applications and scientific research is the possibility of extracting rare earth elements concentrated in phosphogypsum, as well as using this material in the production of construction and technological products.

The compounds formed during acid processing, such as calcium sulfate dihydrate, have the potential for further use as secondary raw materials in the production of gypsum binders and other materials, which is in line with the principles of resource conservation. The implementation of such projects allows us to simultaneously address environmental issues, improve resource efficiency in production, and create new raw material flows for the metallurgical and construction industries, especially in regions with large technogenic accumulations.

For the practical implementation of phosphogypsum processing approaches, it is important to study its behavior under acidic dissolution conditions, evaluate the release of rare earth elements into solution, and assess changes in the phase composition of the solid phase. The objective of this study is to conduct hydrochloric acid leaching experiments to release rare earth elements into solution and produce a solid product suitable for use in the construction industry.

Materials and methods

Object of Study. The material investigated in this work was phosphogypsum generated as a by-product during the industrial production of wet-process phosphoric acid at the Kazphosphate LLC plant. Figure 1 presents a schematic material balance of the sulfuric acid decomposition of phosphate feedstock, illustrating the formation of wet-process phosphoric acid and phosphogypsum.

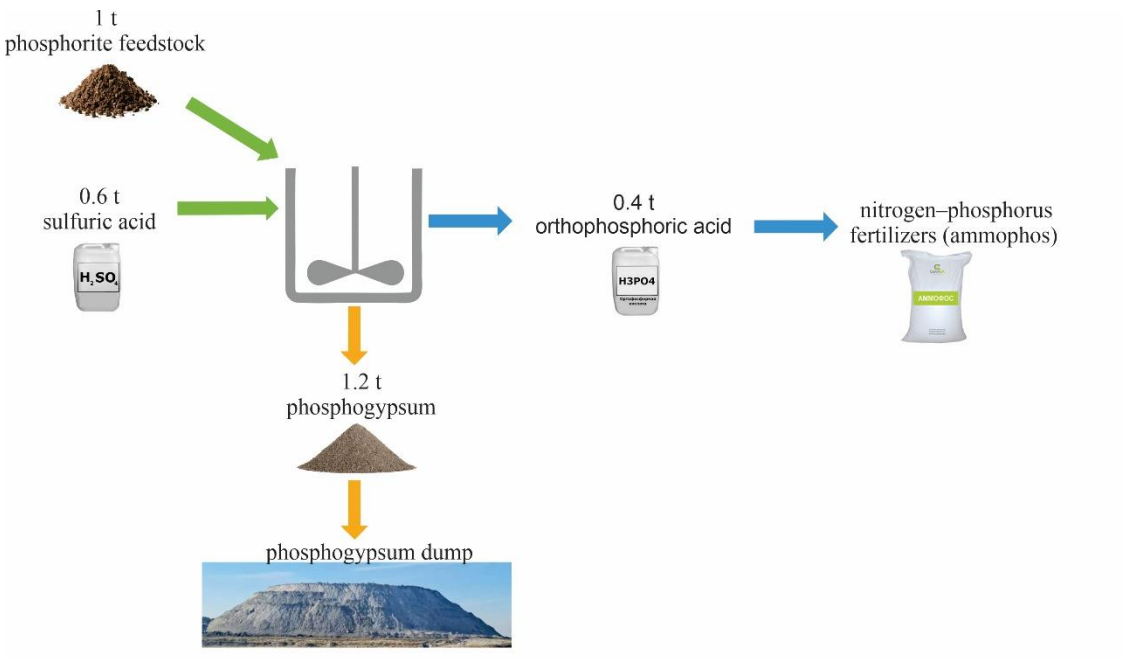


Figure 1. Sulfuric acid decomposition of phosphate feedstock during wet-process phosphoric acid production

Rare earth elements present in phosphogypsum may occur in several forms: (i) as isomorphic substitutions of Ca^{2+} within the crystal lattice of gypsum; (ii) as discrete mineral phases or inclusions such as monazite, xenotime, and residual apatite; and (iii) as ion-adsorbed species represented by secondary precipitates of REE salts (sulfates, carbonates, fluorides) deposited on the surface of gypsum particles (Figure

2). Thus, REEs in phosphogypsum are distributed among the crystal lattice, mineral impurities, and surface-associated formations (Khalil et al., 2025), which collectively determine their behavior during leaching and recovery.

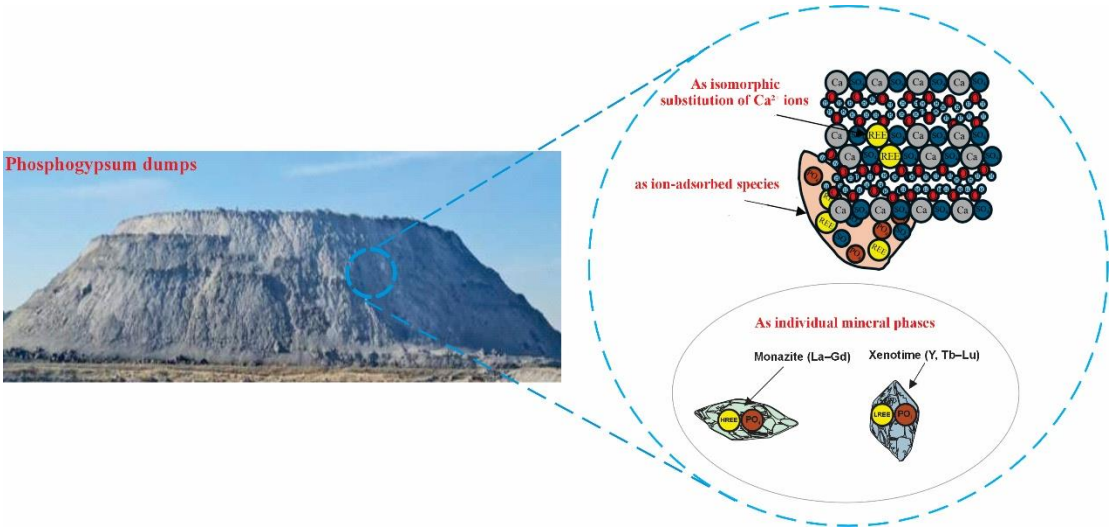


Figure 2. Forms of rare earth element distribution in phosphogypsum

Chemical analysis of the sample showed the following composition (wt.%): Ca – 14.9; Si – 2.9; Al – 0.26; Fe – 0.26; Mg – 0.07; P – 0.5. The total REE concentration is ΣREE = 340.53 g/t, including (g/t): Sc – 0.63; Y – 89; La – 70; Ce – 76; Pr – 12; Nd – 52; Sm – 10.2; Eu – 2.2; Gd – 9.9; Tb – 1.4; Dy – 8.5; Ho – 1.6; Er – 4.4; Tm – 0.5; Yb – 2; Lu – 0.2. Hydrochloric acid of analytical grade ("HCh") was used as the leaching reagent.

Equipment. The laboratory and analytical equipment used in this study included: Pyrex reactor beakers, a VELP Scientifica LS F201A0151 mechanical stirrer, a LOIP LT-100 circulating thermostat, a SNOL 7.2/1300 muffle furnace, a vacuum filtration system, AX1202013 analytical balances, a HANNA HI 2210-02 pH meter, an MIP-25R hydraulic press, a STA 449 F3 Jupiter thermal analyzer, Optima 8300DV ICP-OES and AA-7000 AAS spectrometers, a Bruker D8 ADVANCE XRD diffractometer, and a PANalytical Venus 200 XRF analyzer.

Experimental Procedure. A three-stage counter-current hydrochloric acid leaching scheme was implemented to increase the recovery of REEs and to obtain pregnant solutions with elevated ΣREE concentrations. The process was conducted under optimized conditions: temperature 80 °C, duration of each stage 0.5 h, HCl concentration 10%, sample mass 100 g, and solid-to-liquid ratios S:L = 1:10 and 1:4.

Phosphogypsum batch No. 1 was leached sequentially with three portions of solution, producing residue samples 1/1, 1/2, and 1/3 and their corresponding filtrates. Filtrates 1/2 and 1/3 were subsequently reused as process solutions for leaching phosphogypsum batch No. 2.

Processing of phosphogypsum No. 2 involved three stages: in Stage 1, the material was introduced into the heated filtrate 1/2 to obtain residue 2/1; in Stage 2, residue 2/1 was treated with filtrate 1/3, producing residue 2/2 and solution 2/2, the latter being forwarded to Stage 1 of PG No. 3; in Stage 3, residue 2/2 was leached with fresh acid to obtain residue 2/3 and solution 2/3, which was sent to Stage 2 of PG No. 3.

Phosphogypsum batch No. 3 was processed similarly: residue 3/1 was produced from solution 2/2 at Stage 1; residue 3/2 was formed using solution 2/3 at Stage 2; and the final products – residue 3/3 and filtrate 3/3 – were obtained during Stage 3. All solid and liquid samples from each step were subjected to subsequent chemical analysis.

Since the mass of the solid phase decreased from stage to stage, the S:L ratio was maintained constant by adjusting the solution volume. Despite the multistep configuration, the total acid consumption remained comparable to that of single-stage leaching, while the extraction efficiency increased due to the counter-current mode.

All pregnant leach solutions were cooled, resulting in the precipitation of calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$) due to secondary crystallization. The precipitate was filtered, washed with distilled water, and

dried at 60–80 °C. For the production of gypsum binders, the material was thermally treated at 145–165 °C for 3–4 h to convert it into the hemihydrate form. Cubic specimens (20x20x20 mm) were then prepared for compressive strength testing and XRD analysis, with results evaluated against the requirements for G4–G5 gypsum binders.

Main results and their discussion

Mineralogical composition of phosphogypsum. X-ray phase analysis revealed that the phosphogypsum sample was predominantly composed of the dihydrate form of gypsum, $CaSO_4 \cdot 2H_2O$. A quantitative assessment revealed a gypsum content of 87.5%, with quartz present as a minor phase at 12.5%. No other crystalline components were detected, confirming the homogeneity of the mineral composition and the predominance of calcium sulfate dihydrate (Figure 3).

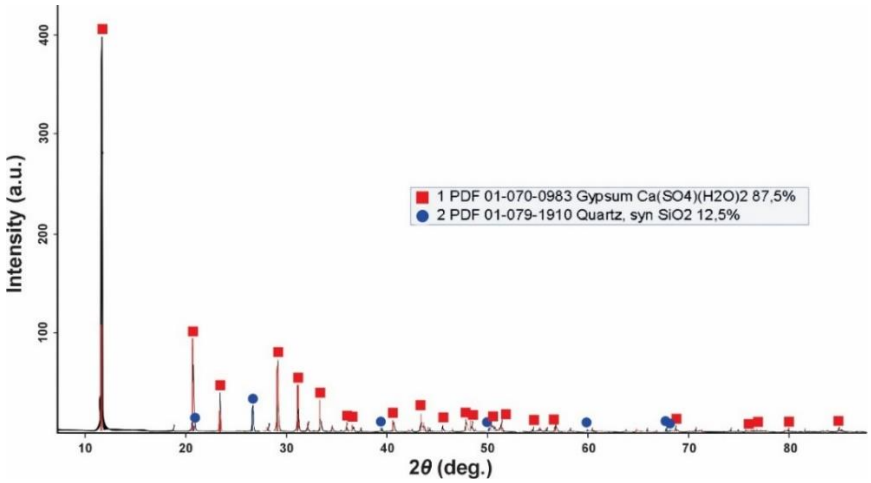


Figure 3. X-ray diffraction pattern of the phosphogypsum sample

Thermal analysis (Figure 4) exhibited transformations characteristic of calcium sulfate dihydrate. Two pronounced endothermic effects were recorded on the DTA curve at 196.1 °C and 225.2 °C, corresponding to the stepwise dehydration of $CaSO_4 \cdot 2H_2O$ with the formation of hemihydrate and anhydrite. The respective peaks on the dDTA curve appear at 165.7 °C and 217.7 °C, while the DTG curve shows mass-loss minima at 166.8 °C and 218.1 °C. An exothermic effect at 457.2 °C indicates structural rearrangement and the formation of insoluble anhydrite. In the high-temperature range, a weak endothermic anomaly near 791–794 °C is associated with minor impurities such as REE-bearing apatite and/or calcite, as well as the polymorphic transition β-$Sr_2P_2O_7$ → α-$Sr_2P_2O_7$. A faint exothermic peak at ~824.8 °C on the dDTA curve may correspond to the crystallization of a dehydrated phosphate phase of composition $YPO_4 \cdot H_3PO_4 \cdot 2H_2O$, typical for structural rearrangements in REE phosphates following the loss of bound water or phosphoric acid groups. The absence of a low-temperature dehydration peak confirms the low content of surface-bound water and the structural stability of the gypsum matrix.

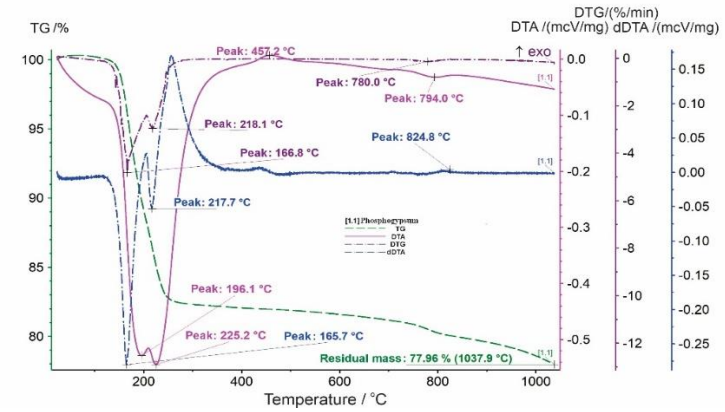


Figure 4. Thermal analysis curve of the phosphogypsum sample

SEM observations demonstrated aggregates of typical platy and needle-like gypsum crystals (Figure 5). Elemental mapping for Ca and S showed uniform distribution of the sulfate phase, while elevated Si and Al signals indicated the presence of silicate and aluminosilicate inclusions. Local enrichment in P is consistent with phosphate impurities. Trace Cr signals reflect minor technogenic inclusions. Semi-quantitative EDS analysis revealed the predominance of O (61.04 wt.%), Ca (16.58 wt.%), Si (9.38 wt.%), P (6.65 wt.%), and S (4.54 wt.%). The Ca/S ratio corresponds to the stoichiometry of $CaSO_4 \cdot 2H_2O$, confirming the results of XRD and thermal analysis.

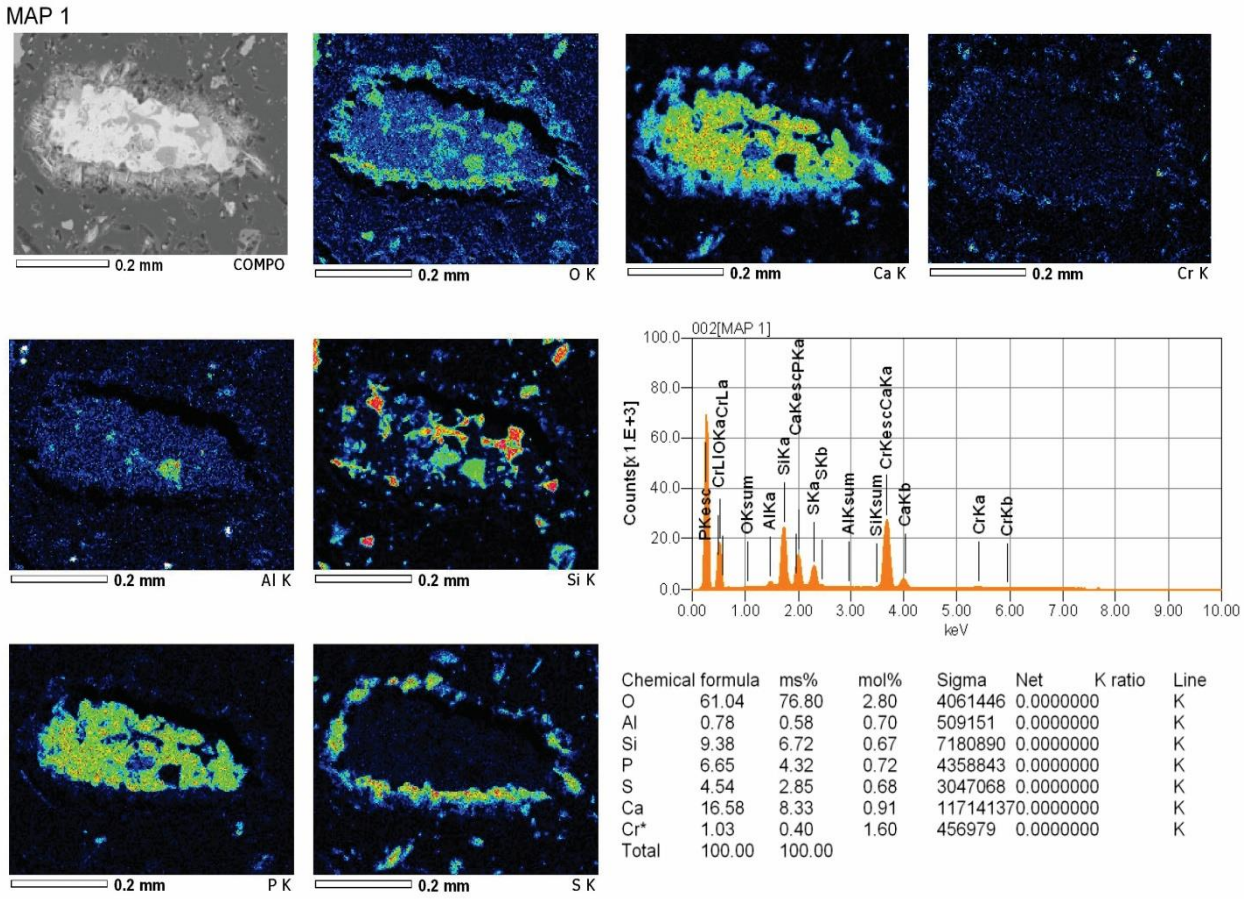


Figure 5. EDS elemental mapping of the examined phosphogypsum sample

Overall, the studied phosphogypsum is mainly represented by $CaSO_4 \cdot 2H_2O$ with silicate and phosphate impurities, consistent with the typical composition of such materials reported in the literature [Lei et al., 2024]. The minor thermal effects observed at 790–825 °C, which are absent in pure gypsum, are characteristic of structural transformations in hydrated REE phosphates (e.g., $YPO_4 \cdot H_3PO_4 \cdot 2H_2O$). The presence of REEs is attributed both to isomorphic substitution within the $CaSO_4$ structure and to microdomains enriched in phosphate phases identified by EDS, where REEs are likely accumulated in their own mineral forms.

Three-Stage Counter-Current Hydrochloric Acid Leaching of Phosphogypsum. Previous studies aimed at determining the optimal conditions for hydrochloric acid leaching have shown that up to 70–75% of REEs can be recovered into solution under single-stage treatment. The three-stage counter-current HCl leaching flowsheet presented in Figure 6 enabled a substantial increase in the extraction efficiency of rare earth elements from phosphogypsum while simultaneously raising the ΣREE concentration in the pregnant leach solutions. The counter-current configuration provides sequential contact of the solid phase with solutions of different stages: fresh phosphogypsum interacts with the most REE-enriched liquor from the second stage, whereas the residues produced in later stages are treated with less concentrated or freshly prepared solutions. This flow arrangement ensures deeper REE dissolution with only minimal additional reagent consumption.

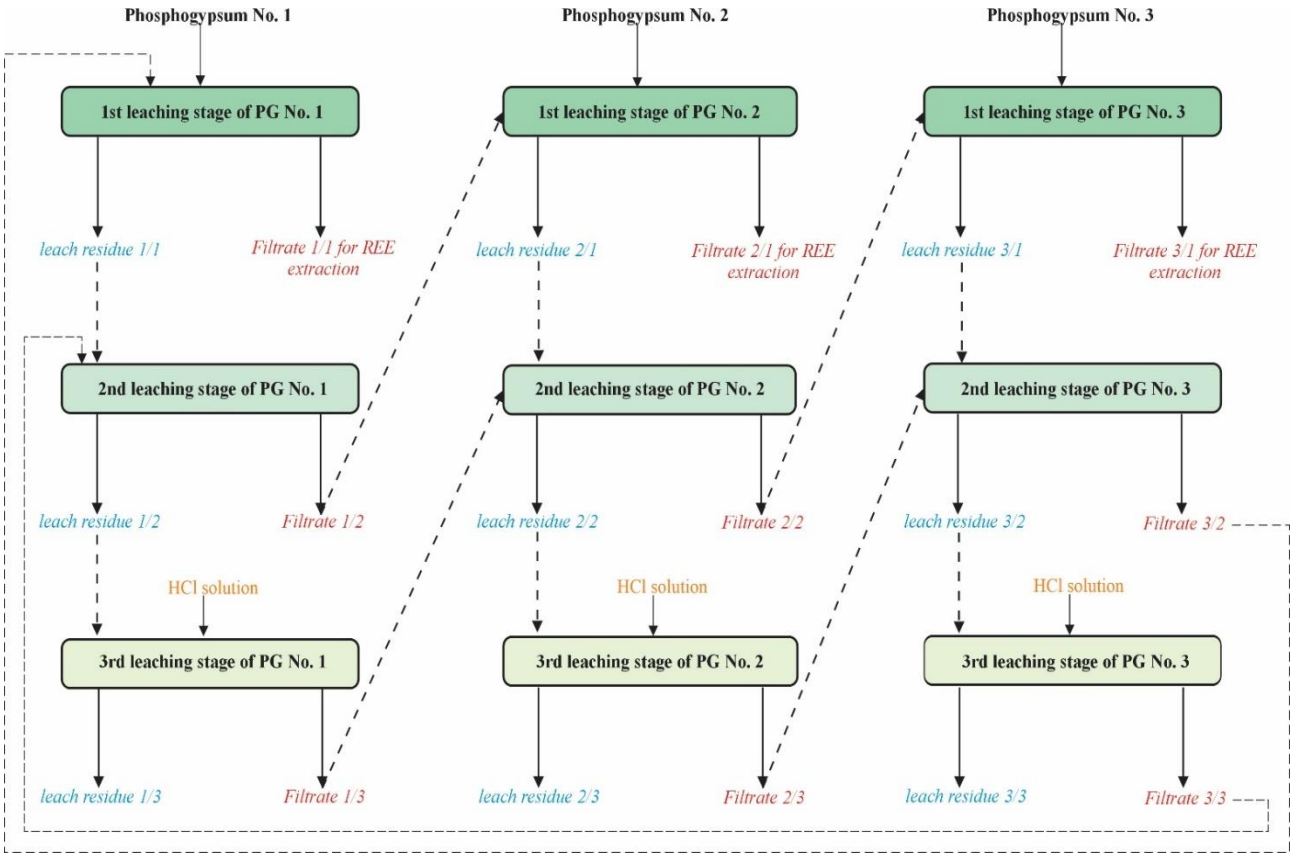


Figure 6. Flow diagram of the three-stage counter-current hydrochloric acid leaching of phosphogypsum

The results of three-stage leaching at a solid:liquid ratio of 1:10 are presented in Table 1. The first stage demonstrates the most intense transfer of rare earth metals into solution – 56.92% ΣREE (Figure 7). This result indicates the high reactivity of some rare earth compounds, which is typical of surface-sorbed and readily soluble forms.

Table 1. Indicators of phosphogypsum leaching with hydrochloric acid according to a three-stage scheme

Name	Concentration in solution, g/dm^3					Extraction, %				
	∑REE	Ca	Al	Fe	Mg	∑REE	Ca	Al	Fe	Mg
Filtrate of Stage 1	0.0272	4.66	0.005	0.332	0.072	56.92	16.44	0.68	47.90	56.93
Precipitate	-	-	-	-	-	8.10	-	-	-	-
Filtrate of Stage 2	0.00936	5.04	0	0.237	0.002	13.73	0.73	0	6.03	0
Precipitate	-	-	-	-	-	2.55	-	-	-	-
Filtrate of Stage 3	0.00735	5.49	0.119	0.22	0.018	17.15	23.49	18.31	45.39	14.82
Precipitate	-	-	-	-	-	0.45	-	-	-	-
Residue	-	-	-	-	-	1.1	-	-	-	-

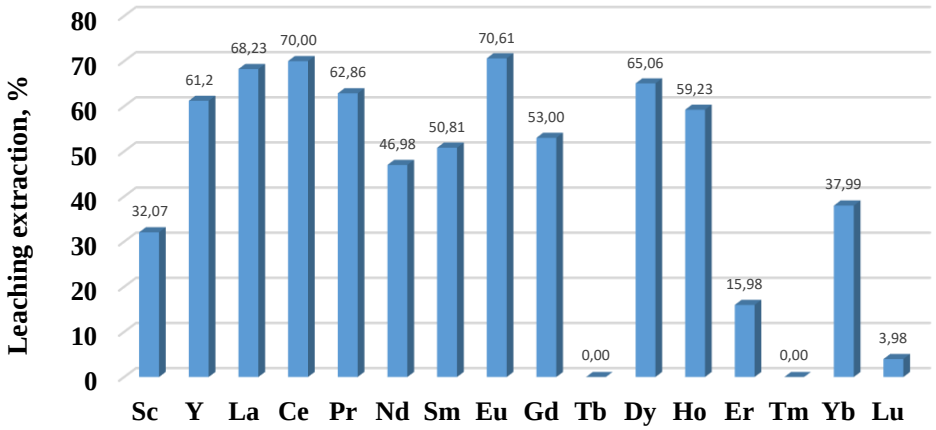


Figure 7. Extraction of REE in the first stage at S:L = 1:10

In the second and third stages, an additional 13.73% and 17.15% of ΣREE are recovered, respectively (Figures 8 and 9), resulting in a total recovery of approximately 88%. This figure significantly exceeds the levels previously achieved with the single-stage process, confirming the effectiveness of the countercurrent approach reflected in the flow chart.

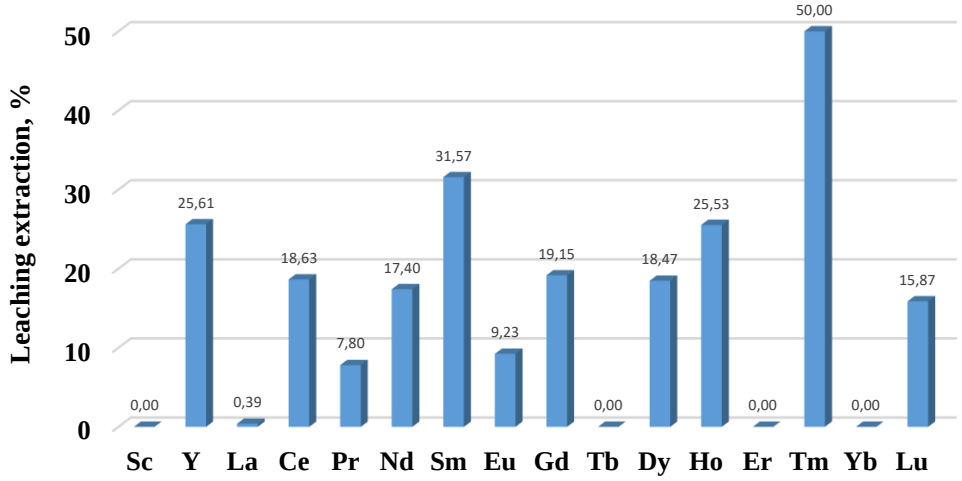


Figure 8. Extraction of REE in the second stage at S:L = 1:10

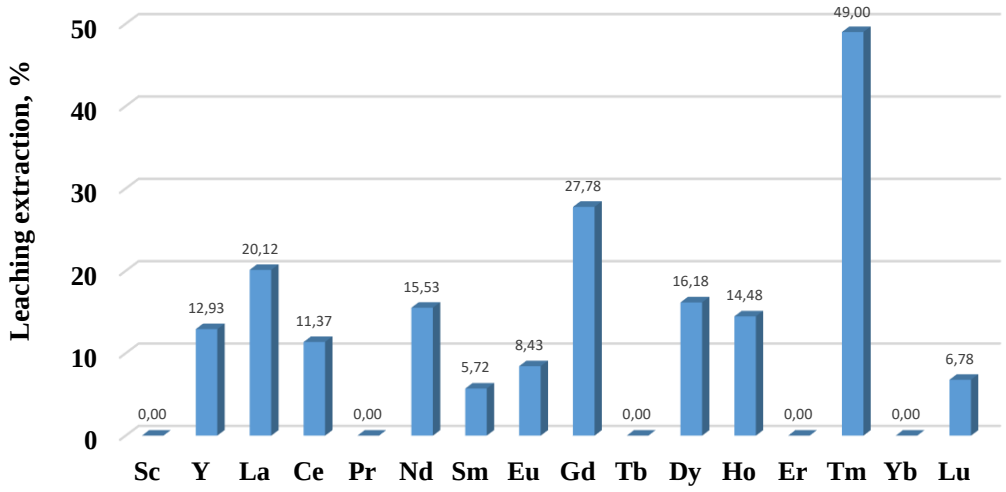


Figure 9. Extraction of REE in the third stage at S:L = 1:10

The behavior of the associated elements is consistent with their chemical nature. Iron and magnesium rapidly dissolve in the first stage. Calcium partially dissolves, simultaneously forming a secondary gypsum precipitate, which accounts for 11.1% of the ΣREE. Only approximately 1.1% of the REE remains in the final residue.

Elemental analysis showed that light REE (La–Nd) are extracted most completely, reaching 60–85%. Among heavy REE, the highest values of dissolution are characteristic of dysprosium, holmium, and thulium, as shown in Figures 7–9. This distribution is due to the higher solubility of the chloride forms of some heavy REE and the lower binding strength within the phosphogypsum microinclusions.

To increase the ΣREE concentration in the solution, three-stage leaching was carried out with a reduced liquid:solid ratio of 1:4. Despite the decrease in the volume of the solution, a significant proportion of 54.28% of ΣREE is extracted at the first stage (Table 2, Figure 10), which indicates the stability of the REE transition kinetics.

Table 2. Extraction of rare earth metals into solution during three-stage hydrochloric acid leaching of phosphogypsum (S:L ratio = 1:4)

Leaching stage	Concentration of ΣREE in solution, g/dm^3	Extraction into solution, %
1	0.0822	54.28
2	0.0403	14.29
3	0.0315	13.83

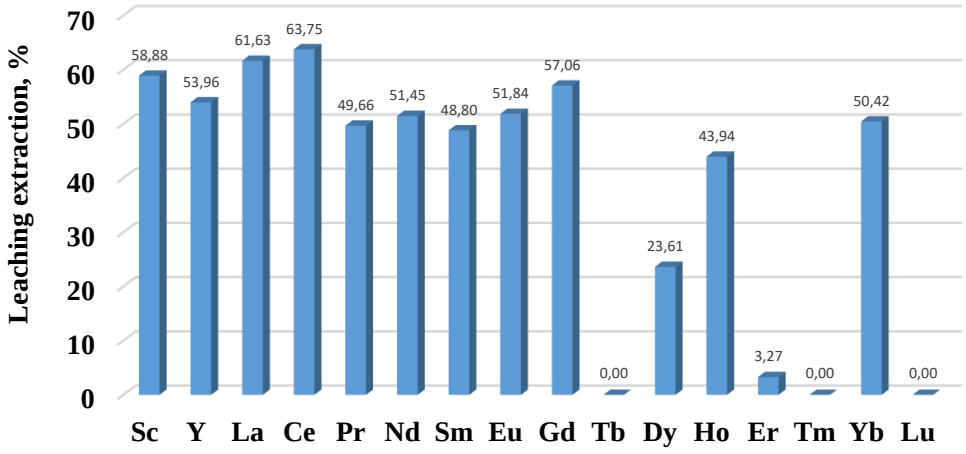


Figure 10. Extraction of REE in the first stage at S:L = 1:4

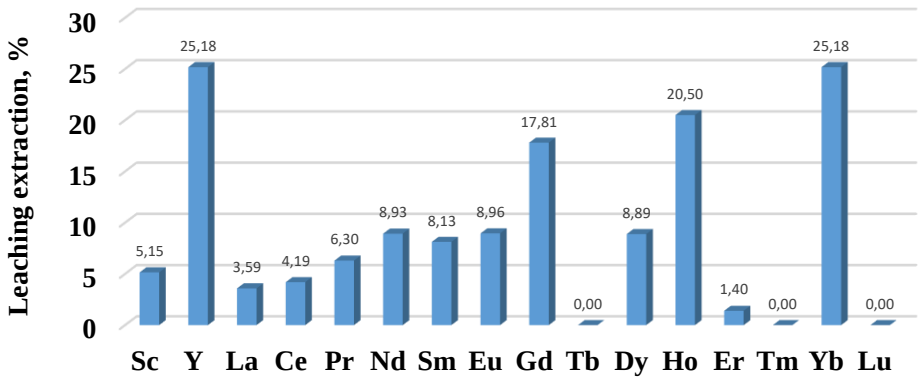


Figure 11. Extraction of REE in the second stage at S:L = 1:4

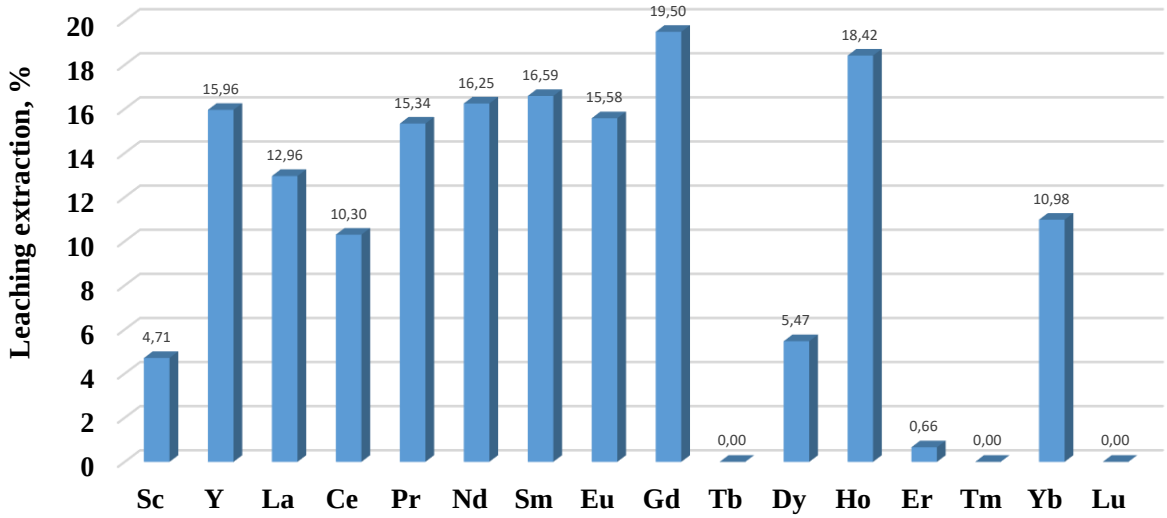


Figure 12. Extraction of REE in the third stage at S:L = 1:4

The second and third stages provide an additional 14.29% and 13.83% of ΣREE (Figures 11 and 12). The total recovery reaches 82.4%, which is slightly lower than the result at a solid: liquid ratio of 1:10. However, the key advantage of the 1:4 mode is a threefold increase in the ΣREE concentration in the solution, which significantly reduces the specific consumption of sorbents or extractants during subsequent processing.

With a decrease in the liquid ratio to S:L = 1:4, the cumulative recovery decreases slightly and amounts to 82.4%, which is due to the partial preservation of calcium sulfate in the solid phase. However, this mode provides a significantly higher concentration of ΣREE in productive solutions. Increasing the concentration by 2.5–3 times is an important technological advantage, since it reduces the consumption of sorbents, extractants, and reagents at subsequent stages of processing, and also reduces the volume of circulating solutions.

X-ray phase analysis of the residue after the third stage of leaching showed that at a ratio of S:L = 1:10, the solid residue is mainly quartz (Figure 13, a), which indicates the almost complete removal of calcium sulfate from the solid phase. When the liquid ratio decreases to S:L = 1:4, in addition to quartz, calcium sulfate semihydrate, and anhydrite are fixed in the residue (Figure 13, b). The preservation of sulfate phases indicates incomplete decomposition of the gypsum matrix at a reduced S:L, which leads to a slight decrease in the degree of REE extraction compared to the optimal mode S:L = 1:10.

A comparative analysis of the two studied leaching modes shows that the ratio of solid and liquid has a significant effect both on the completeness of the transition of rare earth metals into solution and on the phase composition of the resulting solutions and solid products. At S:L = 1:10, the maximum degree of REE extraction into solution is reached, which is about 88%. Under these conditions, the gypsum matrix of phosphogypsum is almost destroyed, which is confirmed by the formation of a residue, represented mainly by quartz. Thus, this mode ensures deep extraction of the target components and effective removal of sulfate phases from intermediate sediments.

A key factor in the high efficiency of the process is the countercurrent stage organization scheme, according to which the most REE-saturated solution is sent to fresh phosphogypsum, while a fresh acid solution is fed to a residue that has undergone two stages of leaching. This flow direction ensures optimal distribution of the reagent, promotes a more complete release of rare earth elements, and eliminates excessive acid consumption. The three-stage scheme demonstrates high technological efficiency, allowing combining deep extraction of REE (82-88%) with the production of concentrated solutions and solid phases of stable mineral composition.

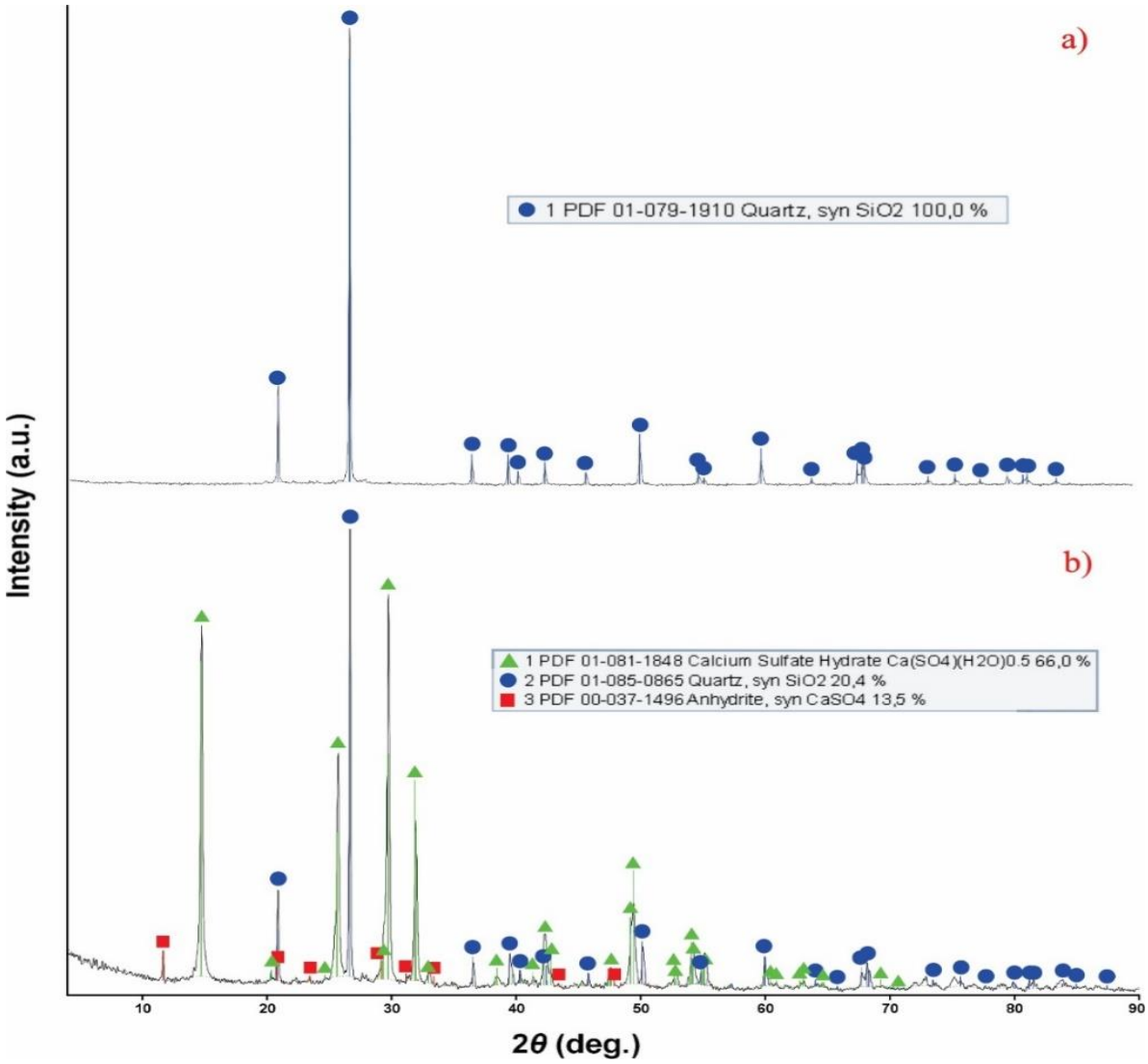


Figure 13. Residue diffractograms after the third stage of phosphogypsum leaching at various ratios S:L: a – 1:10; b – 1:4.

Processing of the Gypsum Precipitate. The properties of the precipitates formed during the cooling of the leached solutions were also studied. According to X-ray fluorescence analysis, the precipitate contains, wt. %: 22.545 Ca; 17.383 S; 52.635 O; 0.011 Si; 0.024 Cl; 0.009 Sr. X-ray phase analysis revealed that the precipitate was predominantly calcium sulfate dihydrate $CaSO_4 \cdot 2H_2O$ (Figure 14, a).

The formation of calcium sulfate from the solution after leaching can be explained by the interaction of calcium chloride with sulfuric acid present in the solution. During the leaching of phosphogypsum with hydrochloric acid, some of the calcium presumably passes into solution via the reaction:

$$CaSO_4 \cdot 2H_2O + 2HCl \leftrightarrow CaCl_2 + H_2SO_4 + 2H_2O \quad (2)$$

After separation of the residue and cooling of the solution below 70°C (Demopoulos et al., 2016), the reaction begins to shift in the opposite direction, which leads to the reprecipitation of calcium sulfate dihydrate.

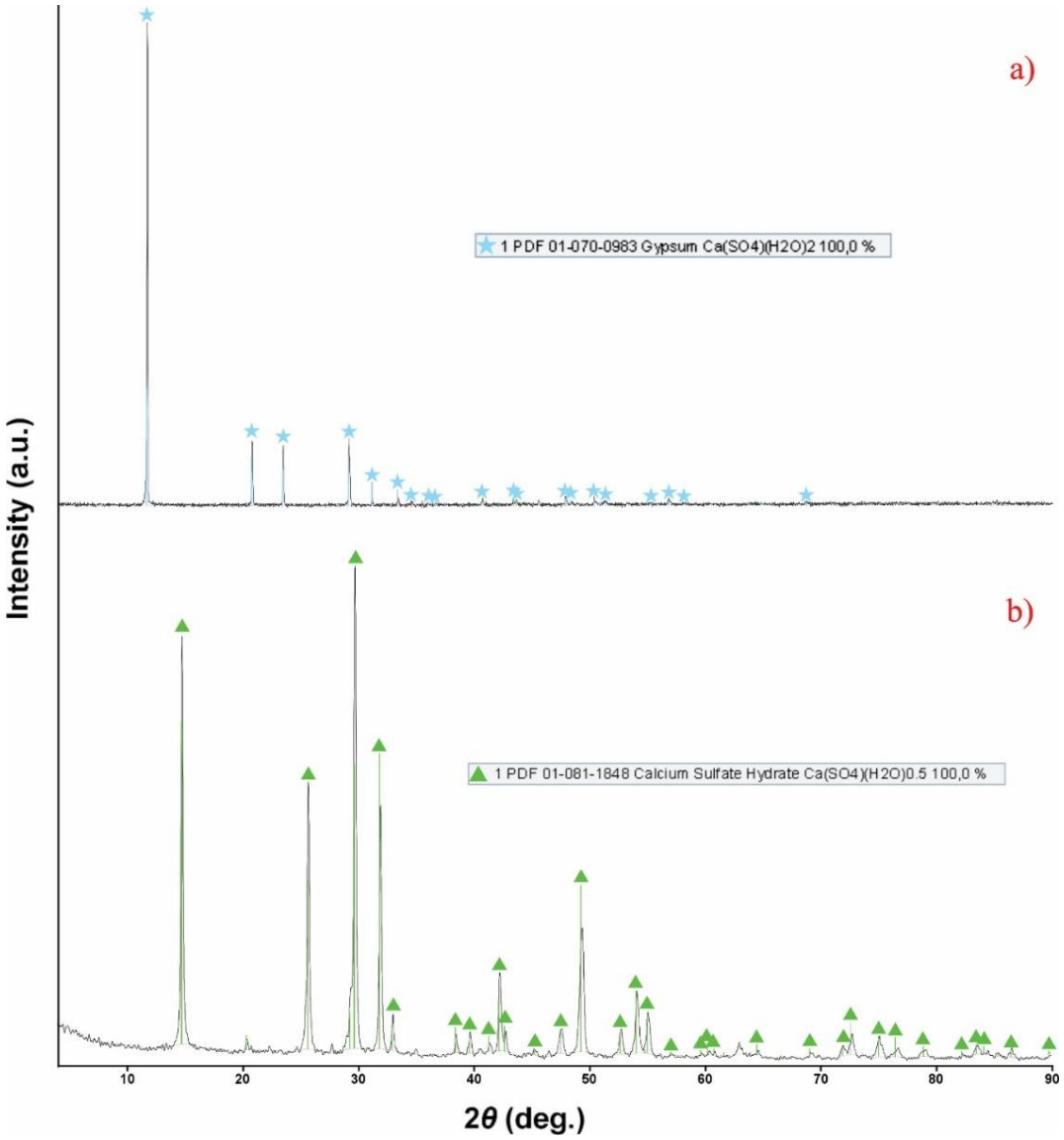


Figure 14. Diffraction patterns of the precipitate before (a) and after calcination (b)

To assess the potential suitability of this material, it was heat-treated to convert the dihydrate gypsum to a hemihydrate form. Calcination at 165°C for 4 hours resulted in the formation of $CaSO_4 \cdot 0.5H_2O$ hemihydrate, as confirmed by the characteristic diffraction pattern (Figure 14, b).

The mechanical properties of the calcined material were evaluated under compression on a mobile MIP-25P press. The ultimate strength of the sample was 5.1 MPa, which corresponds to gypsum binder grade G5. The results obtained show that the precipitate deposited at the stage of cooling the solution can be converted into a semi-hydrate form and meets the requirements for gypsum binders in terms of strength characteristics, at least at the laboratory testing level.

Conclusion

The conducted studies have shown that phosphogypsum, represented mainly by $CaSO_4 \cdot 2H_2O$ dihydrate and containing minor silicate and phosphate compounds, which contain 340.53 g/t of REE, is effectively amenable to three-stage countercurrent hydrochloric acid leaching. The optimal mode is the liquid ratio S:L = 1:10, at which the maximum degree of REE extraction is achieved at 88% and complete removal of calcium sulfate from the solid phase is ensured, whereas at S:L = 1:4, the extraction is 82.4%, but the concentration of REE in solution increases 2.5–3 times. The countercurrent organization of the process

ensures a rational distribution of the reagent and a deep destruction of the gypsum matrix, which is confirmed by mineralogical data. The precipitate $CaSO_4 \cdot 2H_2O$ precipitated during cooling of the solutions is successfully converted to the semihydrate form $CaSO_4 \cdot 0.5\ H_2O$ at 165 °C for 4 hours, forming a 5.1 MPa material corresponding to gypsum binder grade G5. Thus, the proposed scheme provides for the complex processing of phosphogypsum to obtain concentrated REE solutions suitable for further sorption or extraction enrichment, and the formation of a gypsum product that meets the requirements of the construction industry.

CRediT author statement: **A.M. Yessengaziyev**: Writing draft preparation, Proof-reading, Software, Data curation, Validation. **Z.B. Karshyga**: Supervision, Methodology, Conceptualisation. **A.E. Orynbayev**: Visualisation. **T. M. Tastanova & T.M. Arynbayev**: Editing.

Cite this article: Yessengaziyev, A. M. Karshyga, Z. B. Orynbayev, B. M. Tastanova, A. E. Arynbayev, T. M. (2025). Enhancing the Efficiency of Rare Earth Element Recovery from Phosphogypsum by Counter-Current Hydrochloric Acid Leaching. Materials of International Scientific-Practical Internet Conference "Challenges of Science". Issue VIII, pp. 95-108. https://doi.org/10.31643/2025.12

References

Cuadros-Muñoz, J.-R., Jimber-del-Río, J.-A., Sorhegui-Ortega, R., Zea-De la Torre, M., & Vergara-Romero, A. (2024). Contribution of rare earth elements is key to the economy of the future. *Land*, *13*(8), Article 1220. https://doi.org/10.3390/land13081220

Leal Filho, W., Kotter, R., Özuyar, P. G., Abubakar, I. R., Eustachio, J. H. P. P., & Matandirotya, N. R. (2023). Understanding rare earth elements as critical raw materials. *Sustainability*, *15*(3), Article 1919. https://doi.org/10.3390/su15031919

Mukaba, J.-L., Eze, C. P., Pereao, O., & Petrik, L. F. (2021). Rare earths' recovery from phosphogypsum: An overview on direct and indirect leaching techniques. *Minerals*, *11*(10), Article 1051. https://doi.org/10.3390/min11101051

Mashifana, T. P. (2019). Chemical treatment of phosphogypsum and its potential application for building and construction. *Procedia Manufacturing*, *35*, 641–648. https://doi.org/10.1016/j.promfg.2019.06.007

Yang, J., Dong, S., Hu, B., Duan, L., Yan, X., Zhou, G., & Ma, L. (2024). *Review on phosphogypsum high value utilization: Utilization of calcium and oxygen resources* [Preprint]. SSRN. https://doi.org/10.2139/ssrn.4731994

Maina, L., Kiegiel, K., & Zakrzewska-Kołtuniewicz, G. (2025). Challenges and strategies for the sustainable environmental management of phosphogypsum. *Sustainability*, *17*(8), Article 3473. https://doi.org/10.3390/su17083473

Men, J., Li, Y., Cheng, P., & Zhang, Z. (2022). Recycling phosphogypsum in road construction materials and associated environmental considerations: A review. *Heliyon*, *8*(8), Article e11518. https://doi.org/10.1016/j.heliyon.2022.e11518

Hammas-Nasri, I., Horchani-Naifer, K., Férid, M., & Barca, D. (2016). Rare earths concentration from phosphogypsum waste by two-step leaching method. *International Journal of Mineral Processing*, *149*, 78–83. https://doi.org/10.1016/j.minpro.2016.02.011

van Selst, R., Penders, L., & Bos, W. (1997). Processing and application of phosphoric gypsum. In *Studies in Environmental Science* (Vol. 71, pp. 603–615). Elsevier. https://doi.org/10.1016/S0166-1116(97)80244-0

Bilal, E., Bellefqih, H., Bourgier, V., Mazouz, H., Dumitras, D.-G., Bard, F., Laborde, M., Caspar, J. P., Guilhot, B., Iatan, E.-L., Bounakhla, M., Iancu, M. A., Marincea, Ș., Essakhraoui, M., Li, B., Diwa, R. R., Ramirez, J. D., Chernysh, Y., Chubur, V., Roubík, H., Schmidt, H., Beniazza, R., Ruiz Canovas, C., Nieto, J. M., & Haneklaus, N. (2023). Phosphogypsum circular economy considerations: A critical review from more than 65 storage sites worldwide. *Journal of Cleaner Production*, *414*, Article 137561. https://doi.org/10.1016/j.jclepro.2023.137561

Cánovas, C. R., Chapron, S., Arrachart, G., & Pellet-Rostaing, S. (2019). Leaching of rare earth elements (REEs) and impurities from phosphogypsum: A preliminary insight for further recovery of critical raw materials. *Journal of Cleaner Production*, *219*, 225–235. https://doi.org/10.1016/j.jclepro.2019.02.104

Kurkinen, S., Virolainen, S., & Sainio, T. (2021). Recovery of rare earth elements from phosphogypsum waste in resin-in-leach process by eluting with biodegradable complexing agents. *Hydrometallurgy*, *201*, Article 105569. https://doi.org/10.1016/j.hydromet.2021.105569

Kirillov, S. V. (2021). *Physico-chemical foundations for intensifying the extraction of rare earth metals from phosphogypsum* (Candidate of Technical Sciences dissertation). Ural Federal University named after the First President of Russia B. N. Yeltsin. (In Russian)

Lütke, S. F., Oliveira, M. L. S., Waechter, S. R., Silva, L. F. O., Cadaval Jr., T. R. S., Duarte, F. A., & Dotto, G. L. (2022). Leaching of rare earth elements from phosphogypsum. *Chemosphere*, *301*, Article 134661. https://doi.org/10.1016/j.chemosphere.2022.134661

Dong, W., Deng, X., Chai, L., Zhang, Y., Chen, H., Wu, H., & Chi, R. (2025). Leaching characteristics and mechanisms of fluorine and phosphorus from phosphogypsum. *Molecules*, *30*(1), Article 5. https://doi.org/10.3390/molecules30010005

Guan, Q., Sui, Y., Liu, C., Wang, Y., Zeng, C., Yu, W., Gao, Z., Zang, Z., & Chi, R.-A. (2022). Characterization and leaching kinetics of rare earth elements from phosphogypsum in hydrochloric acid. *Minerals*, *12*(6), Article 703. https://doi.org/10.3390/min12060703

Gasser, M. S., Ismail, Z. H., Abu Elgoud, E. M., Abdel Hai, F., Othman, I., & Aly, H. F. (2022). Alkali treatment–acid leaching of rare earth elements from phosphogypsum fertilizer: Insight for additional resource of valuable components. *BMC Chemistry*, *16*(1), Article 45. https://doi.org/10.1186/s13065-022-00845-7

Nsaka Ntumba, C., McCrindle, R., Maree, J., & Ngole-Jeme, V. (2023). The behaviour of selected rare-earth elements during the conversion of phosphogypsum to calcium sulphide and residue. *Journal of Material Cycles and Waste Management*, *25*, 1658–1671. https://doi.org/10.1007/s10163-023-01640-9

Kazinform News Agency. (2024, November 25). *36 million tons of phosphogypsum dumps pose an environmental threat to residents of Taraz*. https://www.inform.kz/ru/36-mln-tonn-otvalov-fosfogipsa-yavlyayutsya-ekologicheskoy-ugrozoy-dlya-zhiteley-taraza-50bbdf

Khalil, F., Pagnanelli, F., & Moscardini, E. (2025). Phosphogypsum as the secondary source of rare earth elements. *Sustainability*, *17*(19), Article 8828. https://doi.org/10.3390/su17198828

Lei, Y., Gong, Y.-J., He, M., Li, L., Qin, J., & Liu, Y. (2024). High-efficiency purification and morphology regulation of $CaSO_4 \cdot 2H_2O$ crystals from phosphogypsum. *Molecules*, *29*(16), Article 3910. https://doi.org/10.3390/molecules29163910

Demopoulos, G., Peethamparan, S., & Neil, S. R. L. (2017). *Production of high strength hydrochloric acid from calcium chloride feed streams by crystallization* (Canadian Patent No. CA2926356A1). Canadian Intellectual Property Office.

Content

Materials of International Scientific-Practical Internet Conference "Challenges of Science" Issue VIII, 2025

Signed for publishing on November 22, 2025
Institute of Metallurgy and Ore Beneficiation JSC, Satbayev University, Almaty, Kazakhstan
Address: 050010, Almaty, Kazakhstan. st. Shevchenko corner ch. Valikhanova, 29/133

Tel.: +7 (727) 298-45-19, +7 (727) 298-45-20, +7 (727) 298-45-22
Web сайт: http://kims-imio.com; URL: https://kims-imio.kz/en/
E-mail: conference@kims-imio.kz