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EXPLORING THE USE OF ARTIFICIAL INTELLIGENCE IN TEACHING CHEMISTRY AT HIGHER EDUCATION INSTITUTIONS: A SYSTEMATIC ANALYSIS AND STUDENT PERSPECTIVES

The article discusses the impact of technology development and the increasing availability of digital educational resources on improving the quality of learning and transforming traditional pedagogical approaches to teaching chemistry. The integration of artificial intelligence (AI) into the process of teaching chemistry opens up new opportunities for personalizing learning, increasing student motivation and developing their analytical and research skills. AI technologies allow effectively adapting the teaching material, optimizing the solution of practical problems and providing a deeper assimilation of the discipline content.The present article is devoted to the system analysis of AI application in chemistry teaching in higher education institutions. The key aspects of AI integration into the educational environment are considered, its advantages and possible challenges are identified. The systematic analysis of scientific literature on the topic was conducted using specialized keywords on Scopus and Google Scholar databases, which allowed identifying current trends and approaches to the application of artificial intelligence in the educational sphere. The empirical part of the study consisted of the results of a survey of 194 students from three leading universities in the South Kazakhstan region, aimed at studying the perception and experience of using AI in the process of studying chemistry. The obtained data indicate the widespread use of AI tools in chemistry teaching and confirm their high potential under the condition of their purposeful and pedagogically sound integration into the learning process.

Key words: teaching chemistry, artificial intelligence (AI), machine learning, neural networks, ChatGPT, modern teaching tools, AI integration in education.

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Жоғары оқу орындарында химияны оқытуда жасанды интеллектті қолдануды зерттеу: жүйелі талдау және студенттер көзқарасы

Мақалада технологиялардың дамуы және цифрлық білім беру ресурстарына қолжетімділікті арттырудың, оқытудың сапасын арттыруға және химияны оқыту кезінде дәстүрлі педагогикалық тәсілдерді өзгертуге әсері қаралады. Химияны оқыту процесіне жасанды интеллект (ЖИ) интеграциясы оқытуды дербестендіру, студенттердің мотивациясын арттыру және олардың талдамалық және зерттеу дағдыларын дамыту үшін жаңа мүмкіндіктер ашады. ЖИ технологиялары оқу материалын тиімді бейімдеуге, практикалық міндеттерді шешуді оңтайландыруға мүмкіндік береді және пәннің мазмұнын неғұрлым терең меңгеруді қамтамасыз етеді.Мақала жоғары оқу орындарында химияны оқытуда ЖИ қолдану бойынша жүйелі талдауға арналған. Білім беру ортасына ЖИ интеграциясының негізгі аспектілері қаралған, оның артықшылықтары мен мүмкін болған кемшіліктері анықталды. Тақырып бойынша ғылыми әдебиетті жүйелі талдау Scopus және Google Scholar дерекқорларында мамандандырылған кілт сөздерді пайдалана отырып жүргізілді, бұл білім беру саласында жасанды интеллектті қолданудың өзекті үдерістері мен тәсілдерін анықтауға мүмкіндік берді. Зерттеудің эмпирикалық бөлігін Оңтүстік Қазақстан өңіріндегі жетекші үш университеттің 194 студенті химияны зерттеу процесінде ЖИ қолдану тәжірибесі мен қабылдауын зерттеуге бағытталған сауалнама нәтижелері құрады. Алынған деректер химияны оқытуда ЖИ құралдардың кең таралғанын көрсетеді және олардың оқу процесіне мақсатты және педагогикалық негізделген интеграциясы жағдайында олардың жоғары әлеуетін растайды.

Түйін сөздер: химияны оқыту, жасанды интеллект (ЖИ), машиналық оқыту, нейро жүйе, ChatGPT, заманауи оқыту құралдары, жасанды интеллект интеграциясы.

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Исследование использования искусственного интеллекта при преподавании химии в высших учебных заведениях: системный анализ и взгляды студентов

В статье рассматривается влияние развития технологий и роста доступности цифровых образовательных ресурсов на повышение качества обучения и трансформацию традиционных педагогических подходов при обучении химии. Интеграция искусственного интеллекта (ИИ) в процесс преподавания химии открывает новые возможности для персонализации обучения, повышения мотивации студентов и развития их аналитических и исследовательских навыков. Технологии ИИ позволяют эффективно адаптировать учебный материал, оптимизировать решение практических задач и обеспечивают более глубокое усвоение содержания дисциплины.

Настоящая статья посвящена системному анализу применения ИИ в преподавании химии в высших учебных заведениях. Рассматриваются ключевые аспекты интеграции ИИ в образовательную среду, выявляются его преимущества и возможные вызовы. Систематический анализ научной литературы по теме был проведён с использованием специализированных ключевых слов на базах данных Scopus и Google Scholar, что позволило выявить актуальные тенденции и подходы к применению искусственного интеллекта в образовательной сфере. Эмпирическую часть исследования составили результаты опроса 194 студентов из трёх ведущих университетов Южно-Казахстанского региона, направленного на изучение восприятия и опыта использования ИИ в процессе изучения химии. Полученные данные свидетельствуют о широком распространении ИИ-инструментов в преподавании химии и подтверждают их высокий потенциал при условии их целенаправленной и педагогически обоснованной интеграции в учебный процесс.

Ключевые слова: преподавание химии, искусственный интеллект (ИИ), машинное обучение, нейронные сети, ChatGPT, современные средства обучения, интеграция ИИ в образование.

Introduction

Digital transformation in modern society requires the implementation of effective measures to foster human ability to live in an information-saturated environment. These shifts have significantly influenced the education system, due to the use of information communication technologies and the Internet.

E.Toffler predicted that continuous learning will become a key skill in the 21st century (Muntean, 2012). In today's information society, individuals who are not ready to constantly update their knowledge and adapt to new technologies are at risk of becoming uncompetitive. To ensure successful self-realization, it is essential to cultivate students' permanent motivation to search and master information using both traditional and digital resources.

The relevance of these issues is reflected in many normative documents. For instance, the Concept of the development of higher education and science in the Republic of Kazakhstan for 2023-2029 determines digital technologies as an integral part of modern life with great potential in the successful implementation of higher education (Message of the head of the state K.K.Tokayev, 2023). The document emphasizes that the incorporating virtual and augmented reality, interactive platforms and simulations into the educational process through using artificial intelligence (AI) methods enables students to acquire theoretical knowledge and practical skills more effectively.

The importance of information and communication technologies (ICT) in human life is increasing daily. Nowadays, the Internet not only offers people a certain type of service, but actively engages even passive users in their development. Consequently, the incorporation of modern technologies into education is considered a demand of modern society. AI opens new horizons in the field of education. Automation of daily tasks, creation of personalized learning trajectories and regular assessment of student progress allow to significantly increase the efficiency of the educational process and the quality of general education.

Integrating AI into natural science subjects such as chemistry, biology and physics improves students' skills, promotes collaborative learning, and creates an accessible research environment. Therefore, it is crucial to study the advantages and disadvantages of AI application in natural science education as highlighted in scientific literature.

The rapid advancement of AI and technological progress has encouraged scientists to actively explore the capabilities of applying digital technologies in education. Research has shown that integrat-

ing AI and digital tools into the chemistry learning process can significantly increase learning effectiveness (Chiu, 2021). At this context, the introduction of advanced technologies such as AI-based eye tracking, learning data analysis, robotics, and virtual and augmented reality technology in chemistry education is a modern requirement.

The aim of this study is to analyze the advantages and disadvantages of integrating AI technologies into the teaching of chemistry in higher educational institutions through a systematic review of the scientific literature. Additionally, the study explores students' perceptions of AI use in chemistry education.

Literature review

The COVID-19 pandemic has shown that digital technologies are capable of ensuring the continuity of the educational process in global crises. Integrating AI into digital educational platforms has opened new possibilities for personalizing chemistry learning, making it more effective and engaging for learners (Fergus et al., 2023). Furthermore, the integration of AI into the chemistry industry has become an important part of the modern demand. Such digital tools as machine learning, big data, digital twins, Internet of Things (IoT), robotic platforms, intelligent control of chemical processes, virtual reality and blockchain are increasingly utilized to enhance research methods, educational approaches and industrial practices in chemistry (Ananikov, 2024).

The study by Yuriev et al., (2024) highlights the significance of generative AI takes in chemistry education, showing its wide scope of research. This technology brings some new changes in chemistry education, ranging from creating new teaching materials to enabling personalized learning. These capabilities are defined by the conceptual term CATALyST (context, application, technology, attitude, learning, skills, tasks) (Yuriev et al., 2024).

Despite these capabilities, international scientists noted that AI and machine learning in chemical education also face several challenges such as data dependence, the risk of bias in algorithms, and the need to train teachers (Iyamuremye et al., 2024). Therefore, addressing these challenges necessitates conduction of further research, development of appropriate methodologies, and organization of teacher training programs to facilitate the effective incorporation of these technologies into the educational process.

AI-based chatbots, such as ChatGPTs, have become important tools in chemistry learning. By providing personalized learning materials, interactive exercises, and 24/7 support, these tools promote students in deeper understanding of complex chemical concepts and developing key skills. Today, the neural network "ChatGPT" is a tool in a great demand for chemical education and research (Kodkin&Artem'eva, 2024).

AI enables researchers to assist in all stages of chemistry education, from literature review to analysis of results (Deng et al., 2023). Moreover, in their chemistry experiment titles "carbon dioxide fountain" Oh and Kang (2021) proved that AI elements can be applied in laboratory work using the Arduino method. Such tools as ChatGPT not only assist in creating personalized learning materials but also enhance problem-solving abilities, significantly improving the chemistry teaching process.

Despite the rapid advancements in AI, chatbots like ChatGPT cannot completely replace teachers, especially in complex subjects such as chemistry, which require a deep understanding of concepts and creative thinking. Clark (2023) underscores this limitation, demonstrating that ChatGPT struggles with closed-response chemistry tasks, and presents open-ended questions giving literary and linguistic definitions. This underlines chatbots's lack of understanding of theoretical chemistry concepts (Clark, 2023). Furthermore, Daher et al., (2023) revealed that ChatGPT faces significant difficulties in solving chemical tasks, especially in the field of material science. This study suggests the need for further development of this model (Daher et al., 2023).

In addition, analysis of literature demonstrates that prospective chemistry teachers often rely on copy-paste methods using ChatGPT during lessons. This describes the limitations of this tool and creates ethical concerns about using within the educational context (Tassoti, 2024). This study indicates a need to develop a specialized training methodology for effective use of AI tools.

Thus, the effective incorporation of digital technologies and AI in chemistry education necessitates a collaborative effort among teachers, programmers, and students to create an optimal learning environment.

Research materials and methods

The study employed the following scientific and pedagogical *methods:*

- Theoretical methods such as critical analysis and review of literature concerning the research

problem were conducted. This enabled to study existing data and approaches in scientific literature.

- Empirical methods such as observation, surveys were utilized to collect qualitative and quantitative data from the research participants.

- Statistical methods allowed analyzing and interpreting the results from the data obtained during the research which were mathematically and statistically processed.

To achieve the research objectives, a critical review of the literature focused on the research issue of AI application in chemistry education was conducted using the structured and systematic methods of Jesson and Lacey (2006). This approach synthesized existing data in a structured format.

Surveys were conducted to investigate students' perspectives on AI technologies. This study aimed at collecting primary data enables to identify students' knowledge of the topic and to plan further research.

Participants. A survey was conducted among university students to explore their perceptions of the use of AI technology. This survey aims to identify students' experiences, interests and possible concerns about the application of AI in teaching. A total of 194 respondents participated in the survey. Among them: 104 students from 1st to 4th year at O.Zhanibekov South Kazakhstan Pedagogical University; 52 students from the 1st to 2nd year of the Bachelor's programs and 1st to 2nd year of the Master's programs at M.Auezov South Kazakhstan University; 38 students from Khoja Akhmet Yassawi International Kazakh-Turkish University.

To ensure the reliability of this survey. Cronbach's Alpha method was employed (Amirrudin et al., 2021), providing the value of $\alpha \geq 0.81$, indicating high reliability. This result manifests that the survey questions were highly reliable. The questions used in the survey are presents in the Table 1.

Table 1 – Questions of the survey

№	List of questions
1	How would you assess your understanding of artificial intelligence (AI) technology?
2	Do you know examples of AI applications in chemistry or chemical education?
3	Have you used AI tools in your education?
4	What type of AI do you often use if you use it?
5	How interested are you in learning about the applications of AI in chemistry?
6	What role do you think AI can play in chemical education? (multiple choices are possible)
7	What are the benefits of AI in chemical education? (multiple choices are possible)
8	What are the disadvantages of AI in chemical education? (multiple choices are possible)
9	In what form of AI are you most interested in teaching chemistry? (choose up to three)
10	Do you think that traditional teaching methods in chemistry classes should be integrated with AI tools?
11	How would you like to integrate AI into the learning processes?

Data analysis. The data were analyzed using descriptive methods.

Results

To achieve the research objectives, a survey was conducted among students from three universities located in the South Kazakhstan region. The survey results were analyzed based on respondents' gender, age, educational institution, academic year and field of study. The survey consisted of 11 questions, including both single-choice and multiple-choice answer formats. The survey covered three main areas: students' general understanding of AI, experience of using AI in chemistry classes, and the future role of AI in the education system

A majority of the respondents were enrolled in pedagogical programs: 50.5% studied in the "chemistry teacher training" program; 46.9% were in the "Chemistry-biology teacher training" program; 2.1% indicated other educational directions.

A significant proportion of participants were 2nd and 4th year students by 26.8% each one, 17.5% studied in the 1st year, 13.9% were in the 3rd year, and 14.9% were postgraduate students, including those in master's and doctoral programs.

The survey demonstrated that more than 71% of students agreed on the use of AI in the educational process. Most respondents were familiar that the use

of artificial intelligence technology opens up new opportunities in the educational system. However, some noted that AI's shortcomings could negatively effect on the lesson. In addition, more than 59% of the respondents supported the integration of AI into the educational process.

To study students' awareness of AI, the survey covered several groups of questions, each addressing specific aspects of the topic. Questions 1 and 2 were aimed at determining respondents' general awareness of AI and their perceptions. Questions 3 and 4 were related to their experience of using AI in both teaching and everyday contexts. Questions 5 and 6 were asked about the specific aspects of AI use in the field of chemistry, focusing on finding out its potential and relevance for this science. Questions 7 and 8 addressed to respondents' opinions about the advantages and disadvantages of using AI in the educational process. Finally, questions 9 through 11 considered the future prospects and expected changes in the use of AI, and its integration into educational practice.

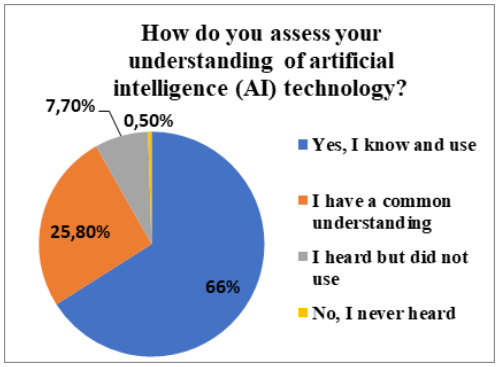

Figure 4 – The student's understanding about AI

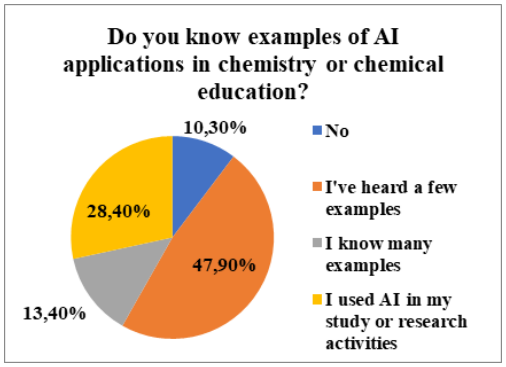

Figure 5 – Understanding examples of AI in chemistry

When asked, "How would you assess your understanding of artificial intelligence (AI) technology?", the majority of respondents 66% reported that they were well aware of AI technologies and actively used them. 25.8% of survey participants noted that they had a general understanding of AI, while 7.7% had heard of AI but had never used it. Only 0.5% of the respondents responded that they had never heard of AI (Figure 4).

The result of the second question demonstrated different levels of students' knowledge about examples of AI use in chemistry and chemical education. 10.3% of the respondents stated that they did not know anything about examples of AI use in chemistry or chemical education. 47.9% had heard several examples, and 13.4% were aware of many examples of AI use in this field. Moreover, 28.4% of students stated that they used AI technologies in their academic or research activities. Few students were familiar with some capabilities of AI application in chemistry. These results indicate a need for deeper knowledge in this field (Figure 5).

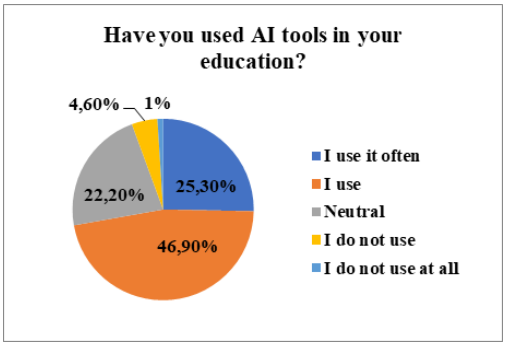

Figure 6 – The experience of using AI in education

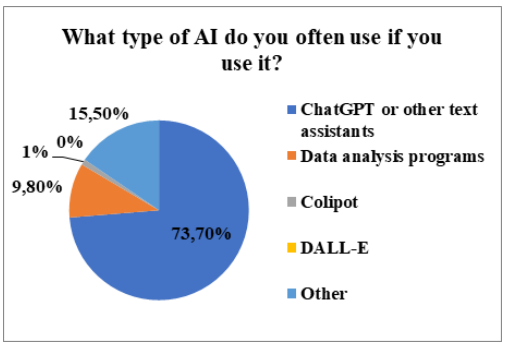

Figure 7 – The form of application of AI

In response to questions concerning the use of AI tools while studying, 25.3% of students informed that they often use them, while 46.9% stated that they sometimes use AI tools. 22.2% of respondents expressed a neutral opinion about the use or non-use of AI tools. In addition, 4.6% of respondents indicated that they do not use AI tools, and 1% reported never using them. In general, the vast majority of students 72.2% apply AI tools at various levels during their studies, indicating that AI technologies are playing a crucial role in the educational system (Figure 6).

When analyzing the types of AI tools frequently used during their studies, the majority of respondents 73.7% said that they often use text-based assistants such as ChatGPT and others. 9.8% of students stated that they use specialized AI tools for data analysis. Only 1% of survey participants mentioned frequently using tools like Colipot. It was found that the AI tool Dall-E, used for creating images or visual content, was not applied by any of the students 0%. 15.5% of the respondents stated that they use other types of AI tools. Among the various AI tools, text-based assistants like ChatGPT were most popular among students (Figure 7).

The fifth question explored students' interest in using AI in chemistry. Only 1% of respondents stated that they were not at all interested in using AI in chemistry, while 2.6% expressed limited interest. 17.5% of students were neutral regarding the use of AI in chemistry. 43.8% showed some interest, and 35.1% considered the application of AI in chemistry to be highly interesting. (Figure 8).

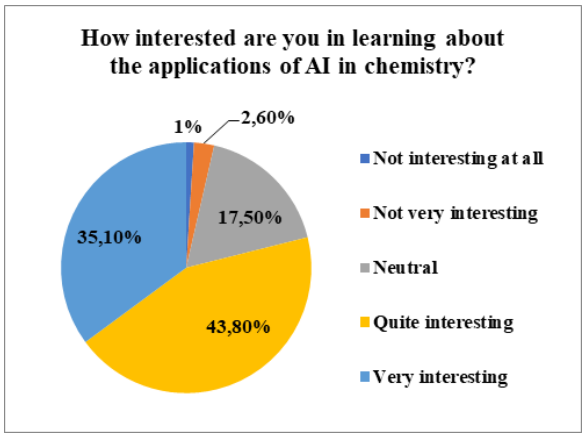

Figure 8 – Interest in using AI in chemistry

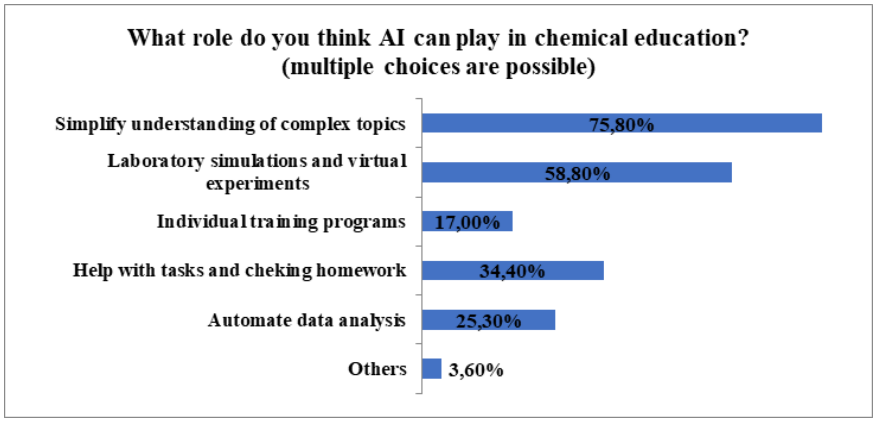

Figure 9 – The role of using AI in chemistry

In researching students' opinion on the role of AI in studying chemistry, the more part of students 75.8% showed that AI aids in appreciating composite themes in chemistry, when 58.8% considered a priority role of AI technologies in laboratory styling and organizing virtual attempts. 17% of respondents allowed the applying of AI as individualized teaching projects to be significant, and 30.4% mounted that AI devices support in determining issues and verifying homework. 25.3% of respondents adverted the application of AI in introduce automation info research, when 3.6% recognized other usage of AI. These revelation manifests that the dormant of AI in educating chemistry is extensively distinguished inter students (Figure 9).

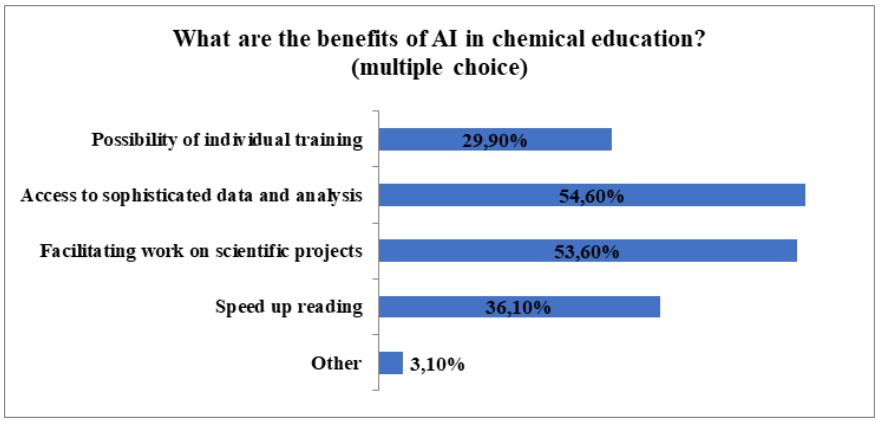

Figure 10 – Advantages of using AI

When consideration the advantages of AI in teaching chemistry, 29.9% of respondents chose the capacity of separated learning possibilities of AI tools. 54.6% of learner remarked that AI afford access to sophisticated information and analysis, while 53.6% provided that AI facilitates functioning on scientific projection. 36.1% of respondents specified that AI technologies assist precipitation of reading, and the last 3.1% chose other benefits of AI (Figure 10).

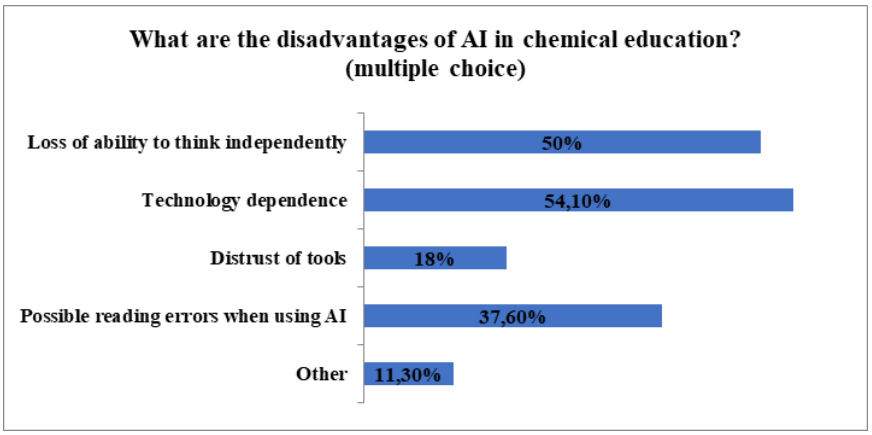

Figure 11 – Disadvantages of using AI

The next question was about the disadvantages of usage AI in learning chemistry. 50% of respondents signified concern that people loss of ability to think independently with AI. 54.1% of students requested technology dependence, while 18% of learners selected distrust of AI devices. 37.6% of students pointed that when using AI it might give possible reading mistakes. 11.3% of respondents chose other drawbacks of AI (Figure 11).

The results of the ninth question revealed diverse student perspectives on the forms of AI application in teaching chemistry. 50.5% of students considered virtual laboratories to be the most interesting form of AI use, while 34% found the use of interactive learning assistants engaging. 36.6% of students expressed interest in AI systems that predict the outcomes of chemical reactions. 42.3% regarded the use of AI tools for processing and analyzing large volumes of data as important. 42.8% of respondents were interested in using AI-generated video tutorials and explanations. The remaining 25.8% of students found the use of AI as a research assistant in scientific studies intriguing (figure 12).

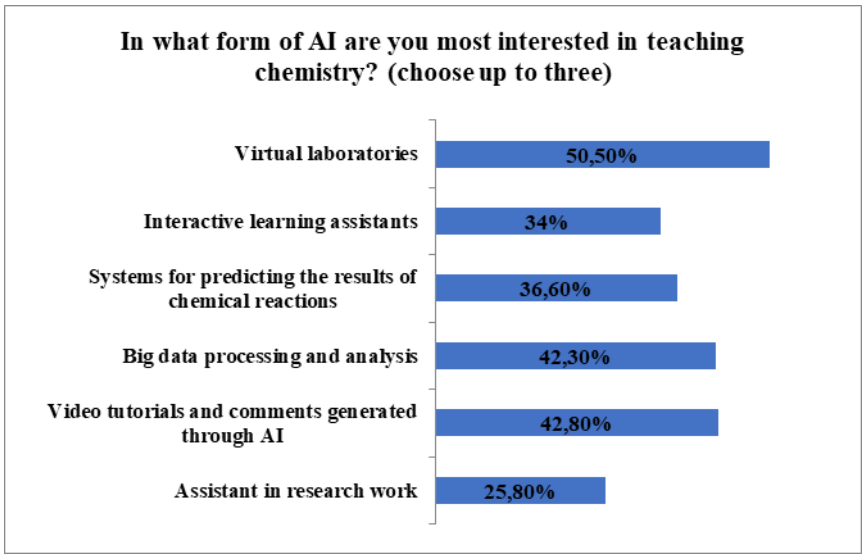

Figure 12 – The form of AI application in chemistry

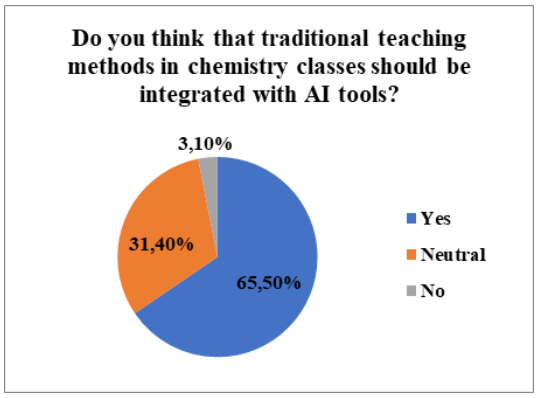

Figure 13 – Integration AI in chemistry Figure

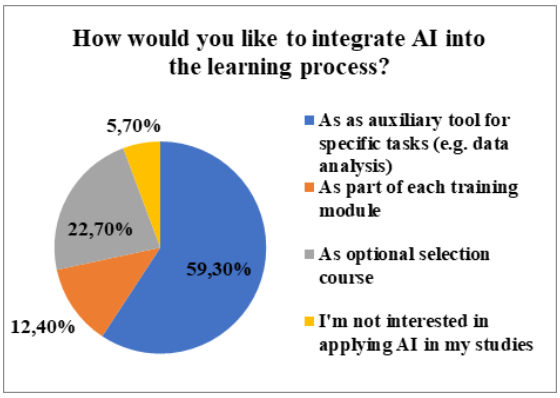

Figure 14 – The process of integrating AI into chemistry

The final two questions focused on integrating traditional teaching methods with AI tools in chemistry lessons, as well as students' preferences for how AI should be integrated into the learning process. The survey result revealed differing opinions on necessity of combining traditional teaching methods with AI tools in chemistry lessons. 65.4% of students felt that AI tools should be used alongside traditional teaching methods, suggesting that a blend of AI and traditional teaching could enhance the effectiveness of learning. In contrast, 31.4% were neutral on the issue, while 3.1% opposed the use of AI tools (Figure 13). Additionally, the majority of students 59.3% who expressed interest in how AI should be integrated into the learning process suggested using AI as an auxiliary tool for specific task, such as data analysis. 22.7% of students wished for AI to be introduced as an additional elective course, and 12.4% preferred it to be incorporated into each educational module. Only 5.7% of students showed no interest in using AI in their studies. These results demonstrate broad support among students for the integration of AI technologies into the learning process, with a preference for its effective and varied application (Figure 14).

Discussion

In line with the research objectives, a search was conducted in scientific databases Scopus and Google Scholar using the keyword "artificial intelligence in chemistry education". Initially, 112 articles were selected based on the search results. Following the application of selection criteria, this list was narrowed down to 80 articles. A content analysis of these 80 articles led to the identification of 17 publications that aligned with the research goals. The methodology used for organizing the literature was based on the approach outlined by A.Siddaway (2014). To ensure the relevance of the selected articles to the research objectives, the presence of key terms in the article titles and abstracts was verified. The search was restricted to peer-reviewed articles with full text available in the scholar.com database.

The following criteria were used for selecting the articles necessary for analysis:

- Studies published between 2020 and 2024;
- Research published in journals indexed in Scopus and Web of Science;
- Studies analyzing the advantages and disadvantages of applying artificial intelligence in chemistry education.

The criteria for excluding articles that were not relevant to the study included:

- Research published as conference papers;
- Studies integrating chemistry with fields such as physics, scientific chemistry, and medicine;
- Research with full texts not available online.

Figure 1 illustrates the publication history and frequency of the selected articles according to the selection criteria. It is evident that the number of relevant articles has steadily increased over the years. This trends indicates the growing interest and relevance of artificial intelligence in teaching chemistry among researchers.

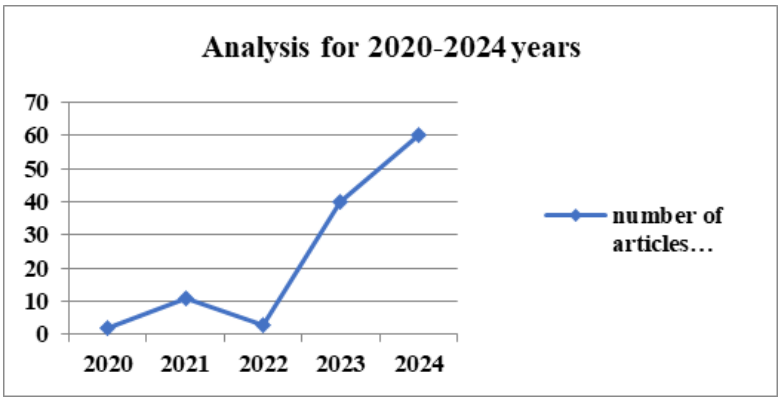

Figure 1 – Publication history and frequency of selected articles from Google Scholar database

Additionally, a search in the Scopus database using the keyword “artificial intelligence in chemistry education” revealed the comparative popularity of this topic among researchers. Figure 2 shows the frequency and publication history of articles published between 2020 and 2024 in Scopus-indexed journals.

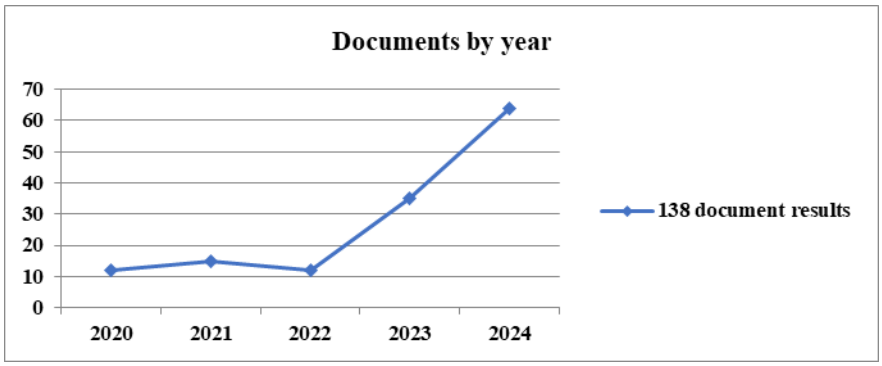

Figure 2 – The results of selection by Scopus

Figure 3 – The keywords in the selected articles
(The illustrative picture is made with the help of Dall-E artificial intelligence)

Figure 3 presents the key terms used in the selected articles. An analysis of articles published between 2020 and 2024 in Google Scholar on the application of artificial intelligence reveals that the topic is commonly linked to machine learning, digital technologies, ChatGPT, neural networks, and the integration of AI.

The analysis of the selected articles identified the following advantages of using AI in chemistry education:

Personalized learning: traditional teaching methods in large classrooms often fail to provide individualized attention to each student. However, AI can address this issue. By analyzing the data of each student, AI helps educators tailor instructional materials and teaching methods tpo meet individual needs, thereby enhancing the quality of education.

Timely feedback: the use of AI in teaching chemistry allows students to receive immediate feedback on completed tasks. This significantly increases the effectiveness of learning, as students can quickly correct mistakes and reinforce previously learned material. AI makes the learning process dynamic and interactive, which positively influences student motivation.

Focus on emotional comfort: AI creates a safe and non-judgmental learning environment where students can make mistakes and learn from them.

The absence of evaluation anxiety encourages students to engage more actively in the learning process and feel comfortable asking questions.

Facilitating changes in the role of the teacher: the advent of AI in education does not eliminate the role of the teacher but transforms it. Rather than being a passive source of information, the teacher becomes an active mentor who helps students manage the flow of knowledge and solve complex problems. Automating routine tasks allows teachers to focus more on individualized attention and the development of students' creative potential.

A thoughtful approach to teaching: AI offers new opportunities for creating engaging and interactive learning materials. Personalized games, quizzes, and other interactive formats make the chemistry learning process both enjoyable and effective, enhancing student engagement (Akatyev, 2024, Shefieva&Isaeva, 2020, Kuz'min et al., 2024).

Based on the result of our study, the use of AI in teaching chemistry demonstrate several advantages and disadvantages. The survey results of students considered a priority advantages of AI in analyzing data and easy to work with scientific projects. Our data arrange with the ideas of the above mentioned authors, who mentioned that the integration of artificial intelligence into education helps each student individually. In our study, respondents to the survey stated the great potential of artificial intelligence in terms of personalization of the educational process for each student.

The analysis revealed the following disadvantages: approachability and digital proficiency, private and information safety, ethic speculation and prejudgment. Usage of this biased data can mistakenly increase being disparities and prejudice. To assure the impartial and ethical usage of AI in education process, information must be gently chosen and operated to guaranty in the concrete (Zyk, 2023, Shadieva, 2024).

The results of survey give that students recognize the benefits of application of artificial intelligence in chemistry lessons, namely in understanding complex problems, even to do laboratory work and also analyzing complex information. Most students were not against the integration of artificial intelligence in the learning process, replacing the traditional teaching method. But the integration of these technologies requires full readiness and strategy.

In spite of these benefits, our study showed several drawbacks. According to the results of the answers to the survey, such disadvantages as dependence on technology, the ability not to think for yourself, but to copy from the artificial intelligence database were identified.

Conclusion

Thus, we believe that the use of artificial intelligence in teaching chemistry is huge. Moreover, for this technology to be fully integrated in the educational process, several issues need to be resolved. Mainly, specific applications and types of artificial intelligence for chemistry need to be developed, and more research needs to be done to improve students' outcomes using AI.

In line with the research objectives, a systematic analysis of the scientific literature and an assessment of students' perspectives on the use of AI in the learning process revealed both the advantages and limitations of its application in education. According to the responses from the survey participants, AI serves as a key factor in creating an educational environment that balances technological innovation with human factors. AI has the potential to revolutionize education through personalized learning plans and effective support. However, to fully leverage these advantages, AI must be integrated responsibly, taking into account its capabilities and limitations.

Moreover, it is important to remember that AI should be used in conjunction with traditional teaching methods. The teacher's role remains crucial, especially in creating a motivational and supportive learning environment. The study also highlights the need for further research to develop effective methods and strategies for utilizing AI in teaching chemistry.

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