Торайғыров университетінің
ҒЫЛЫМИ ЖУРНАЛЫ

НАУЧНЫЙ ЖУРНАЛ
Торайгыров университета

ТОРАЙҒЫРОВ УНИВЕРСИТЕТІНІҢ ХАБАРШЫСЫ

ПЕДАГОГИКАЛЫҚ СЕРИЯСЫ

1997 ЖЫЛДАН БАСТАП ШЫҒАДЫ

TORAIGHYROV UNIVERSITY

ВЕСТНИК ТОРАЙГЫРОВ УНИВЕРСИТЕТА

ПЕДАГОГИЧЕСКАЯ СЕРИЯ

ИЗДАЕТСЯ С 1997 ГОДА

ISSN 2710-2661

№ 2 (2024)

ПАВЛОДАР

НАУЧНЫЙ ЖУРНАЛ
Торайгыров университета

Педагогическая серия
выходит 4 раза в год

СВИДЕТЕЛЬСТВО
о постановке на переучет периодического печатного издания,
информационного агентства и сетевого издания
№ KZ03VPY00029269
выдано
Министерством информации и коммуникаций
Республики Казахстан

Тематическая направленность
публикация материалов в области педагогики,
психологии и методики преподавания

Подписной индекс – 76137

https://doi.org/10.48081/QWNJ5612

БІЛІМ БЕРУДІҢ ЗАМАНАУИ ТЕХНОЛОГИЯЛАРЫ,
IT-ТЕХНОЛОГИЯЛАР

SRSTI 14.35.07

https://doi.org/10.48081/QEWS3041

N. V. Akatyev
M. Utemisov West Kazakhstan university,
Republic of Kazakhstan, Uralsk
*e-mail: nikolay.akatyev@wku.edu.kz

MODERN STATE OF APPLICATION OF AI TECHNOLOGIES IN CHEMICAL EDUCATION: PROBLEMS AND APPROACHES

The integration of artificial intelligence (AI) technologies into education systems has been a transformative force across multiple disciplines, with chemistry education proving particularly fertile ground for innovation. As we consider the prospects of AI in chemistry education, it is important to recognize the unique opportunities and challenges that this integration brings. AI technologies, ranging from machine learning algorithms to advanced simulation tools, offer unprecedented opportunities to improve the way chemistry is taught and learned. By introducing interactive content, personalized learning experiences, and improved visualization techniques, these technologies not only enable deeper understanding of complex chemical concepts but also transform traditional teaching methods. This article examines the current state of AI applications in chemistry education and highlights the significant benefits and potential future developments that could further transform this field. As AI continues to advance, its role in educational contexts, particularly in chemistry, promises to be both transformative and far-reaching, paving the way for more effective educational technologies.

Keywords: chemistry, artificial intelligence, chemistry education, modern education trends, methods of teaching chemistry.

Introduction

Digital technologies have been used in chemistry education for several decades, and their relevance has recently become increasingly important. In

current year, V. Ananikov identified 20 main areas of application of artificial intelligence (AI) in chemistry [1]. Among other things, it highlights that AI technologies significantly improve chemistry teaching through the integration of digital platforms and simulation software. These technologies, particularly through virtual and augmented reality (VR and AR), provide educational experiences that are engaging, safe and accessible. This approach not only improves the quality of chemistry education, but also equips researchers with the skills and knowledge they need to succeed in today's scientific world. The use of digital technology in chemistry teaching has been proven to improve the quality of teaching from a technical, cognitive and social perspective. In addition, a study on the impact of a proposed science curriculum based on digital technologies found that the experimental group that used digital technology-based lessons showed higher motivation to learn science subjects and achieved better learning outcomes [2]. A systematic review of the literature revealed that VR and digital learning applications are commonly used, indicating the spread of pedagogical innovations associated with new technologies [3]. This clearly shows that the use of digital technologies is crucial for teaching chemistry today.

Materials and methods

In this work the main focus was shifted to the process of literature collection, evaluation, and synthesis. Research methods of systematic review of international high-level scientific literature using the ASC, Wiley and RSC databases over the last two decades were used, followed by a sampling of the most frequently cited qualitative research findings. Research protocol included the comprehensive literature search using the keywords in above databases.

Results and discussion

Figure 1 represents a chronology of the integration of digital technologies in chemistry education from the 1990s to the present.

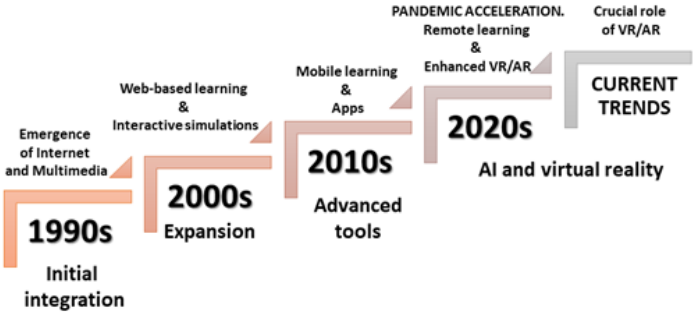

Figure 1 – The chronology of the integration of digital technologies in chemistry education

Digital technologies first found their way into chemistry lessons in the 1990s, influenced by the emergence of the Internet and multimedia tools. The 2000s were followed by a period of growth in web-based learning platforms and interactive simulations that enhance the educational experience. The 2010s became an era of more sophisticated digital tools, including the introduction of educational applications on various mobile platforms (iOS, Android, WindowsOS), specifically designed for the study of chemistry using smartphones and tablet computers. In the current era of the 2020s, new directions in chemical education focus on integrating AI and VR technologies, providing an immersive and interactive learning experience, including distance learning [3].

One of the first educational platforms on the Internet was YouTube video hosting. Teaching on YouTube presents a unique landscape with its own opportunities and challenges, particularly when it comes to understanding the specific needs and intent of audiences, providing high-quality content, and balancing quality and quantity. Ruiz-Morillas examined the digital landscape of YouTube teaching compared to traditional face-to-face teaching, which provided insight and guidance for teachers to create and develop a chemistry teaching channel, taking into account the diversity of the audience for a global reach of teaching [4].

The COVID-19 pandemic has significantly accelerated the introduction and integration of digital tools and methods and led to global changes in chemistry education. This had a significant impact on the use of digital technologies in teaching. Traditional methods were used less during the lockdown, while mobile learning was used more [5]. The transition to distance learning required the rapid adoption of digital technologies, which were crucial in maintaining educational continuity during the pandemic. The sudden shift to digital learning highlighted significant technological inequalities, particularly among students from different socio-economic backgrounds. This inequality affected access to digital resources and the overall effectiveness of distanced learning in chemistry [6].

The pandemic forced teachers to quickly adapt to online teaching including the use of various online platforms, digital simulators, and virtual laboratories [7]. Teachers have had to rethink their teaching strategies to better adapt to the online format. The experience also highlighted the importance of teacher training in digital tools and pedagogical methods suitable for online teaching and has led to a better understanding of how digital tools can improve teaching and learning and stimulated discussions about the best ways for integrating of IT into chemistry education [8].

The integration of tools like ChatGPT into education is changing the landscape of chemistry teaching and learning. As an AI-driven platform, ChatGPT offers a

dynamic and interactive approach to chemistry teaching, enabling personalized learning experiences and instant feedback. This technology not only supports the traditional educational frameworks but also improves the accessibility and efficiency of learning chemical concepts. ChatGTP's chatbot has quickly gained global attention as the easy and instant access and use of AI has become widely available. The chatbot can be given very complex tasks, including those from chemistry lessons, which it processes in detail and (partially) correctly. These new and comprehensive possibilities offer both for teaching and learning [9].

Nevertheless, in the field of education, ChatGPT has become a topic of debate. Students' experience of a ChatGPT enabled final exam in a non-majors chemistry course was investigated by Holme. During investigation students were asked to compare their paper to one produced on the same topic by ChatGPT. It was revealed that essay whritten by the ChatGPT did not read as «human-like», because of using more intricate words, and often did not include enough science to support its arguments [10]. It was also shown that ChatGPT, have the potential to help students learn mechanistic aspects of organic reactions through the generated responses. Study findings show that responses are fully explain reaction mechanisms and the majority contain predominantly accurate explanations of chemical phenomena and identification of nucleophiles and electrophiles [11].

However, introducing ChatGPT into chemistry education is not without challenges. Issues such as technological inequality and the need for comprehensive teacher training stand in the way of full integration. Despite these challenges, the continued development and adaptation of ChatGPT in educational institutions promises a more engaging and effective learning environment for students and paves the way for an innovation in chemistry education [12]. In the most of studies, the attitudes of students towards artificial intelligence distributes from enthusiastic to indifferent and cautious. However, after the first experience, most of the students declared themselves adopters of the new technology [13]. Nevertheless, there are risks that individuals may become over-reliant on AI, that can result a reduced capacity for critical thinking, or a decline in memory retention. Therefore, further research into the long-term cognitive effects of interacting with advanced AI models.

The use of AI in chemistry curriculum creation is an emerging area that leverages technology to improve educational content. Figure 2 shows how AI technologies can be used to improve the content and delivery of chemistry curricula, making education more effective and adaptable to student needs.

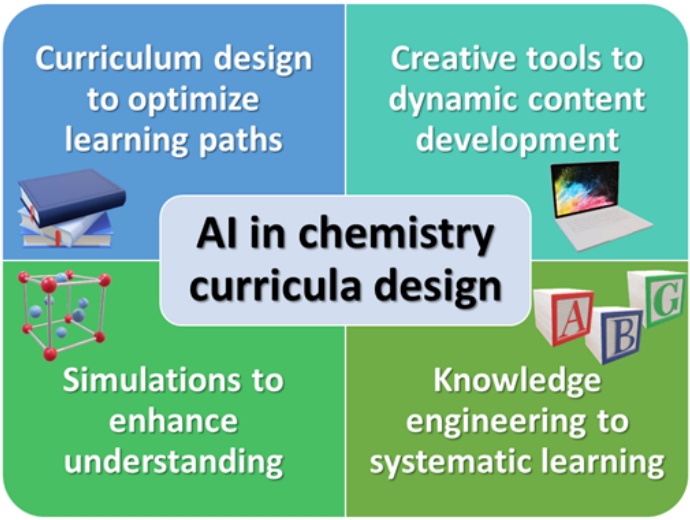

Figure 2 – The application of AI in chemistry curriculum design

As can be seen, AI helps optimize learning paths through curriculum design by analyzing educational data to tailor the curriculum to better meet student needs and improve learning outcomes. It also facilitates the creation of dynamic content that adapts to changes in educational standards and student performance, ensuring the curriculum remains relevant and engaging. The possibilities of ChatGPT-4 to improve their lesson plans for the Thomson, Millikan, and Rutherford historical experiments were explored by Clark. As a result, only limitation of ChatGPT-4 was its ability to create images or visual aids. Overall, it was found that the chatbot can support, but not replace, a lecturer [14].

Integrating AI into traditional chemistry curricula development also poses several challenges both for technical and pedagogical aspects. One of the biggest technical challenges is the lack of existing infrastructure and resources to support AI technologies in many educational institutions. This includes hardware such as computers and software as well as the expertise required to effectively implement and maintain AI systems [15]. From a pedagogical perspective, there are concerns that integrating AI into curriculum design could overshadow traditional learning methods. Therefore, teachers need to strike a balance when using of AI tools without diminishing the importance of fundamental chemistry concepts and practical laboratory experiences [16]. Ethical issues such as data protection and

the digital divide also pose significant challenges as they require careful planning to ensure that all students have equal access to AI-powered education [17].

AR and VR technologies are increasingly being integrated into chemistry education, improving student engagement and understanding through interactive simulations of chemical structures and experiments [3]. AI-driven VR and AR tools enable students to visualize and interact with molecular structures and chemical reactions in three-dimensional space. This skill transforms abstract chemical concepts into tangible and understandable visual experiences, significantly contributing to better comprehension and retention. In particular there are already several examples of the successful use of virtual reality technologies in teaching organic chemistry [18]. The VR system allows students to conduct virtual experiments, while observing chemical reactions in a simulated 3D environment. Students can interact with virtual chemical apparatus and observe reactions in real-time (Fig. 3).

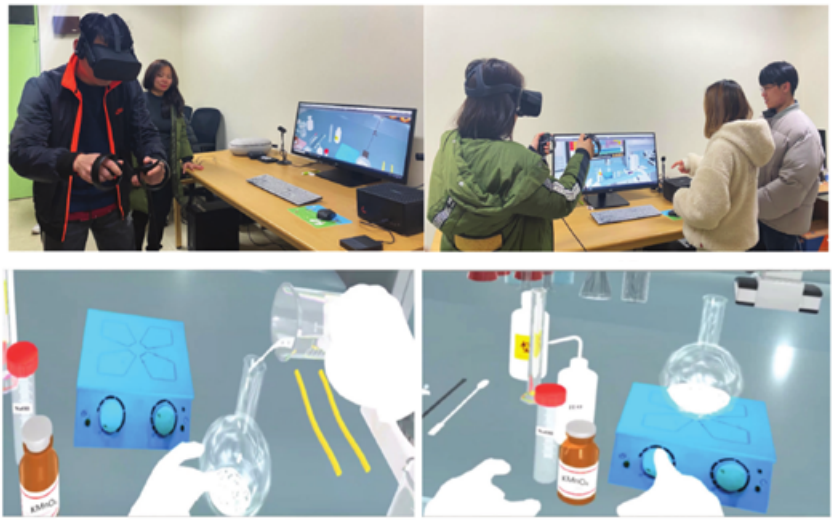

Figure 3 – Student immersive experience in
VR chemical reaction simulation (adopted from [18])

Students and teachers also use different software to analyze chemical data and predict results using machine learning algorithms. By analyzing student performance data, these algorithms can tailor the pace and style of content delivery to individual learning preferences, ensuring each student can learn at their optimal speed and manner [19]. In particular, AR has the potential to increase students'

motivation, interest and attitude towards learning chemistry by making the learning process more interactive and immersive [20]. This integration of AI into chemistry education not only promises better educational outcomes, but also prepares students for a future where digital literacy and AI skills will be paramount.

In order to successfully use AI in chemistry lessons, both teachers and students must have a certain level of computer and IT skills. First, teachers and students must have a clear understanding of AI concepts based on fundamental knowledge of AI, machine learning, and data analysis. Knowledge of basic computer operations, managing files, and using common software applications is also essential. Knowledge of accessing online resources, databases and AI tools through effective internet navigation and research skills is required. Knowledge about protecting personal and sensitive information when using AI technologies is important to ensure data security. Continuous learning and adaptability to new AI tools and technologies are required to keep pace with advances in the field.

The advantages and disadvantages of using AI technologies in chemistry education are summarized in Figure 4.

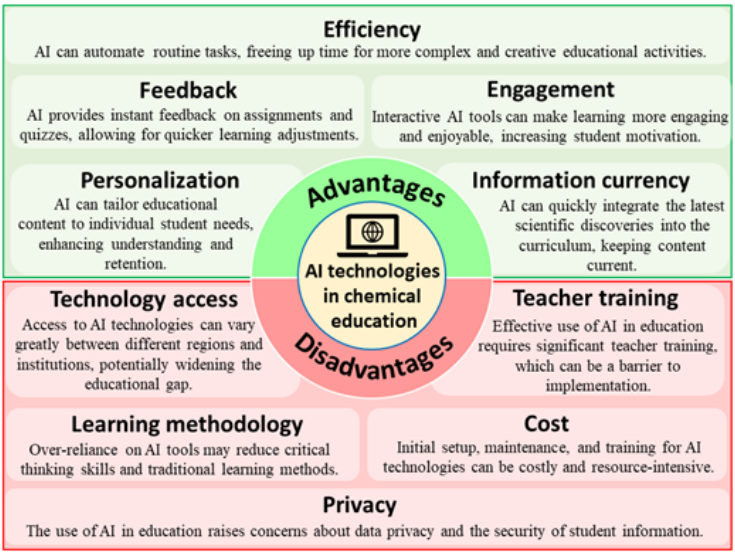

Figure 4 – Advantages and disadvantages of using AI technologies in chemistry education

Figure 4 represents that AI technologies have a set of significant benefits for chemical education. Personalization suggest that educational content is tailored to students' individual needs, improving understanding and retention providing instant feedback on assignments and tests. AI also increases efficiency by automating routine tasks, frees up time for more complex and creative activities. In addition, AI ensures access to up-to-date information by quickly integrating the latest scientific findings into the curriculum. However, there are several disadvantages. Access to AI technologies can vary widely, potentially widening the education gap. There is also a risk of dependence on technology, which can impact critical thinking skills and reliance on traditional learning methods. Privacy concerns are also of great importance as the use of AI in education raises issues regarding the security of student data. The cost of implementing AI technologies can be high and requires significant resources for initial setup, maintenance, and training. Finally, teacher training represents a critical barrier, as effective use of AI in education requires significant training efforts.

Based on a literature analysis that reflects the current state of AI technologies, we can provide some practical tips for successfully integrating AI into the teaching and learning process:

1 Educational institutions should implement training programs that focus on improving the AI-related skills of teachers and students. These programs should include basic computer skills, Internet research techniques, and an introduction to AI concepts and applications in chemistry.

2 Teachers need to stay up to date on the latest AI tools and technologies. This can be facilitated through workshops, online courses and professional learning communities.

3 Integrate AI technologies education into the chemistry curriculum to give students hands-on experience with AI tools. This integration should also take into account ethical considerations and data security practices.

4 Educational institutions should provide resources for the necessary hardware and software that support AI technologies. This includes access to AI platforms, high-speed internet and secure computing environments.

5 Building partnerships with AI experts and technologists to provide insights and support for implementing AI tools in chemistry education. This collaboration can also help adapt AI solutions to educational needs.

By following these recommendations, educational institutions can ensure that both teachers and students are well prepared to effectively use AI technologies in the teaching and learning of chemistry. By integrating AI with other digital technologies, educators gain a comprehensive toolkit to improve both the delivery

and content of chemistry lessons. This integration fully meets modern educational needs and standards and makes the learning process more engaging and effective.

Conclusion

In summary, the prospects for the use of AI in chemical education are very promising. AI has already begun to transform the landscape of chemistry teaching and learning by improving teaching tools, developing new pedagogical frameworks, and facilitating interdisciplinary research. AI-driven technologies such as virtual and augmented reality have significantly improved the visualization of complex chemical structures and processes, making chemistry more accessible and engaging for students. Additionally, AI-driven platforms provide personalized learning experiences and self-assessment tools that address students' diverse needs and promote a deeper understanding of chemical concepts. As AI continues to develop, its integration into chemistry education is expected to deepen and more sophisticated tools and methods emerge that could revolutionize the way chemistry is taught and learned. Ongoing research and development in AI promises to not only improve educational outcomes, but also inspire new educational technologies that could address knowledge and accessibility gaps. Ultimately, integrating AI into chemistry education has the potential to create a more interactive, effective, and inclusive educational environment and better prepare students for future challenges in chemistry education.

References

1 **Ananikov, V.** Top 20 Influential AI-Based Technologies in Chemistry // ChemRxiv. – 2024. – [Electronic resource]. – URL: https://chemrxiv.org/engage/chemrxiv/article-details/66176d4391aefa6ce150c0d6.

2 **Alnajjar, E. A. M.** The Impact of a Proposed Science Curriculum based on Digital Technologies on Students' Achievement and Motivation towards Learning Science // Webology. – 2022. – Vol. 19 – P. 434–446.

3 **Ali, S. B., Abdul Talib, C., Jamal, A. M.** Digital Technology Approach In Chemistry Education: A Systematic Literature Review // Journal of Natural Science and Integration. – 2023. – Vol. 6 – P. 1–13.

4 **Sánchez-Gonzaga, V., Ruiz-Morillas, N.** Differences and Similarities between Face-to-Face and YouTube Chemistry Teaching // Journal of Chemical education. – 2024. – Vol. 101. – № 8. – P. 1905 – 1913.

5 **Jiménez Sánchez, E., Montes-López, E., Santos Sánchez, M. J.** Impact of the COVID-19 Confinement on the Physics and Chemistry Didactic in High Schools // Sustainability. – 2022. – Vol. 14. – № 11. – P. 6754.

6 **Bedin, E., Marques, M., Das Graças Cleophas, M.** Research on the Content, Technological, and Pedagogical Knowledge (TPACK) of Chemistry Teachers During Remote Teaching in the Pandemic in the Light of Students' Perceptions // Journal of Information Technology Education: Research. – 2023. – Vol. 22. – P. 1–24.

7 **Reyes, C. T., Thompson, C. D., Lawrie, G. A., Kyne, S. H.** Insights into a Community of Inquiry that emerged during academics' emergency remote university teaching of chemistry in response to concern for students // Research in Science & Technological Education. – 2023. – P. 1–27.

8 **Huang, J.** Successes and Challenges: Online Teaching and Learning of Chemistry in Higher Education in China in the Time of COVID-19 // Journal of Chemical education. – 2020. – Vol. 97. – № 9. – P. 2810–2814.

9 **Pawlak, F.** ChatGPT – a revolution for teaching and learning in chemistry education?! // Chemkon. – 2024. – Vol. 31. – № 2. – P. 48–53.

10 **Clark, M. J., Reynders, M., Holme, T. A.** Students' Experience of a ChatGPT Enabled Final Exam in a Non-Majors Chemistry Course // Journal of Chemical education. – 2020. – Vol. 97. – № 9. – P. 2810–2814.

11 **Yik, B. J., Dood, A. J.** ChatGPT Convincingly Explains Organic Chemistry Reaction Mechanisms Slightly Inaccurately with High Levels of Explanation Sophistication // Journal of Chemical education. – 2024. – Vol. 101. – № 5. – P. 1836–1846.

12 **Nwafor, S. C., Ibe, F. N., Muoneke, N. M.** Optimizing information and communication technology applications in chemistry learning // J Journal of Research in Instructional. – 2022. – Vol. 2. – № 2. – P. 151–152.

13 **Šedlbauer, J., Činčera, J., Slavík, M., Hartlová, A.** Students' reflections on their experience with ChatGPT // Journal of Computer Assisted Learning. – 2024. – Vol. 2. – № 2. – P. 1–9.

14 **Clark, T. M., Fhaner, M., Stoltzfus, M. Queen, M. S.** Using ChatGPT to Support Lesson Planning for the Historical Experiments of Thomson, Millikan, and Rutherford // Journal of Chemical education. – 2024. – Vol. 101. – № 5. – P. 1992–1999.

15 **Singh, N., Adhikari, D.** Challenges and Solutions in Integrating AI with Legacy Inventory Systems // International Journal for Research in Applied Science and Engineering Technology. – 2023. – Vol. 11. – № 12. – P. 609–613.

16 **Kahila, J., Vartiainen, H., Tedre, M., Arkko, E., Lin, A., Pope, N., Jormanainen, I., Valtonen, T.** Pedagogical framework for cultivating children's data agency and creative abilities in the age of AI // Informatics in Education. – 2024.

17 **Abuodha, L., Kipkebut, A.** Disruptive AI in Education: Transforming Learning in the Digital Age // International Journal for Research in Applied Science and Engineering Technology. – 2024. – Vol. 12. – № 2. – P. 195–199.

18 **Kounlaxay, K., Yao, D., Woo Ha, M., Kyun Kim, S.** Design of Virtual Reality System for Organic Chemistry // Intelligent Automation & Soft Computing. – 2022. – Vol. 31. – № 2. – P. 1119–1130.

19 **Kuntz, D., Wilson, A. K.** Machine learning, artificial intelligence, and chemistry: How smart algorithms are reshaping simulation and the laboratory // Pure and Applied Chemistry. – 2022. – Vol. 94. – № 8. – P. 1019–1054.

20 **Abdul Talib, C., Romainor, N., Aliyu, F.** Augmented Reality in Chemistry Education: A Literature Review of Advantages on Learners // Journal of Natural Science and Integration. – 2022. – Vol. 5. – № 1. – P. 126.

Received 20.05.24.
Received in revised form 24.05.24.
Accepted for publication 12.06.24.

**Н. В. Акатьев*
М. Өтемісов атындағы
Батыс Қазақстан университеті,
Қазақстан Республикасы, Орал қ.
20.05.24 ж. баспаға түсті.
24.05.24 ж. түзетулерімен түсті.
12.06.24 ж. басып шығаруға қабылданды.

ХИМИЯ БІЛІМ БЕРУДЕГІ AI ТЕХНОЛОГИЯЛАРЫН ҚОЛДАНУДЫҢ ҚАЗІРГІ ЖАҒДАЙЫ: МӘСЕЛЕЛЕР МЕН ТӘСІЛДЕР

Жасанды интеллект (AI) технологияларының білім беру жүйесіне интеграциясы көптеген пәндер бойынша өзгертуші күшке айналды, бұл ретте химия білімі инновациялар үшін ерекше құнарлы жер екенін дәлелдеді. Химия біліміндегі AI болашағын қарастыра отырып, бұл интеграция әкелетін бірегей мүмкіндіктер мен қиындықтарды мойындау маңызды. Жасанды интеллект технологиялары машиналық оқыту алгоритмдерінен бастап жетілдірілген модельдеу құралдарына дейін химияны оқыту және үйрену әдісін жақсарту үшін бұрын-соңды болмаған мүмкіндіктер ұсынады. Интерактивті мазмұнды, жекелендірілген оқыту тәжірибесін және жақсартылған

визуализация әдістерін енгізу арқылы бұл технологиялар күрделі химия ұғымдарын тереңірек түсінуді қамтамасыз етіп қана қоймайды, сонымен қатар дәстүрлі оқыту әдістерін түрлендіреді. Бұл мақалада химия біліміндегі AI қолданудың ағымдағы жай-күйі қарастырылады және саланы одан әрі өзгерте алатын маңызды артықшылықтар мен әлеуетті болашақ әзірлемелер көрсетіледі. Жасанды интеллект дамып келе жатқандықтан, оның білім беру контекстіндегі, әсіресе химиядағы рөлі, тиімдірек және тартымды білім беру технологияларына жол ашатын трансформациялық және ауқымды болуға уәде береді.

Кілтті сөздер: химия, жасанды интеллект, химиялық білім, білім берудегі заманауи тенденциялар, химияны оқыту әдістемесі.

**Н. В. Акатьев*
Западно-Казахстанский университет
имени М. Утемисова,
Республика Казахстан, г. Уральск.
Поступило в редакцию 20.05.24.
Поступило с исправлениями 24.05.24.
Принято в печать 12.06.24.

СОВРЕМЕННОЕ СОСТОЯНИЕ ПРИМЕНЕНИЯ ТЕХНОЛОГИЙ ИИ В ХИМИЧЕСКОМ ОБРАЗОВАНИИ: ПРОБЛЕМЫ И ПОДХОДЫ

Интеграция технологий искусственного интеллекта (ИИ) в системы образования стала преобразующей силой в различных дисциплинах, причем химическое образование оказалось особенно благодатной почвой для подобных инноваций. Рассматривая перспективы применения ИИ в химическом образовании, важно признать уникальные возможности и вызовы, которые представляет эта интеграция. Технологии искусственного интеллекта, начиная с алгоритмов машинного обучения и заканчивая передовыми инструментами моделирования, открывают беспрецедентные возможности для улучшения методов преподавания и изучения химии. Благодаря внедрению интерактивного контента, персонализированного обучения и усовершенствованных методов визуализации эти технологии не только способствуют более глубокому пониманию сложных химических концепций, но и

трансформируют традиционные методы обучения. В данной статье рассматривается текущее состояние применения ИИ в химическом образовании и подчеркиваются значительные преимущества и потенциал для будущих разработок, которые могут еще больше усовершенствовать эту область. По мере того, как ИИ продолжает развиваться, его роль в образовательном контексте, особенно в химии, имеет как преобразующее, так и расширяющее воздействие, открывая путь для более эффективных образовательных технологий.

Ключевые слова: химия, искусственный интеллект, химическое образование, современные тенденции образования, методика преподавания химии.

Теруге 12.06.2024 ж. жіберілді. Басуға 28.06.2024 ж. қол қойылды.
Электронды баспа
1,55 Kb RAM
Шартты баспа табағы 5,75.
Таралымы 300 дана. Бағасы келісім бойынша.
Компьютерде беттеген З. Ж. Шокубаева
Корректорлар: А. Р. Омарова
Тапсырыс № 4243

Сдано в набор 12.06.2024 г. Подписано в печать 28.06.2024 г.
Электронное издание
1,55 Kb RAM
Усл.п.л. 5,75. Тираж 300 экз. Цена договорная.
Компьютерная верстка З. Ж. Шокубаева
Корректоры: А. Р. Омарова
Заказ № 4243

«Toraighyrov University» баспасынан басылып шығарылған
Торайғыров университеті
140008, Павлодар қ., Ломов к., 64, 137 каб.

«Toraighyrov University» баспасы
Торайғыров университеті
140008, Павлодар қ., Ломов к., 64, 137 каб.
8 (7182) 67-36-69
e-mail: kereku@tou.edu.kz
www.pedagogic-vestnik.tou.edu.kz