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INTEGRATING ARTIFICIAL INTELLIGENCE INTO CHEMISTRY EDUCATION: PEDAGOGICAL APPROACHES AND SURVEY RESULTS

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Abstract. The integration of Artificial Intelligence (AI) into chemistry education offers innovative opportunities to enhance student learning, engagement, and problem-solving skills. This study explores pedagogical approaches for incorporating AI tools into chemistry curricula and evaluates their effectiveness through a survey of educators and students. Results indicate that AI-supported instruction can improve conceptual understanding, foster active learning, and facilitate personalized feedback, while also presenting challenges related to accessibility, training, and curriculum adaptation. The findings provide practical guidance for educators seeking to implement AI technologies in chemistry teaching and highlight potential avenues for future research in AI-driven science education. (Avci et. al., 2025).

Keywords: Artificial Intelligence; chemistry education; pedagogical approaches; survey study; AI-enhanced learning; STEM education

Introduction

The rapid advancement of Artificial Intelligence (AI) has led to significant transformations across various sectors, including healthcare, engineering, communication, and education. In recent years, the integration of AI into educational settings has gained substantial attention due to its potential to personalize learning, enhance student engagement, and improve educational outcomes (Joshi, 2024). As an emerging technology, AI offers innovative ways to design, deliver, and assess instruction, providing opportunities to reimagine traditional teaching methods. Within the field of science education – particularly chemistry – AI-based tools and approaches have the potential to revolutionize how students understand complex scientific concepts and engage with abstract phenomena that are often difficult to visualize or experiment with in conventional classroom environments (Zhu, 2024).

Chemistry, as a discipline, presents a unique set of challenges for both teachers and learners. It requires not only the memorization of theoretical concepts and formulas but also the ability to understand abstract molecular structures, chemical

reactions, and the dynamic behavior of matter (De Jong & Taber, 2013; Berber et al., 2025).

Traditional pedagogical approaches, while effective in establishing foundational knowledge, often fall short in sustaining student motivation and promoting higher-order thinking skills. Laboratory experiments, which are central to chemistry education, can be limited by time, resources, and safety constraints. As a result, many educators are exploring digital technologies – and more recently, AI-driven solutions – as a means to overcome these barriers and create more interactive, adaptive, and engaging learning experiences (Jarilkapovich, 2024).

AI technologies can be applied to chemistry education in numerous ways. Intelligent tutoring systems and adaptive learning platforms can assess individual students' progress and adjust instruction accordingly, offering personalized feedback and targeted practice. AI-powered simulations and virtual laboratories allow students to conduct experiments safely in a digital environment, providing opportunities to test hypotheses, visualize molecular interactions, and analyze data in real time. Furthermore, natural language processing tools such as AI chatbots can assist students in answering questions, explaining chemical processes, or guiding them through problem-solving activities. These applications align with modern pedagogical paradigms that emphasize learner-centered approaches, experiential learning, and active knowledge construction.

Despite the promising potential of AI in chemistry education, its successful integration depends heavily on pedagogical strategy, teacher preparedness, and student acceptance (Iyamuremye et al., 2024).

While some studies have reported positive effects of AI tools on student learning outcomes and engagement, others have highlighted challenges such as a lack of digital literacy, limited access to technology, and ethical concerns related to data privacy (Boubker, 2024). Moreover, most existing research has focused on the technical design of AI systems rather than the pedagogical frameworks necessary for their effective classroom implementation.

Several empirical studies internationally have examined student perceptions of AI in education. For example, a multi-institutional survey with 410 students reported varying levels of optimism and skepticism toward AI usage in learning environments (Alpizar-Chacon et al., 2025). Similarly, research with secondary education students analyzed attitudes and anxiety regarding AI tools in science classrooms (Sivenas, 2025). Another study focusing on higher education students identified distinct attitudinal dimensions toward AI tools and their acceptability (Tang et al., 2025). To our knowledge, there are limited empirical studies in Bulgaria addressing secondary students' perceptions of AI integration, particularly in chemistry education, highlighting the need for the present study.

Therefore, this study seeks to examine the pedagogical potential of AI integration in chemistry education by focusing on students' perceptions and experiences (Shi et al., 2024).

The research aims to identify which AI-supported learning approaches are most effective in enhancing understanding, engagement, and interest in chemistry. To achieve this, a survey was conducted among secondary school students studying chemistry to collect data on their familiarity with AI tools, their attitudes toward AI-based learning, and their views on its advantages and limitations.

By analyzing these perceptions, the study aims to provide valuable insights into how AI can be meaningfully incorporated into chemistry instruction and how educational institutions can design strategies that align with both technological advancement and pedagogical effectiveness. The findings are expected to contribute to a deeper understanding of the interplay between AI technologies and science education, offering practical recommendations for educators seeking to foster innovative, student-centered learning environments in the digital age (Sherley et al., 2025).

Methodology

Research Design

This study employed a quantitative research design to investigate students' perceptions and experiences regarding the integration of Artificial Intelligence (AI) into chemistry education. The research focused on examining students' attitudes toward AI-based learning tools, their familiarity with such technologies, and their views on how AI could enhance their understanding of chemistry concepts.

Participants

The participants in this study were 65 students from the 9th grade enrolled in chemistry courses across three different secondary schools in Blagoevgrad, representing different types of institutions. Among the participants, **45 students (69.2%) were boys and 20 students (30.8%) were girls**. Participation was voluntary, and all responses were collected anonymously to ensure ethical integrity and unbiased feedback. Students were informed about the purpose of the study and assured that their responses would be used solely for academic research purposes. The data collection took place in **November 2025**.

Data Collection Instrument

Data were collected using a structured online questionnaire developed specifically for this study. The survey comprised two main sections:

Demographic Information – including participants' gender and grade level.

Experience with AI Tools – items assessing students' familiarity with and frequency of use of AI-based applications, such as chatbots, educational apps, or simulations.

The questionnaire also included items that examined students' perceptions of AI's usefulness, ease of use, engagement potential, and its impact on learning chemistry.

The survey was distributed online using Google Forms, which allowed for easy access and data collection in a secure environment.

Data Analysis

The collected data were analyzed using descriptive statistical methods, including frequency distributions, means, and percentages, to summarize students' responses. Because the questionnaire consisted solely of closed-ended items, the analysis focused exclusively on quantitative measures. The results are presented through graphical representations, which illustrate the key patterns and trends observed in the data.

Ethical Considerations

All participants were informed about the study's purpose and provided their consent before participating. No personal information was collected, ensuring anonymity and confidentiality. The study adheres to ethical research standards in educational contexts.

Results

For the purposes of this study, a survey **was conducted** among 65 ninth-grade students from three secondary schools in Blagoevgrad, Bulgaria. Of the 65 participants, 64 responded to the question regarding school affiliation. The participants **were distributed** as follows: 17 students (26.6%), 25 students (39.1%), and 22 students (34.4%) from the three schools, respectively. Among the participants, 45 students (69.2%) were boys and 20 students (30.8%) were girls.

The survey was aimed at 9th grade students and aimed to determine the level of knowledge and use of various artificial intelligence tools, as well as students' attitudes towards the integration of these technologies in chemistry education.

The data obtained provide valuable information about students' current interaction with AI and allow identifying opportunities for improving pedagogical approaches in chemistry education.

The survey aimed to establish both the level of knowledge of various AI tools and the actual frequency of their use in the learning process. The data obtained provide a valuable basis for assessing the current state of digital competences and reveal which technologies are most widespread and which still remain insufficiently implemented in educational practice.

The conducted study reflects real trends in the way students interact with new technologies and allows for the identification of potential directions for the development and improvement of pedagogical approaches when incorporating artificial intelligence into chemistry education.

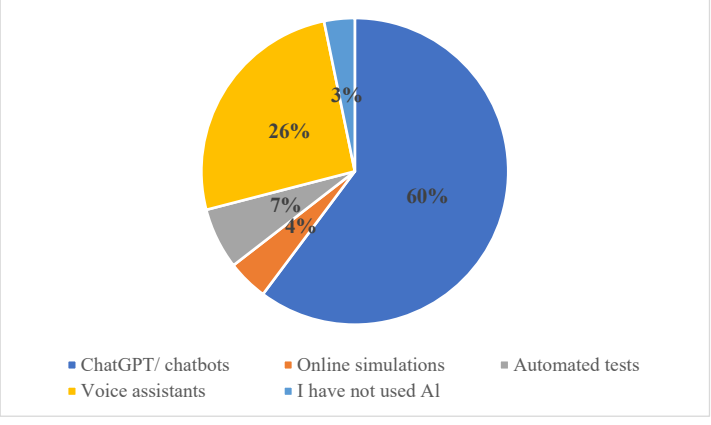

Figure. 1. Distribution of student familiarity and usage of various artificial intelligence tools

The first question of the survey (Fig. 1) asked students which artificial intelligence tools they knew or had used, focusing specifically on AI use in the context of education rather than general AI usage.

The data clearly showed that the most recognizable and used AI tool in the context of education was the chatbot, supporting the idea that the introduction of generative models (such as ChatGPT) into chemistry education had the potential for mass applicability.

Conversely, more specialized tools such as visual laboratories, which could directly benefit chemistry by simulating processes and experiments, are still underutilized. This highlights the need for:

– better awareness among students and teachers,
– institutional provision of access,
– integration into teaching materials and lessons.

Most participants indicated that they would use AI to explain difficult lessons or equations (43.1%), indicating an interest in helping to understand complex chemical concepts. 26.2% of students would use it to prepare homework and projects, highlighting the potential of AI to support learning and organizational tasks. 9.2% chose AI for laboratory simulations, indicating that although interest in practical applications is lower, students see potential in using AI for visualization and experimental exercises. A relatively small share (21.5%) stated that they would not use AI, indicating that the majority of students are open to integrating new technologies into the learning process.

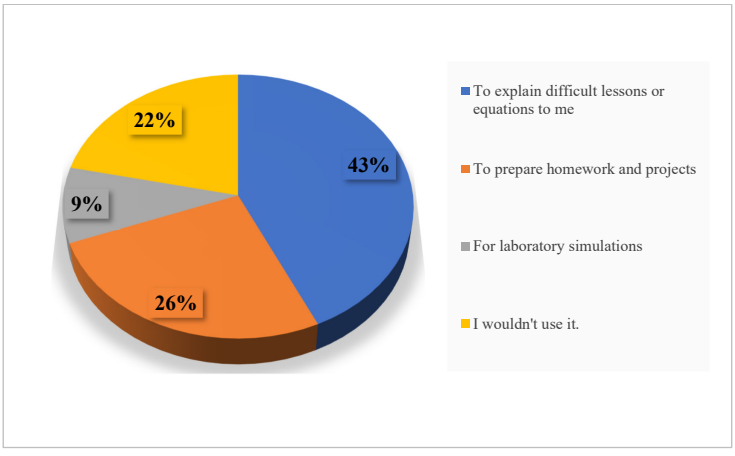

Figure 2. Distribution of student responses on the purposes of using artificial intelligence in chemistry classes

Most participants (67.2%) believe that the main benefit of using AI is easier understanding of difficult topics, indicating that students see potential in AI to help them understand complex chemical concepts. 57.8% of participants indicate that AI allows for faster information retrieval, which highlights its role as a tool for effective learning and independent work. 26.6% believe that AI can provide individual assistance according to their needs, indicating an expectation for personalized and adaptive learning. 17.2% indicate that the use of AI would help improve test scores, while 9.4% believe that AI would increase motivation to learn. Finally, 15.6% of participants do not see any particular benefits from AI, indicating that despite the large majority with a positive attitude, some students remain skeptical about the integration of technology into the learning process.

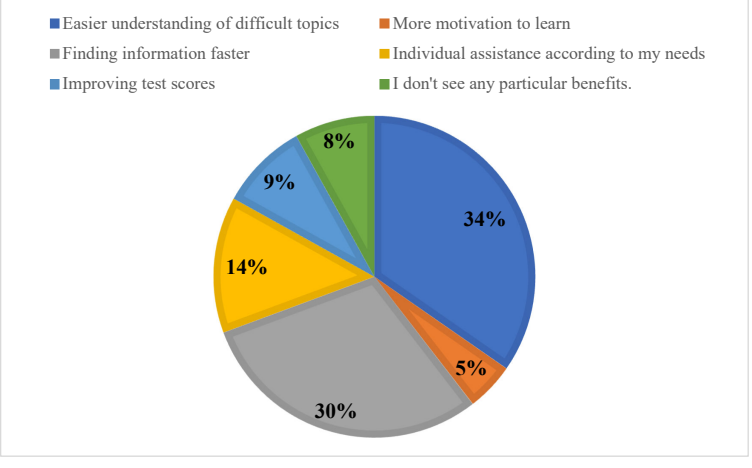

Figure 3. Perceived benefits of using artificial intelligence in chemistry learning

The largest share of participants (41.5%) believe that students should be trained by special IT trainers, which indicates that a large proportion of students see a need for expert training for responsible work with AI. 36.9% believe that no special training is necessary, which suggests that some students are confident in their ability to handle technology on their own. 18.5% believe that students themselves can train through practice, showing interest in independent and active learning through experimentation with AI. The smallest share (3.1%) indicates that chemistry teachers should train students, which indicates that for the time being few participants expect training to come directly from subject teachers.

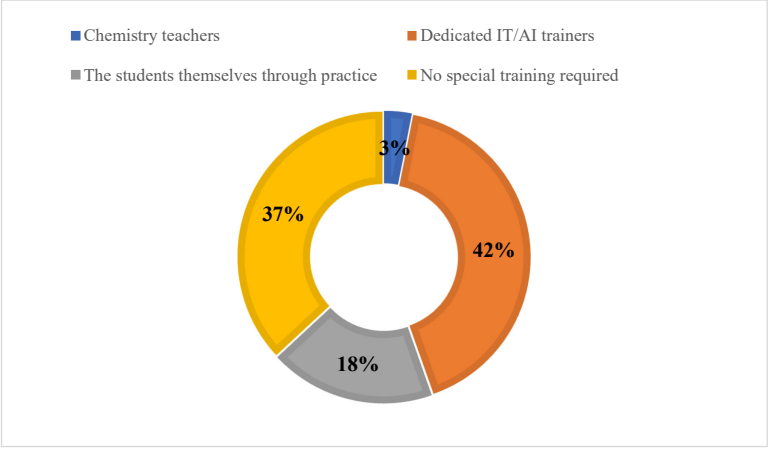

Figure 4. Students' opinions on who should provide training for responsible use of AI in chemistry education

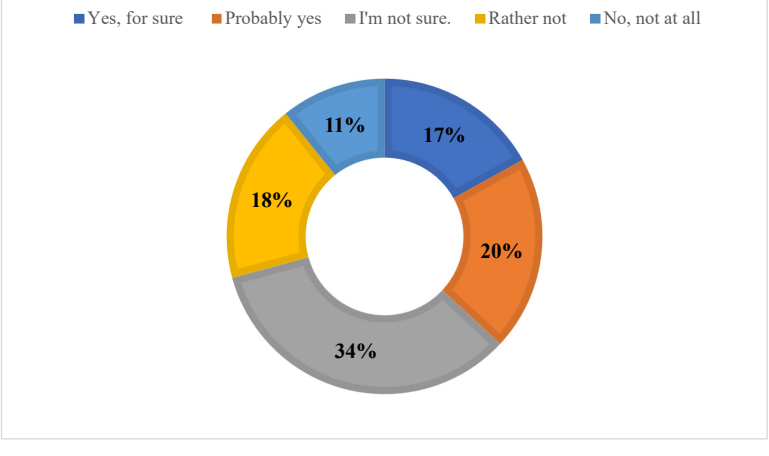

Figure 5. Student willingness to participate in a school course on using AI in science

The largest proportion of respondents (33.8%) are unsure whether they would participate.

The overall interest in the course ("Probably yes" + "Yes, definitely") is 36.9%, while around 29.3% express reluctance ("Rather no" + "No, not at all").

The data shows moderate interest, but there is a significant group that is hesitant, which may indicate a need for more information or promotion of the course.

Conclusion

The survey among 65 9th grade students in three schools in the city of Blagoevgrad shows that students are well acquainted with various artificial intelligence tools, the most popular being chatbots (ChatGPT and similar). Most students perceive AI as a useful tool for easier understanding of difficult topics, faster information retrieval, and individualized assistance according to their needs, while a smaller share is interested in practical applications such as laboratory simulations or does not see any particular contribution from AI.

Regarding training in the responsible use of AI, students believe that this should be mainly provided by dedicated IT trainers, while only a small proportion rely on chemistry teachers or self-study. Willingness to participate in AI courses in science is moderate: around a third of students are willing to participate, but a large share remains uncertain, highlighting the need for more information, demonstrations of benefits, and support for students.

These findings align with international studies, where students generally view AI as supportive but express varying levels of interest and confidence in its use in science education (Alpizar-Chacon et al., 2025; Sivenas, 2025; Tang et al., 2025). To my knowledge, a similar empirical investigation has not yet been conducted in Bulgaria, particularly in the context of chemistry education, which emphasizes the novelty and relevance of the present study.

Overall, the results indicate a high readiness for integrating AI into chemistry education, while also emphasizing the need for structured training, pedagogical guidance, and adaptation to individual student needs. These findings can serve as a basis for developing effective strategies for implementing AI in the learning process, enhancing digital competence, and stimulating interest in the natural sciences. They also provide valuable insights for educators seeking to design student-centered, technologically informed learning environments.

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