

# PRISMA SYSTEMATIC REVIEW: AI MODELS APPLIED TO CHEMISTRY EDUCATION.

Yessica Viviana Barragán Orjuela  
Laura Brand López

NATIONAL PEDAGOGICAL UNIVERSITY



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**TRADUCCIÓN:** ADALGISA VILLARREAL

Departamentolinguística e Idiomas - Facultad de Ciencias Humanas - Universidad de Nariño.

## Resumen.

This review analyzes the contributions of emerging technologies, particularly artificial intelligence, to chemistry education, highlighting its pedagogical value. The objective is to identify and classify potential applications of these technologies for the learning of chemical concepts and provide an overview of their use in this field. The methodology is a systematic review of scientific articles and theses published between 2005 and 2024 in recognized databases, covering work in Spanish, English, and Portuguese. The results underscore the implementation of technologies that facilitate understanding of chemical phenomena at symbolic, macroscopic, microscopic, and process levels. Categorization includes models such as deep learning, supervised, unsupervised, and generative learning. Data reveals the participation of several countries in the analyzed studies. It is concluded that the integration of AI and emerging technologies in chemistry education holds significant potential to enrich education by improving the accuracy, accessibility, and personalization of learning.

**Keywords:** Artificial intelligence, chemistry education, simulations, information and communication technologies, teacher trainees.

## Abstract.

Esta revisión analiza los aportes de las tecnologías emergentes, en particular la inteligencia artificial (IA), en la enseñanza de la química, destacando su valor pedagógico. El objetivo es identificar y clasificar las aplicaciones potenciales de estas tecnologías para el aprendizaje de conceptos químicos y ofrecer una visión general de su uso en este campo. La metodología es una revisión sistemática de artículos científicos y tesis publicadas entre 2005 y 2024 en bases de datos reconocidas, abarcando trabajos en español, inglés y portugués. Los resultados subrayan la implementación de tecnologías que facilitan la comprensión de fenómenos químicos a nivel simbólico, macroscópico, microscópico y de procesos. La categorización incluye modelos de aprendizaje profundo, supervisado, no supervisado y generativo. Los datos revelan la participación de varios países en los estudios analizados. Se concluye que la integración de IA y tecnologías emergentes en la enseñanza de la química tiene un gran potencial para enriquecer la educación, mejorando la precisión, accesibilidad y personalización del aprendizaje.

## PRISMA SYSTEMATIC REVIEW OF AI MODELS APPLIED IN CHEMISTRY TEACHING.

**Palabras Clave:** Inteligencia artificial, enseñanza de la química, simulaciones, tecnologías de la información y la comunicación, profesores en formación.

## I. INTRODUCTION.

This review is part of the pedagogical practices of the Bachelor's Degree Program in Chemistry at the National Pedagogical University and aims to analyze the contributions and applications of artificial intelligence (AI) in the teaching and learning of chemistry. In a global context where information and communication technologies (ICT) are redefining educational approaches, the integration of AI into science education is no longer merely a trend but an emerging necessity. Chemistry, a discipline that requires a high level of abstraction and logical reasoning, stands to benefit significantly from the possibilities offered by these technologies.

Through this systematic review, the study aims to identify the potential of implementing ICT and AI in science education, particularly in chemistry teaching, highlighting their capacity to transform teaching-learning processes. AI not only enables the automation of certain pedagogical tasks but also provides powerful tools to personalize instruction by adapting it to students' individual needs, thereby improving the understanding of complex concepts. In this context, ICTs facilitate access to interactive and visual resources that enrich the educational experience and allow for a more direct connection with chemical phenomena (Lindgren, 2023).

Understanding chemical phenomena involves multiple cognitive processes structured across different levels of representation: (a) the symbolic level, which includes formulas, equations, and graphs; (b) the macroscopic

level, which encompasses observable phenomena; (c) the microscopic or submicroscopic level, which requires explanations at the particle level; and (d) the process level, which addresses dynamic interactions between substances (Pérez, 2018; Cruz, 2023). These levels often pose challenges for students; however, AI and ICT can facilitate transitions between them by providing visualizations and simulations that support more intuitive comprehension.

AI applied to chemistry education can optimize processes such as chemical reaction simulation, complex data analysis, and prediction of molecular behavior. Technologies such as augmented and virtual reality, along with deep learning models, not only improve conceptual representation but also make learning more accessible and engaging. These tools help overcome traditional barriers to science learning—such as limited laboratory resources—by offering immersive environments and practical simulations.

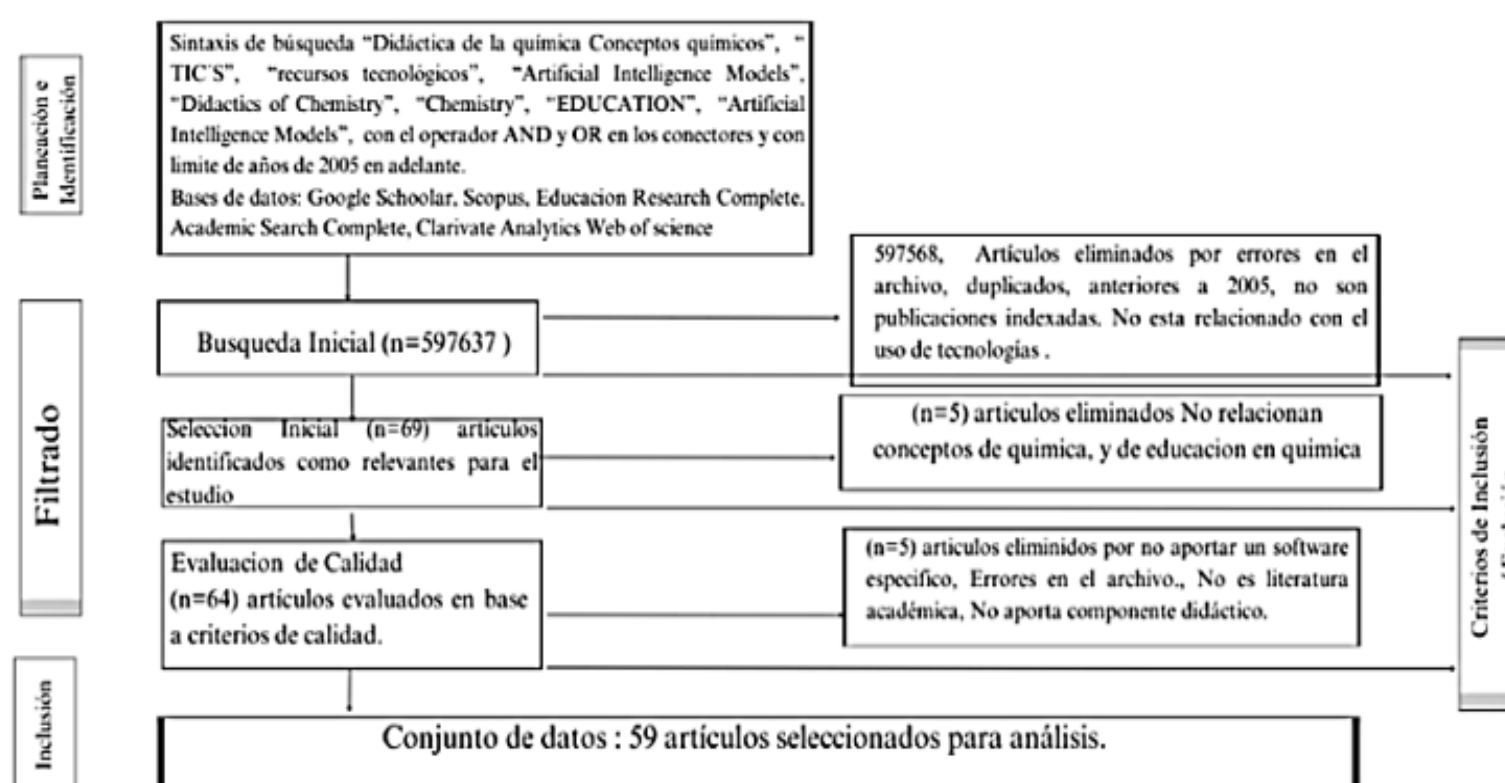
## II. METHODOLOGY.

The PRISMA protocol was employed to conduct a systematic review of scientific articles and theses published between 2005 and 2024. Sources were selected from recognized databases using keywords such as chemistry education, artificial intelligence, and laboratory practices. Inclusion criteria were based on relevance to the teaching of chemical concepts and the use of ICT and AI in educational contexts.

The guiding research questions were: What is the current landscape of ICT and AI in chemistry education, and what are their main contributions to the teaching–learning process?

The review included studies in Spanish, English, and Portuguese from various countries. The PRISMA methodology enabled accurate categorization of the studies, classifying AI models into categories such as deep learning, supervised learning, unsupervised learning, and generative models, among others (see Figure 1).

**Figure 1:** PRISMA process flowchart.



### III. RESULTS.

The data collected and presented in Table 1 provide a comprehensive overview of publications on AI and ICT in chemistry education between 2005 and 2024. The yearly distribution of publications (Graph 1) reveals a marked increase over the past five years. This growth coincides with the rise of emerging educational technologies and the COVID-19 pandemic, which accelerated the adoption of digital tools in teaching, particularly in experimental disciplines such as chemistry.



**Graph 1:** Relationship of publications per year. Own source.

The analysis of AI techniques shows a clear evolution toward more sophisticated and adaptive models. Deep learning, for instance, has played a key role in analyzing complex data such as molecular images and three-dimensional structures. This approach facilitates the visualization of chemical structures and supports the development of critical visuospatial skills, which are traditionally difficult to achieve in conventional settings (Rojas, 2023).

Supervised learning models enhance the educational experience by training algorithms with labeled data, enabling predictions of experimental outcomes (Fergus, 2023; Jha et al., 2018). For example, students can simulate chemical reactions and predict products under varying conditions, transforming the teaching of complex concepts such as stoichiometry.

Unsupervised learning has proven particularly useful for identifying patterns in unlabeled data, such as predicting molecular electronic properties. These models promote autonomous learning by allowing students to explore relationships between molecular descriptors and observed properties without direct instructor intervention (Montavon et al., 2013; Cabrera, 2018; Back et al., 2024).

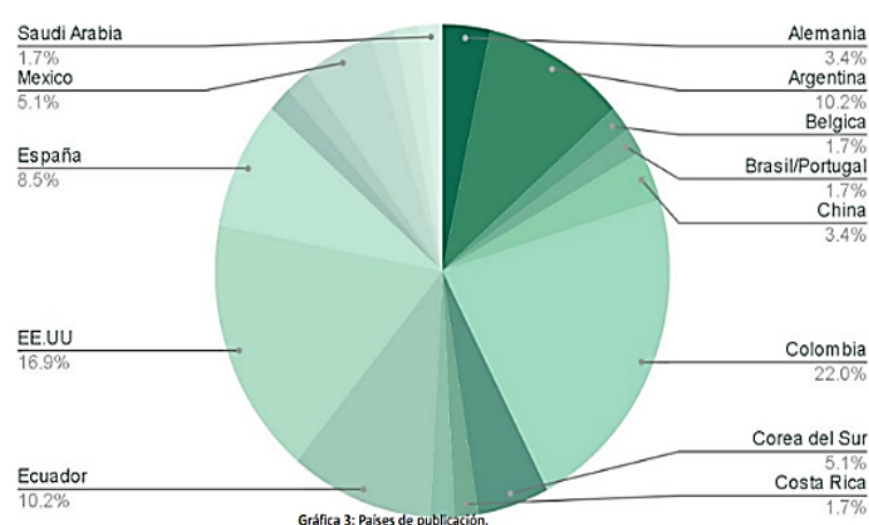
Generative models are increasingly being used to design systems that mimic key chemical processes, including pattern recognition and decision-making in compound synthesis. This not only enhances conceptual understanding but also allows students to engage in molecular design, an essential component of advanced chemistry education (Goh et al., 2020; Amirbekova et al., 2024).

Natural language processing (NLP) has also shown significant potential in chemistry education by enabling the analysis of large volumes of scientific information and facilitating the assessment of students' responses through real-time feedback (Jha et al., 2018).

Modelos de IA	Artículos	Técnicas
Aprendizaje Profundo	Cataldi, Donnamaria, Lage, (2009), Chen, et. al (2023), Cárdenas (2024), Hao Zhu, (2019), Gentili, Stano (2023), Asfaram, Ghaedi, Azghandi, Dastkhoona, (2016), Martin, Kranz, Wulff, Graulich (2023), Goh, Siegel, Vishnu, Hodas, Baker (2017), Jha et.al (2018) Dobbelaere, Plehiers, Van de Vijver, Stevens, Van Geem (2020), Keith et.al (2021), Fergus, (2023), Montavon et.al (2013), Kwak et.al (2024), Rojas (2023), Alhumade, Rezk, rahim Al-Zahrani, Zaman, Askalany (2021).	Redes Neuronales Artificiales (ANN), Aprendizaje Profundo (Deep Learning) redes neuronales convolucionales (CNN) aprendizaje automático
Aprendizaje Supervisado y No Supervisado	Sanz, Martinez, (2005), Johnson-Glenberg, Birchfield, Sibel, (2009), Proszek, Ferreira, (2009), Venkatasubramanian (2018), Martin, Vaishali, Jain, Ghosh, Tembaya, (2024).	Procesamiento Automático y análisis de Datos, Evaluación Adaptativa, Aprendizaje Basado en el Reconocimiento de Patrones, sistemas expertos basados en conocimiento, redes neuronales recurrentes, Árboles de Decisión (Decision Tree).
Generativos	Hocky, White, (2022).	Codex GPT-3 (Generative Pre-trained Transformer 3)
NLP	Chiu, (2021), Hocky, White, (2022), Chen et.al, (2023), Mancera et.al, (2023), Yik, Doad, (2024), Martin, Kranz, Wulff, Graulich, (2023), Kwak et.al, (2024).	NLP, GPT-3.5/ Large language model (LLM), BERT, RoBERTa, SciBERT, Deep Neural Networks (DNN), Transformer

**Table 1:** Categories of AI Models. Own source

Regarding geographical distribution, the review indicates that although Colombia shows growing interest in these technologies, most advanced studies originate from countries with greater technological resources. This highlights the need to strengthen efforts to bridge the technological gap in Colombia.



**Graph 2:** Participation by country. Own source.

The reviewed studies demonstrate that AI and ICT not only support the teaching of basic chemical concepts but also contribute to research and the development of innovative pedagogical strategies. Notably, these technologies help overcome barriers such as limited access to laboratories by enabling advanced simulations, which is particularly relevant for institutions with scarce resources.

Finally, Table 2 illustrates the broad range of AI applications in chemistry, from advanced research to foundational teaching. The growing use of these technologies signals a paradigm shift in science education.

**Table 2:** Extraction of analyzed data. Own source

#	Artículo	Técnicas Utilizadas	Tema
1	Sanz, Martínez, (2005). El Uso De Los Laboratorios Virtuales en la asignatura bioquímica como alternativa para la aplicación de las tecnologías de la información y la comunicación. Sanz	Modelación, Simulación, Procesamiento Datos, Laboratorios Virtuales.	Bioquímica
2	Johnson-Glenberg, Birchfield, Sibel, (2009). SMALLab: virtual geology studies using embodied learning with motion, sound, and graphics.	Seguimiento del Movimiento, Interacción, Análisis de Datos Educativos, Simulación.	Mineralogía
3	Cataldi, Donnataria, Lage, (2009). Didáctica de la química y TICs: laboratorios virtuales, modelos y simulaciones como agentes de motivación y de cambio conceptual	Redes Neuronales Artificiales (ANN), Aprendizaje Profundo (Deep Learning), Algoritmos de Aprendizaje Supervisado y No Supervisado	Hibridación, Ley de gases, estructuras químicas.
4	Pérez et al. (2009). Experiencias de enseñanza de la química con el apoyo de las TIC's.	Sistemas expertos	Química General
5	Proszek, Ferreira, (2009). Enseñanza de la Química en Ambientes Virtuales: Blogs	NLP	Petroquímica
6	Prado, (2009). Aprendizaje colaborativo mediado como estrategia didáctica para la enseñanza del equilibrio químico ácido base	Plataforma "CouldLabs"	Equilibrio químico
7	González et al. (2011). Estrategia didáctica con mediación de las TIC, propicia significativamente el aprendizaje de la Química Orgánica en la educación secundaria	Recursos Educativos Digitales (RED)	Química Orgánica
8	Marzocchi, Vilchez, DiMato, (2012). Incorporación de TICs de modelado molecular en la enseñanza universitaria de la Química	Blog, Bubl, Jmol	Química Inorgánica
9	Chavarría (2013). Medios didácticos basados en las TIC, como herramientas de apoyo virtual en la enseñanza de la química orgánica.	Plataforma Arduino	Estructura de Lewis, carga formal.
10	Hernández, Rodríguez, Parra, Velázquez, (2014). Las Tecnologías de la Información y la Comunicación TIC's en la enseñanza aprendizaje de la química orgánica a través de imágenes, juegos y video.	laboratorios virtuales	Química orgánica
11	Hernández, (2014) Implementación de las TIC en la enseñanza de la cinética y equilibrio químico en los estudiantes del grado 11 de la Institución Educativa Emiliano García	Recurso didáctico ChemCollective para aprendizaje de Química Analítica	Cinética química y equilibrio químico
12	Fiad, Galaza, (2015) El Laboratorio Virtual como Estrategia para el Proceso de Enseñanza-Aprendizaje del Concepto de Mol.	laboratorio virtual	mol
13	Sasson, Dari, (2015). A Three-Attribute Transfer Skills Framework - Part II: Applying and Assessing the Model in Science Education	Herramientas de Química Computacional (ORCA y Avogadro)	ácidos bases

14	Rodríguez, (2018). (2018) Tecnologías de hoy: perspectivas y desafíos de la educación en la era digital. Homenaje a los 25 años de creación de la maestría en Tecnologías de la Información Aplicadas a la Educación	Simulación molecular	Educación científica
15	Cabrera (2018). Empleo de software de simulación de prácticas de laboratorio en el desarrollo de las clases prácticas en la cátedra de química analítica I.	Entornos inmersivos.	Espectrofotometría
16	Vera, Irene, Stoppello, Petris, Giménez, (2018). Recursos TIC para el aprendizaje de la química y la física en el ciclo básico universitario.	Laboratorios virtuales Crocodile Chemistry	Química General
17	Guerrero, Ramos (2018). Uso de un simulador para facilitar el aprendizaje de las reacciones de óxido-reducción. Estudio de caso Universidad de Málaga	Simuladores y plataformas de aprendizaje en línea	Reacciones de Óxido reducción, Electroquímica
18	Rojas, Zapata, Sánchez, Montaño (2018) Nuevas TIC: herramientas para propuestas didácticas en el área de Química.	(ChatGPT, Perplexity)	Química general
19	Amaral, Eichler, (2018). As tecnologías digitais e o ensino de Química: o caso do Programa de Desenvolvimento Profissional para Professores da CAPES.	Modelado molecular computacional	Química general
20	Velanda, (2020) TIC en el aula de química: Incidencia en los procesos de aprendizaje de conceptos básicos de estequiometría en estudiantes de grado décimo de educación media.	Modelado molecular	Estequiometría
21	Sosa, Rodríguez, Alvarez, Forero, (2020). Mobile learning como estrategia innovadora en el aprendizaje de la química inorgánica	Moodle	Grupos funcionales inorgánicos
22	Romero, (2021) Integración efectiva de las TIC en la enseñanza de química: estrategias innovadoras para la docencia universitaria.	Aprendizaje Adaptativo	Enseñanza de la química
23	Arroba, Acurio, (2021). Laboratorios virtuales en entorno de aprendizaje de química orgánica, para el bachillerato ecuatoriano. recurso didáctico para el aprendizaje de Química Analítica con estudiantes de cuarto semestre de la carrera de Pedagogía de las Ciencias Experimentales: Química y Biología.	Modelado molecular y herramientas de Química Computacional (ORCA y Avogadro)	Escala de PH Estados de la materia Propiedades de los gases
34	Vergara, Carrillo, (2023). Uso de Inteligencia Artificial para diseñar propuestas didácticas de Física y Química en Educación Secundaria	TIC, laboratorios virtuales, simuladores, encuestas, análisis estadístico	Química Analítica
35	Chen et al. (2023). Application and teaching of computer molecular simulation embedded technology and artificial intelligence in drug research and development.	ChatGPT y Perplexity	Química general.
36	aprendizaje de química por personas con escolaridad inconclusa.	Aprendizaje Automático (Machine Learning): Modelado de Redes Neuronales Artificiales Simulación Molecular por Computadora (Computer Molecular Simulation)	Docking molecular
37	Cruz, (2023) Reestructuración de laboratorios de química para docentes en formación. una mirada diagnóstica y de pilotaje hacia laboratorios tri-componente.	lenguaje natural, Sistemas de recomendación.	Química general.
38	laboratorio extendido simplificado en secuencias de enseñanza aprendizaje en el ciclo básico del nivel secundario de Córdoba	(ChatGPT, Perplexity)	laboratorio química instrumental, teorías químicas.
39	Rojas, (2023). Análisis de buenas prácticas en la implementación de dos herramientas computacionales para el abordaje del tema Geometría Molecular en un curso de Química Orgánica a nivel universitario	Simulación molecular,	propiedades de los materiales.
40	Cárdenas, (2024). El uso de la inteligencia artificial en la creación de entornos de aprendizaje inmersivos en la educación superior. Revisión sistemática.	Algoritmos de optimización heurística, aprendizaje automático.	Geometría molecular, química orgánica.
41	Venkatasubramanian (2018) "The Promise of Artificial Intelligence in Chemical Engineering: Is It Here, Finally?"	Modelos Generativos Adversarios (GAN): Redes Neuronales Recurrentes (RNN): Aprendizaje por Refuerzo (RL):	Química General
42	Dobbelaere, Plehiers, Van de Vijver, Stevens, Van Geem (2020). "Machine Learning in Chemical Engineering: Strengths, Weaknesses, Opportunities, and Threats.	Estrategias de Inferencia / Simulación y Modelos Híbridos	catalizadores, la síntesis de procesos.
43	Keith et al (2021) Combining Machine Learning and Computational Chemistry for Predictive Insights Into Chemical Systems.	aprendizaje automático (machine learning)	Modelado químico
44	Zhu, (2019) "Big Data and Artificial Intelligence Modeling for Drug Discovery"	Aprendizaje automático	Propiedades Moleculares
45	Fergus, Batha, Mehroobh, (2023) Evaluating Academic Answers Generated Using ChatGPT.	Redes Neuronales Convolucionales (CNN) - Modelos de Aprendizaje Profundo Generativo (GAN)	Estructura química de compuestos
46	Asfaram, Ghaedi, Azghandi, Dastkhaana, (2016). Statistical experimental design, least squares support vector machine (LS-SVM) and artificial neural network (ANN) methods for modeling the facilitated adsorption of methylene blue dye.	Procesamiento del Lenguaje Natural	Química orgánica
47	Montavon et al (2013). "Machine learning of molecular electronic properties in chemical compound space.	Redes Neuronales Artificiales (ANN)/ Máquina de Vectores de Soporte de Mínimos Cuadrados (LS-SVM)	Nanopartículas
48	Jha et al (2018) "ElemNet: Deep Learning the Chemistry of Materials From Only elemental Composition".	Modelo de representación de características/ Simulación.	electrónicas moleculares
49	Deep Neural Network with Minimal Chemistry Knowledge Matches the Performance of Expert-developed QSAR/QSPR Models.	DNN/ CNN	Composición elemental/ interacciones químicas/
50	Yik, Daod (2024) "ChatGPT Convincingly Explains Organic Chemistry Reaction Mechanisms Slightly Inaccurately with High Levels of Explanation Sophistication"	(CNN).	estructura molecular, descriptores moleculares.
51	Martin, Vaisalli, Jain, Ghasb, Temitayo, (2024). ChemAlstry: A Novel Software Tool for Teaching Model Training in K-8 Education.	GPT-3.5/ Large language model (LLM)	química orgánica, mecanismos de reacción,
52	Amirbekova, Shertayeva, Mironova (2024). "Teaching chemistry in the metavers: the effectiveness of using virtual and augmented reality for visualization"	Árbol de decisión (Decision Tree)	laboratorio/ Equipos de protección personal (PPE)/
53	Alhumade, Rezk, Al-Zahrani, Zaman, Askalany (2021) "Artificial Intelligence Based Modelling of Adsorption Water Desalination System"	Motores gráficos y algoritmos de interacción para la creación y control de macromoléculas biológicas en realidad mixta.	Química Orgánica e Inorgánica/ Química Analítica y Espectroscopía
54	Gentili, Stano (2023) "Tracing a new path in the field of AI and robotics: mimicking human intelligence through chemistry. Part II: systems chemistry.	multiagente/ redes neuronales profundas / Docking molecular / lógica difusa.	Compuestos moleculares y supramoleculares/
55	Martin, Kranz, Wulff, Graulich (2023). Exploring new depths: Applying machine learning for the analysis of student argumentation in chemistry.	Modelado Molecular y Simulación Computacional, Sistemas Basados en Reglas - Modelado de Agentes Autónomos - Técnicas de Control	Bioquímica/ química de materiales/ química computacional/
56		BERT, RoBERTa, SciBERT (Scientific BERT). Deep Neural Networks.	Reacciones Químicas

56	Martin, Kranz, Wulff, Graulich(2023). Exploring new depths: Applying machine learning for the analysis of student argumentation in chemistry.	BERT, RoBERTa, SciBERT (Scientific BERT), Deep Neural Networks.	Reacciones Químicas
57	Back et al.(2023). Accelerated chemical science with AI	Aprendizaje automático machine learning	industria y la investigación.
58	Kwak et al. (2024). GeoT: A Geometry-Aware Transformer for Reliable Molecular Property Prediction and Chemically Interpretable Representation Learning.	Transformer	molecular. Propiedades moleculares
59	Kim et al.(2023) Chemistry-informed machine learning: Using chemical property features to improve gas classification performance.	Support Vector Classifier (SVC) - Clasificador de Máquinas de Vectores de Soporte.	Propiedades químicas de los análisis

## IV. DISCUSSION.

The analysis reveals that emerging ICT and AI models have the potential to transform scientific learning spaces, such as chemistry labs, making them more accessible, dynamic, and efficient. In particular, technologies such as augmented reality and immersive simulations allow students to immerse themselves by interacting with abstract concepts in a more intuitive and visual way. These tools make it possible for complex chemical processes, which are traditionally difficult to teach thru conventional methods, to be understood in a more interactive and visual way. During the pandemic, for example, the use of these technologies grew exponentially, allowing laboratory practices to be conducted virtually, which demonstrated their relevance in replicating experimental educational environments remotely and flexibly (Amaral-Rosa & Eichler, 2018; Venkatasubramanian, 2018; Guevara et al., 2020).

This experience marked a key starting point for rethinking deep learning models applied to the teaching of chemistry. Technologies such as artificial intelligence not only enrich learning through advanced simulations but also foster the development of critical skills, such as the three-dimensional visualization of molecules and the ability to make predictions about chemical reactions (Chen, 2023; Rojas, 2023). In this sense, augmented and mixed reality simulations are not merely a complement, but a key resource for integrating theory and practice in scientific education.

However, in the Colombian context, it is observed that the implementation of AI is still in its early stages. Although the use of ICT has been fundamental in improving access to educational resources, the transition toward the use of AI faces significant challenges, such as the need to train personnel skilled in its implementation. This poses a challenge both for educational institutions and for the education system as a whole, as training teachers in AI and ICT is essential for these to promote a more innovative

and participatory pedagogical approach (González Llanos, 2011; Largo Taborda et al., 2022; Cárdenas, 2024). It is vital that educational approaches are oriented toward generating more access and participation, encouraging students to actively engage in the creation of knowledge. AI and ICT not only enable more personalized teaching but also pave the way for the democratization of access to scientific knowledge, especially in institutions with infrastructure limitations. Students can experiment and develop hypotheses about complex chemical systems in virtual environments, something that would otherwise be beyond their reach in a physical laboratory.

Improvements in academic performance, particularly in simulated experimental environments, highlight how AI can transform the teaching of chemistry. Molecular simulations, for example, allow for better visualization of chemical systems and the formulation of more well-founded hypotheses. This type of technology facilitates the analysis and understanding of molecular geometry, an area traditionally challenging for students (Pino et al., 2001; Montavon et al., 2013; Chiu, 2021 Mesías Álvarez, 2023).

It also highlights how the limitations of access to physical laboratories in institutions with scarce resources can be mitigated thru the use of AI-based virtual laboratories. These tools allow access to quality training without the need for physical facilities, democratizing education and providing innovative solutions to long-standing structural problems in the Colombian educational system.

## V. CONCLUSIONES.

This systematic review demonstrates that the integration of AI and ICT in chemistry education offers significant potential to transform scientific education in classrooms. These technologies facilitate the teaching and learning of complex concepts, such as chemical reactions and molecular geometry, and in turn, open new avenues for personalized learning and equitable access to advanced educational resources.

As has been stated, one of the most revealing findings is the impact that simulations and immersive technologies, such as augmented reality and mixed reality, can have on the teaching of chemistry. These tools have proven to be especially useful in overcoming the traditional barriers associated with experimental teaching, allowing

students to interact with chemical phenomena in a more tangible and comprehensible way. AI, by personalizing learning and providing immediate feedback, facilitates the development of a different perspective on the relationship between abstract concepts, which translates into better knowledge retention and more active and autonomous learning.

However, for AI and ICT to unleash their full transformative potential, it is necessary for educational institutions to adopt a more comprehensive approach that includes teacher training, investment in technological infrastructure, and the development of educational policies that promote the innovative use of these technologies. In the Colombian context, although there has been a growing interest in the implementation of AI in education, this process is still in an early stage, highlighting the urgent need for training in technological and pedagogical skills for teachers.

Moreover, AI has the potential to revolutionize not only teaching but also research in chemistry. AI-based tools, such as deep learning and natural language processing, allow students and educators to explore new frontiers in the analysis of complex data and the formulation of scientific hypotheses. These technologies contextualized in the educational field can enhance students' ability to visualize and understand chemical phenomena, facilitating a deeper learning experience connected to scientific practice.

Although this systematic review demonstrates the transformative potential of artificial intelligence and ICT in chemistry education, some limitations that must be considered are identified. Most of the reviewed studies come from contexts with high technological availability, which limits the direct applicability of their results to environments with infrastructure constraints, such as many educational institutions in Latin America. Additionally, a low representation of research focused on basic school levels or initial teacher training programs was observed.

Consequently, it is recommended to promote research situated in diverse educational contexts, especially those with limited resources. Likewise, it is suggested to promote institutional policies that encourage teacher training in emerging technologies, as well as the design of AI-mediated educational resources that respond to local needs. This type of initiative will allow technological innovation to translate into real and equitable improvements in the teaching of chemistry.

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