

Artificial Intelligence in Chemistry Education for Students with Disabilities: A Scoping Review of Applications Supporting Inclusive Teaching Practices

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ABSTRACT:

Objective: To map evidence on AI applications in chemistry education for students with disabilities and identify outcomes and barriers for inclusive teaching.

Methods: A scoping review was conducted following Arksey & O'Malley's framework and PRISMA-ScR. Scopus and Google Scholar were searched. Eligible studies were thematically analyzed.

Results: Five studies were included. AI applications were mainly supportive (animation tools, translation systems, computer-assisted instruction, teacher training, LLM evaluation). Evidence was mostly descriptive, showing perceived benefits in accessibility and engagement but limited learning outcome data. Key barriers included low teacher readiness, infrastructure gaps, and limited reliability of generative AI.

Conclusion: AI in inclusive chemistry education remains early-stage, with emphasis on accessibility rather than adaptive pedagogy. Stronger empirical evidence is needed.

Keywords: Artificial intelligence; chemistry education; disability; inclusion; scoping review.

Introduction

Artificial intelligence (AI) in chemistry education for students with disabilities is an emerging but rapidly expanding field at the intersection of inclusive education, educational technology, and discipline-specific pedagogy.

Inclusive education has become a central priority in contemporary educational reform, emphasizing equitable access and participation for students with disabilities in mainstream

learning environments (Gonçalves et al., 2025; Pagliara et al., 2024). This need is particularly pronounced in chemistry education, where learning depends heavily on abstract concepts, symbolic representations, molecular visualization, and laboratory-based experiences, all of which may create substantial barriers for students with sensory, cognitive, physical, or communication-related disabilities (Abdurazov et al., 2025; Nsabayeze et al., 2022; Ugwuanyi et al., 2025). In this context, AI is increasingly

positioned as a potential enabler of inclusive teaching through adaptive learning systems, intelligent tutoring systems, assistive technologies, virtual laboratories, and AI-supported instructional design aimed at reducing barriers and enhancing participation (Iyamuremye et al., 2024; Moya et al., 2025).

Recent literature suggests that AI can strengthen accessibility and personalization in education by adapting content, pacing, and feedback to individual learner needs, thereby supporting more inclusive pedagogical approaches (Barus et al., 2025; Chalkiadakis et al., 2024; Li et al., 2025). In chemistry education specifically, intelligent tutoring systems and adaptive platforms have been highlighted as promising tools for monitoring learner progress and supporting differentiated instruction (Ahmed et al., 2025; Iyamuremye et al., 2024).

Complementary technologies such as virtual laboratory simulations have also demonstrated potential in enhancing engagement, independence, and learning outcomes among students with disabilities by reducing physical and cognitive barriers inherent in traditional laboratory environments (Abdurazov et al., 2025). In addition, AI-enabled accessibility tools—including speech-to-text, text-to-speech, translation systems, captioning, and content conversion technologies—further expand access for learners with diverse needs, while multilingual AI systems may also reduce linguistic barriers in chemistry learning contexts (Adeniyi et al., 2024; Ahmed et al., 2025; Martin & Graulich, 2024). However, concerns remain regarding generative AI limitations, including reasoning errors, hallucinations, and bias, highlighting the need for careful and responsible implementation (Feldman-Maggior et al., 2024; Uçar et al., 2025).

Despite these advances, the current literature indicates that AI does not automatically translate into equitable educational outcomes and may even reinforce disparities when access, infrastructure, and teacher capacity are uneven (Bulathwela et al., 2024). Persistent barriers include limited digital infrastructure, inadequate teacher training, low AI literacy, privacy

concerns, and algorithmic bias across inclusive education contexts (Chalkiadakis et al., 2024; Hussein et al., 2025; Li et al., 2025). In chemistry education specifically, research remains fragmented, with studies dispersed across assistive technologies, virtual laboratories, teacher education, and broader AI-in-education frameworks, resulting in limited integrated understanding of how AI supports inclusive chemistry teaching in practice (Naumann & Markic, 2026; Pagliara et al., 2024). Therefore, a scoping review is needed to systematically map existing evidence on AI applications in chemistry education for students with disabilities, identify the types of tools used, the disability groups addressed, the pedagogical roles of teachers, and the reported educational outcomes, and clarify gaps in knowledge that must be addressed to support equitable and inclusive chemistry education.

Materials and Methods

This study employed a scoping review methodology to systematically examine and synthesize existing literature on the applications of artificial intelligence in chemistry education for students with disabilities, with a specific focus on inclusive teaching practices. Guided by Arksey and O'Malley's (2005) seminal framework (Levac et al., 2010), the review enabled a structured and comprehensive mapping of evidence related to AI-enabled accessibility, personalization, and pedagogical support in chemistry education. Scoping review methodology is particularly appropriate for this field because research on AI in inclusive chemistry education remains conceptually diverse, methodologically heterogeneous, and rapidly evolving across educational, technological, and disability studies contexts.

Unlike traditional systematic reviews, the scoping approach is iterative and exploratory, allowing refinement of scope as patterns emerge from the literature. The review followed Arksey and O'Malley's five-stage framework and was reported in accordance with the PRISMA Extension for Scoping Reviews (PRISMA-ScR),

ensuring transparency, rigor, and reproducibility (Page et al., 2021).

Formulating the research questions

The review began with the formulation of research questions designed to systematically map how artificial intelligence is being applied in chemistry education to support students with disabilities. These questions were developed to ensure conceptual clarity while maintaining alignment with inclusive education principles and Universal Design for Learning (UDL) (Priyadharsini & Mary, 2024).

The first set of research questions aimed to identify and describe the types of AI technologies used in chemistry education for students with disabilities, including intelligent tutoring systems, generative AI tools, adaptive learning platforms, virtual laboratories, and assistive technologies. This facilitated a comprehensive understanding of the technological landscape and its educational applications in chemistry contexts.

A second set of questions examined how AI-based interventions support inclusive chemistry teaching practices, particularly in relation to accessibility, personalization, and learner engagement across different types of disabilities, including visual, hearing, cognitive, learning, and physical impairments. This focus was necessary to capture how AI contributes to reducing barriers inherent in chemistry learning, such as abstract representations and laboratory-based instruction.

Finally, the research questions explored the enabling and limiting factors affecting the implementation of AI in inclusive chemistry education. These included teacher preparedness, digital infrastructure, pedagogical integration, ethical concerns, and issues of equity and access. Together, these guiding questions ensured a structured and comprehensive examination of how AI is conceptualized and operationalized within inclusive chemistry education.

Identifying and retrieving relevant literature

A systematic search was conducted across major academic databases including Scopus and Google Scholar. These databases were selected due to their broad coverage of peer-reviewed literature in education, chemistry education, special education, and artificial intelligence research. The search focused on studies published between 2015 and 2025 to capture contemporary developments in AI technologies, inclusive education frameworks, and chemistry pedagogy.

A structured keyword strategy using Boolean operators was applied to ensure both sensitivity and specificity of the search. The search string combined four conceptual domains: artificial intelligence, chemistry education, disability/inclusive education, and educational context. The final Boolean search strategy was formulated as:

("artificial intelligence" OR "machine learning" OR "generative AI" OR "intelligent tutoring system" OR "educational technology") AND ("chemistry education" OR "chemistry teaching") AND ("disability" OR "students with disabilities" OR "special education" OR "inclusive education" OR "accessibility") AND ("school" OR "higher education" OR "university" OR "classroom").

These keywords were selected to ensure comprehensive coverage of studies addressing both technological innovation and inclusive chemistry teaching practices. The use of combined Boolean operators allowed the identification of studies spanning different educational levels, disability categories, and AI applications, while maintaining relevance to chemistry education contexts.

Selection of studies

As shown in the PRISMA-ScR flow diagram, all retrieved records underwent a multi-stage screening process to ensure relevance and methodological rigor. (Figure 1)

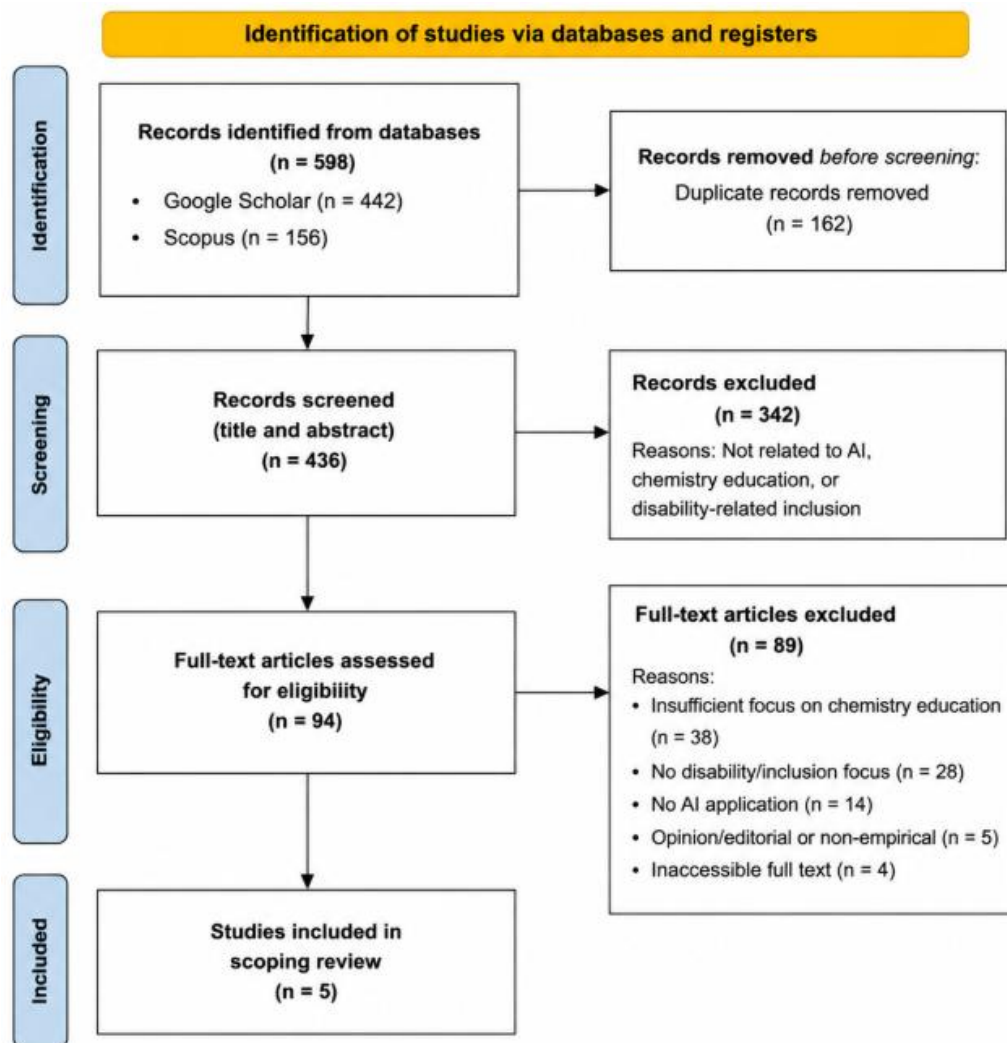


Figure 1. PRISMA flow chart

The initial database search yielded a total of 598 records. After removal of 162 duplicates, 436 records remained for title and abstract screening. At this stage, 342 records were excluded due to lack of relevance to artificial intelligence, chemistry education, or disability-related inclusion. A total of 94 full-text articles were assessed for eligibility, of which 89 were excluded for reasons including insufficient focus on chemistry education, absence of disability-related or inclusive education components, lack of AI-related application, or limited empirical or conceptual contribution. Ultimately, 5 studies were included in the final synthesis.

To ensure methodological rigor and reduce selection bias, the screening process was conducted independently by two reviewers. Any discrepancies in inclusion decisions were resolved through discussion and consensus. This

approach ensured consistency in applying eligibility criteria and enhanced transparency in study selection.

Studies were included if they explicitly examined applications of artificial intelligence in chemistry education with a clear connection to inclusive education or learners with disabilities. Eligible studies comprised empirical research designs (including mixed-methods and research-and-development studies), teacher education interventions, validation studies of AI-enabled or AI-related tools, and experimental or analytical studies of AI systems relevant to chemistry learning. All included studies were published in English within the 2015–2025 timeframe to capture contemporary developments in AI technologies, including adaptive learning systems, multilingual machine learning tools, and generative AI applications.

Studies were excluded if they focused on artificial intelligence in education without a chemistry-specific context, did not address inclusion or disability-related learning needs, were purely opinion-based or editorial in nature, or did not provide sufficient methodological or analytical detail to contribute to the synthesis. Non-peer-reviewed sources and inaccessible full-text records were also excluded to maintain academic rigor and ensure the reliability of the synthesized evidence.

Data charting and organization

A structured data charting process was implemented to extract and organize relevant information from all included studies. For each article, bibliographic details (author, year, country), study design, educational level, and research objectives were recorded. In addition, specific AI technologies (e.g., intelligent tutoring systems, generative AI, virtual laboratories, assistive technologies), chemistry content areas, and disability types addressed were systematically extracted.

The charting framework also captured pedagogical dimensions, including instructional strategies, inclusive teaching approaches, and alignment with Universal Design for Learning principles. Reported outcomes such as learning achievement, accessibility improvements, engagement, and teacher-related outcomes were also documented.

All extracted data were organized into analytical matrices, enabling systematic comparison across studies based on AI type, disability category, educational context, and pedagogical function. This structured organization facilitated identification of recurring patterns, conceptual overlaps, and contextual differences across the literature.

Data synthesis and interpretation

A thematic synthesis approach was used to analyze and integrate the extracted data. This method was appropriate given the heterogeneity of study designs, AI technologies, and educational contexts included in the review. The synthesis process involved iterative coding,

categorization, and refinement of themes based on recurring concepts across the literature.

Initial codes were generated from key findings related to AI applications, accessibility functions, teacher roles, and inclusive chemistry teaching practices. These codes were subsequently grouped into higher-order analytical categories, which were refined through repeated comparison and synthesis across studies. This process resulted in the identification of major thematic dimensions reflecting how AI is used to support students with disabilities in chemistry education.

The thematic synthesis captured both technological and pedagogical aspects of AI integration, including personalization of learning, accessibility enhancement, virtual experimentation, and instructional support. It also highlighted barriers such as limited teacher preparedness, infrastructure constraints, ethical concerns, and uneven implementation across educational contexts. These synthesized findings provided a structured foundation for interpreting the current state of research and identifying gaps for future investigation in inclusive chemistry education supported by artificial intelligence.

Results

Characteristics of included studies

Five studies were included in this scoping review, published between 2022 and 2026. The studies employed diverse designs, including research and development using the ADDIE model, validation studies of multilingual tools, mixed-methods research combining surveys and interviews, participatory action research with pre-post assessment, and experimental evaluation of large language model (LLM) reasoning in chemistry-related tasks. The evidence base reflects early-stage and methodologically heterogeneous research on artificial intelligence applications in chemistry education for learners with disabilities and related inclusion needs.

The study populations varied across educational levels and contexts. Two studies focused on secondary education and inclusive classroom settings, including students with sensory disabilities. One study targeted undergraduate

chemistry students engaged in multilingual learning contexts. One study involved pre-service chemistry teachers, while one study assessed AI systems rather than human participants. Sample

size reporting was inconsistent, with two studies not specifying participant numbers and one study not applicable due to its focus on AI system evaluation.

Table 1: General characteristics of the five selected studies.

Author (Year)	Country	Study Design	Population	Sample Size
Ayudia & Kamaludin (2024)	Indonesia	Research and development using ADDIE	Tenth-grade senior high school students in inclusive schools, including students with disabilities	Not stated in the provided excerpts
Martin & Graulich (2024)	Not stated	Validation study comparing translation tools and multilingual ML approaches	Undergraduate chemistry students not yet fluent in the language of instruction	Not stated in the provided excerpts
Uçar et al. (2025)	Not stated	Evaluation of LLM reasoning using targeted adversarial prompts	AI systems in chemistry education tasks rather than a human learner cohort	Not applicable
Naumann & Markic (2026)	Not stated	Participatory action research with pre-post AI literacy survey	Chemistry student teachers	Not stated in the provided excerpts
Nsabayezu et al. (2022)	Rwanda	Mixed-method study using survey and interviews	15 chemistry teachers and 10 students with hearing or visual disabilities from five inclusive schools	25 participants

Types of AI and digital applications for inclusion in chemistry education

The included studies demonstrate a limited but functionally diverse range of AI and digital applications supporting inclusion in chemistry education.

AI-supported instructional media was represented by animation-based learning resources developed using digital platforms such as Powtoon. These tools were designed to support conceptual understanding of chemical bonding and to enhance learner motivation in inclusive classrooms (Ayudia & Kamaludin, 2024). This form of application reflects early-stage use of AI-adjacent content generation rather than adaptive or autonomous AI systems.

Multilingual machine learning and translation-based tools were used to support chemistry learning and assessment for students learning in

a non-native language. These tools enabled learners to access formative assessment tasks in preferred languages and supported comparative analysis of written scientific reasoning across linguistic contexts (Martin & Graulich, 2024). This application primarily addressed language accessibility as a dimension of inclusion rather than disability-specific adaptation.

Generative AI, specifically large language models, was evaluated in terms of chemistry reasoning performance. Rather than being implemented as instructional tools, these systems were tested for their capacity to respond to chemistry prompts, revealing both functional potential and conceptual limitations in reasoning accuracy (Uçar et al., 2025). The focus of this study was diagnostic rather than pedagogical application.

Teacher education-oriented AI integration was represented through seminar-based interventions

designed to develop AI literacy and inclusive pedagogy competencies among future chemistry teachers. The intervention combined conceptual training with reflective activities aimed at preparing teachers for AI-supported inclusive instruction (Naumann & Markic, 2026). This reflects an indirect application of AI through capacity building rather than classroom deployment.

Computer-assisted instruction was applied in inclusive chemistry classrooms to support students with hearing and visual disabilities through multimedia resources, including video, audio, and simulation-based materials (Nsabayezu et al., 2022). This approach represents a foundational form of digital inclusion, with limited adaptive AI functionality but direct relevance to accessibility enhancement.

Table 2: Types of AI and digital applications used to support inclusion in chemistry education.

Study	AI or Digital Application	Inclusion Target	Reported Purpose	Educational Purpose
Ayudia & Kamaludin (2024)	AI-supported animation video development with Powtoon	Students with disabilities in inclusive classrooms	Improve motivation and support understanding of chemical bonding	
Martin & Graulich (2024)	Translation tools and multilingual ML for formative assessment	Students learning chemistry in an additional language	Enable assessment in preferred languages and broaden access	
Uçar et al. (2025)	Large language models challenged with chemistry prompts	General chemistry learners and teachers using GAI tools	Examine strengths and limits of AI reasoning for educational use	
Naumann & Markic (2026)	Seminar integrating AI literacy with inclusive pedagogy	Future chemistry teachers	Prepare teachers to use AI responsibly for learner diversity	
Nsabayezu et al. (2022)	Computer-aided chemistry instruction	Students with hearing and visual disabilities	Improve access through videos, audio, and simulations	

3.3 Reported outcomes of AI-supported inclusive chemistry education

The outcomes reported across studies were predominantly descriptive, evaluative, or perceptual in nature, with limited inferential measurement of learning impact.

The study on AI-supported animation videos reported high validation scores from material experts (97.57%), media experts (93.75%), reviewers (96.22%), and students (94.6%), indicating strong perceived feasibility and acceptance of the instructional media in inclusive chemistry learning contexts (Ayudia & Kamaludin, 2024). These results primarily reflect perceived quality and motivational value rather than measured learning gains.

The multilingual machine learning study demonstrated functional applicability of translation tools for supporting chemistry reasoning across languages. The findings highlighted the comparative strengths of different translation approaches in enabling analysis of student written responses, although outcomes were framed in terms of methodological feasibility rather than educational effectiveness (Martin & Graulich, 2024).

The evaluation of large language models in chemistry tasks revealed inconsistent performance, particularly in reasoning accuracy and conceptual reliability. The study reported limitations in AI-generated responses and emphasized the need for cautious application of

generative AI in chemistry education due to potential errors and hallucinations (Uçar et al., 2025).

The participatory action research on AI literacy showed improvement in affective dimensions of AI literacy among pre-service chemistry teachers, including increased awareness and positive attitudes toward AI integration. However, behavioral readiness for implementation remained comparatively lower, indicating a gap

between conceptual understanding and practical application (Naumann & Markic, 2026).

The mixed-methods study on computer-assisted instruction reported that students with sensory disabilities experienced improved understanding of chemistry concepts through multimedia learning resources. However, the findings were primarily descriptive and based on perceptions rather than controlled outcome measures (Nsabayezu et al., 2022).

Table 3: Reported outcomes and key findings from the selected studies.

Study	Main Outcomes	Statistics or Key Findings
Ayudia & Kamaludin (2024)	Inclusive animation videos were judged suitable and motivating (Ayudia & Kamaludin, 2024)	Ratings were 97.57% from material experts, 93.75% from media experts, 96.22% from reviewers, and 94.6% from students (Ayudia & Kamaludin, 2024)
Martin & Graulich (2024)	Multilingual approaches supported chemistry reasoning assessment across languages (Martin & Graulich, 2024)	The study compared three translation tools and multilingual models, showing opportunities for simultaneous analysis of written arguments in different languages (Martin & Graulich, 2024)
Uçar et al. (2025)	LLMs showed mixed performance and exposed reasoning weaknesses (Uçar et al., 2025)	The authors reported inherent weaknesses in current AI systems and argued for cautious deployment in chemistry teaching (Uçar et al., 2025)
Naumann & Markic (2026)	Seminar participation improved affective AI literacy and reflective awareness (Naumann & Markic, 2026)	Affective AI literacy improved, but behavioral indicators remained comparatively low (Naumann & Markic, 2026)
Nsabayezu et al. (2022)	Computer use supported chemistry learning for students with sensory disabilities (Nsabayezu et al., 2022)	Teachers and students reported improved understanding through recorded videos, audio, and simulations, but results were descriptive rather than effect-estimate based (Nsabayezu et al., 2022)

Barriers and implementation requirements for inclusive AI in chemistry education

Across the included studies, several recurring barriers and implementation needs were identified, primarily related to teacher capacity, infrastructure, literacy, system reliability, and evidence limitations.

Teacher preparation emerged as a central constraint, with evidence indicating that educators require additional training to effectively integrate computer-based and AI-

supported tools in inclusive chemistry classrooms (Nsabayezu et al., 2022). This limitation directly affected the consistency and quality of implementation in disability-inclusive learning environments.

Infrastructure-related barriers were also reported, particularly limited access to computers, assistive devices, and supporting equipment such as headphones, which restricted the accessibility of digital learning materials for students with sensory disabilities (Nsabayezu et al., 2022).

These constraints highlight persistent inequities in resource availability.

In the context of AI literacy development, pre-service teacher education demonstrated improvements in affective readiness but limited translation into behavioral implementation capacity, indicating that awareness alone is insufficient to ensure classroom adoption (Naumann & Markic, 2026). This gap suggests structural limitations in translating training into practice.

Concerns regarding AI system reliability were identified in relation to generative AI tools, which

showed weaknesses in chemistry reasoning tasks and raised concerns about the validity of AI-generated outputs in educational settings (Uçar et al., 2025). This limitation underscores the need for critical oversight in AI use.

Finally, methodological limitations were noted in intervention-based studies, where positive perceptions of AI-supported instructional tools were reported but without robust measurement of learning outcomes. This indicates a broader need for more rigorous experimental evaluation of AI interventions in inclusive chemistry education (Ayudia & Kamaludin, 2024).

Table 4: Barriers and implementation needs reported across the selected studies.

Barrier or Need	Evidence From Selected Studies	Implication for Inclusive Chemistry Teaching
Limited teacher preparation	Teachers needed more training to use computers effectively in inclusive classrooms (Nsabayezu et al., 2022)	Professional development is necessary for equitable implementation
Inadequate infrastructure	Lack of sufficient computers and headphones constrained access (Nsabayezu et al., 2022)	Hardware access remains a practical barrier for disability inclusion
Low enactment of AI literacy	Behavioral AI literacy remained lower than affective gains in teacher education (Naumann & Markic, 2026)	Confidence alone does not ensure classroom integration
Unreliable AI reasoning	Generative AI produced weaknesses in chemistry reasoning and required critical scrutiny (Uçar et al., 2025)	AI use should be supervised and embedded in critical evaluation tasks
Need for further outcome testing	The animation-video study recommended future testing on classroom learning outcomes (Ayudia & Kamaludin, 2024)	More robust effectiveness studies are still needed

Discussion

The findings of this scoping review indicate that AI integration in chemistry education for students with disabilities remains at an early and uneven stage of development, with evidence dominated by a small number of heterogeneous and methodologically diverse studies. Across the included literature, AI-related applications are primarily represented by animation-based instructional tools, multilingual translation systems, computer-assisted instruction, teacher education interventions, and experimental

evaluations of large language models. However, these applications remain largely supportive and adjunctive, rather than constituting fully adaptive or autonomous AI systems capable of individualized chemistry learning. For instance, AI-supported animation videos for teaching chemical bonding were highly positively evaluated, with validation scores consistently exceeding 90% across experts, reviewers, and students, indicating strong perceived feasibility and motivational value in inclusive classrooms (Ayudia & Kamaludin, 2024). Similarly,

computer-assisted instruction using multimedia resources such as video, audio, and simulations was reported to enhance conceptual understanding among students with hearing and visual disabilities, although the evidence remained primarily descriptive and lacked robust effect estimation (Nsabayezu et al., 2022). These findings align with broader literature suggesting that AI in inclusive STEM education is still largely exploratory and fragmented, with limited progression toward integrated pedagogical systems that transform chemistry learning design (Hussein et al., 2025).

A second key interpretation is that inclusion in chemistry education is predominantly operationalized through accessibility enhancement and universal design principles rather than disability-specific AI design. The included studies demonstrate that AI and related technologies are mainly used to expand access to learning content through multimedia instruction, translation systems, and computer-assisted tools, rather than to redesign chemistry cognition processes for specific disability profiles. For example, multilingual machine learning tools enabled students to complete chemistry assessments in preferred languages and supported comparative analysis of scientific reasoning across linguistic contexts (Martin & Graulich, 2024), while computer-assisted instruction provided multimodal access through audio-visual and simulation-based resources (Nsabayezu et al., 2022). Nevertheless, these approaches primarily address surface-level accessibility barriers rather than deeper cognitive or procedural challenges associated with chemistry learning, such as molecular visualization or laboratory reasoning. This reflects a broader pattern in STEM inclusion literature where Universal Design for Learning (UDL) principles and accessibility features dominate, while disability-specific AI systems remain limited and underdeveloped (Akanke et al., 2025; Allotey & Benedetto, 2025; Ariza & Hernández, 2025). Consequently, inclusion is often achieved at the level of content delivery rather than through pedagogically adaptive

systems tailored to diverse disability-related learning needs.

The review further highlights that the evidence base for AI in inclusive chemistry education is predominantly descriptive and perception-oriented, with limited rigorous evaluation of learning outcomes. Across the included studies, outcomes were mainly reported in terms of validation scores, user satisfaction, perceived usefulness, and attitudinal or affective changes. For instance, AI-supported animation videos achieved high acceptance ratings exceeding 90% across different stakeholder groups, suggesting strong perceived quality but not necessarily measurable learning gains (Ayudia & Kamaludin, 2024). Similarly, studies on multilingual machine learning approaches emphasized methodological feasibility in analyzing student reasoning across languages rather than demonstrating direct educational effectiveness (Martin & Graulich, 2024). In contrast, evaluations of large language models revealed substantial limitations in chemistry reasoning accuracy and conceptual reliability, highlighting risks associated with uncritical adoption of generative AI in instructional contexts (Uçar et al., 2025). Although teacher education interventions demonstrated improvements in affective dimensions of AI literacy, behavioral readiness for implementation remained limited, indicating a gap between awareness and practical application (Naumann & Markic, 2026). Collectively, these findings underscore a persistent mismatch between the optimistic framing of AI potential in inclusive education and the limited availability of robust, outcome-based evidence.

Finally, the synthesis identifies persistent structural, pedagogical, and technological barriers that constrain the effective implementation of AI in inclusive chemistry education. Teacher preparedness emerges as a central constraint, with insufficient training in both AI literacy and inclusive pedagogical strategies limiting the ability to meaningfully integrate digital tools into chemistry instruction (Daher, 2025; Nsabayezu et al., 2022). This gap is further compounded by the low translation of AI literacy gains into classroom

practice, suggesting that cognitive readiness does not automatically lead to behavioral adoption (Naumann & Markic, 2026). Infrastructure limitations, including inadequate access to digital devices and assistive technologies, further restrict equitable implementation, particularly in inclusive chemistry classrooms where multimedia simulations and digital laboratories require stable technological environments (Iskandarova et al., 2024). In addition, concerns regarding the reliability, bias, and reasoning limitations of generative AI systems introduce epistemic and ethical uncertainty, especially in chemistry

contexts where conceptual accuracy is critical for learning (Landa-Blanco, 2026; Voultsiou & Moussiades, 2025).

Conclusion

Overall, these findings suggest that AI integration in inclusive chemistry education is not solely a technological innovation challenge but a complex socio-technical issue requiring coordinated development across teacher education, infrastructure, curriculum design, and ethical governance to ensure meaningful and equitable educational impact.

References

- Abdurazov, P. A., Ussenbay, A., & Aldanazarov, M. S. (2025). Advancing inclusive education: the impact and potential of virtual laboratory simulations for students with disabilities in chemistry. *THE BULLETIN*. <https://doi.org/10.32014/2025.2518-1467.879>
- Adeniyi, I. S., Adeleye, O. O., & Abimbola, C. (2024). Innovative teaching methodologies in the era of artificial intelligence: A review of inclusive educational practices. *World Journal of Advanced Engineering Technology and Sciences*. <https://doi.org/10.30574/wjaets.2024.11.2.0091>
- Ahmed, S., Rahman, M. S., Kaiser, M., & Hosen, A. (2025). Advancing Personalized and Inclusive Education for Students with Disability Through Artificial Intelligence: Perspectives, Challenges, and Opportunities. *Digit.*, 5, 11. <https://doi.org/10.3390/digital5020011>
- Akande, F. O., Koranteng, U., Mensah, D., Mensah, T. K., & Awah, L. C. (2025). Technology-Supported Inclusive Education: A Systematic Review of Digital Accessibility and Universal Design for Learning. *Asian Journal of Current Research*. <https://doi.org/10.56557/ajocr/2025/v10i49950>
- Allotey, G. A., & Benedetto, D. (2025). Beyond Braille: A Systematic Review of Assistive Technologies and Inclusive Pedagogy in STEM Higher Education for Students with Visual Impairments. *African Journal of Educational Studies in Mathematics and Sciences*. <https://doi.org/10.4314/ajesms.v21i1.6>
- Ariza, J. Á., & Hernández, C. H. (2025). A Systematic Literature Review of Research-based Interventions and Strategies for Students with Disabilities in STEM and STEAM Education. *International Journal of Science and Mathematics Education*, 23, 2863–2893. <https://doi.org/10.1007/s10763-025-10544-z>
- Ayudia, I., & Kamaludin, A. (2024). Animation videos to enhance senior high school students' motivation in learning chemistry : A learning media in inclusive schools. *Indonesian Journal of Science and Mathematics Education*. <https://doi.org/10.24042/ijsme.v5i1.21261>
- Barus, E. L. B., Bunawan, W., & Ridho, D. (2025). AI for Inclusive Learning: A Review of Adaptive Technologies for Disabled Students. *Jurnal Penelitian Pendidikan IPA*. <https://doi.org/10.29303/jppipa.v11i12.13144>
- Bulathwela, S., Pérez-Ortiz, M., Holloway, C., Cukurova, M., & Shawe-Taylor, J. (2024). Artificial Intelligence Alone Will Not Democratise Education: On Educational Inequality, Techno-Solutionism and Inclusive Tools. *Sustainability*. <https://doi.org/10.3390/su16020781>
- Chalkiadakis, A., Seremetaki, A., Kanellou, A., Kallishi, M., Morfopoulou, A., Moraitaki, M., & Mastrokourou, S. (2024). Impact of Artificial Intelligence and Virtual Reality on Educational Inclusion: A Systematic Review of Technologies Supporting Students with Disabilities. *Education Sciences*. <https://doi.org/10.3390/educsci14111223>
- Daher, R. (2025). Integrating AI literacy into teacher education: a critical perspective paper. *Discover Artificial Intelligence*, 5. <https://doi.org/10.1007/s44163-025-00475-7>
- Feldman-Maggor, Y., Blonder, R., & Alexandron, G. (2024). Perspectives of Generative AI in Chemistry Education Within the TPACK Framework. *Journal of Science Education and Technology*, 34, 1–12. <https://doi.org/10.1007/s10956-024-10147-3>

- Gonçalves, V., Mendes, E. G., & Castro, S. (2025). Artificial intelligence and other educational digital technologies to promote accessibility for people with disabilities. *Arts & Humanities Open Access Journal*. <https://doi.org/10.15406/ahoaj.2025.07.00261>
- Guo, X. (2026). Construction and Empirical Validation of The "Faculty-Student-Ai-Environment-Culture" Five-Element Synergistic Model In Higher Education: Evidence From The Integration Of Sdg 4 And Artificial Intelligence. *International Journal of Engineering Sciences & Research Technology*, 15(1), 16–32. Available at: <https://doi.org/10.64149/j.ijesrt.15.1.16-32>
- Hussein, E., Hussein, M., & Al-Hendawi, M. (2025). Investigation into the Applications of Artificial Intelligence (AI) in Special Education: A Literature Review. *Social Sciences*. <https://doi.org/10.3390/socsci14050288>
- Iskandarova, S., Yusif-Zada, K., & Mukhtarova, S. (2024, 2024–10–13). Integrating AI Into Higher Education Curriculum in Developing Countries.
- Iyamuremye, A., Niyonzima, F., Mukiza, J., Twagillimana, I., Nyirahabimana, P., Nsengimana, T., De Dieu Habiaremye, J., Habimana, O., & Nsabayeze, E. (2024). Utilization of artificial intelligence and machine learning in chemistry education: a critical review. *Discover Education*, 3. <https://doi.org/10.1007/s44217-024-00197-5>
- Landa-Blanco, M. (2026). Artificial intelligence in education: applications and limitations for teachers in low- and middle-income countries. *Frontiers in Education*. <https://doi.org/10.3389/educ.2025.1681836>
- Levac, D., Colquhoun, H., & O'Brien, K. K. (2010). Scoping studies: advancing the methodology. *Implement Sci*, 5, 69. <https://doi.org/10.1186/1748-5908-5-69>
- Li, J., Yan, Y., & Zeng, X. (2025). Exploring Artificial Intelligence in Inclusive Education: A Systematic Review of Empirical Studies. *Applied Sciences*. <https://doi.org/10.3390/app152312624>
- Martin, P., & Graulich, N. (2024). Beyond Language Barriers: Allowing Multiple Languages in Postsecondary Chemistry Classes Through Multilingual Machine Learning. *Journal of Science Education and Technology*, 33, 333–348. <https://doi.org/10.1007/s10956-023-10087-4>
- Moya, J. G., Alcívar, Y. A. A., Sánchez, A. T., & Gironzini, M. M. A. (2025). Artificial intelligence applications to improve accessibility in education for students with disabilities. *Data and Metadata*. <https://doi.org/10.56294/dm20251081>
- Naumann, L., & Markic, S. (2026). AI and inclusion for future chemistry teachers: a seminar approach. *Chemistry Teacher International*, 0. <https://doi.org/10.1515/cti-2025-0104>
- Nsabayeze, E., Iyamuremye, A., Urengejeho, V., Mukiza, J., Ukobizaba, F., Mbonyirivuze, A., & De Dieu Kwitonda, J. (2022). Computer-based learning to enhance chemistry instruction in the inclusive classroom: Teachers' and students' perceptions. *Education and Information Technologies*, 27, 11267–11284. <https://doi.org/10.1007/s10639-022-11082-9>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S.,... Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Bmj*, 372, n71. <https://doi.org/10.1136/bmj.n71>
- Pagliara, S., Bonavolontà, G., Pia, M., Falchi, S., Zurru, A. L., Fenu, G., & Mura, A. (2024). The Integration of Artificial Intelligence in Inclusive Education: A Scoping Review. *Inf.*, 15, 774. <https://doi.org/10.3390/info15120774>
- Patel V., Suthar C., Patel D., (2026). Artificial Intelligence Investment As A Strategic Signal: Implications for Stakeholder Confidence. *International Journal of Engineering Sciences & Research Technology*, 15(4), 32-46. <https://doi.org/10.64149/j.ijesrt.15.4.32-46>
- Priyadharsini, V., & Mary, S. (2024). Universal Design for Learning (UDL) in Inclusive Education: Accelerating Learning for All. *Shanlax International Journal of Arts, Science and Humanities*, 11, 145–150. <https://doi.org/10.34293/sijash.v11i4.7489>
- Uçar, S., Lopez-Gazpio, I., & Lopez-Gazpio, J. (2025). Evaluating and challenging the reasoning capabilities of generative artificial intelligence for technology-assisted chemistry education. *Education and Information Technologies*, 30, 11463–11482. <https://doi.org/10.1007/s10639-024-13295-6>

- Ugwuanyi, C., Mabel, A. C., Okeagu, R., & Salifu, M. (2025). Leveraging on Artificial Intelligence (AI) to Make Learning More Inclusive for Students with Learning Disabilities in Mathematics Education. *International Journal of Latest Technology in Engineering Management & Applied Science*. <https://doi.org/10.51583/ijltemas.2025.140500114>
- Voultsiou, E., & Moussiades, L. (2025). A systematic review of AI, VR, and LLM applications in special education: Opportunities, challenges, and future directions. *Education and Information Technologies*, 30, 19141–19181. <https://doi.org/10.1007/s10639-025-13550-4>