



Enhancing Chemistry Learning Outcomes through Interactive Learning Media to Support Sustainable Development Goals (SDGs): A Systematic Literature Review

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ABSTRACT

This study systematically reviews the influence of interactive learning media on students' achievement in chemistry. Using a qualitative descriptive approach, ten journal articles published between 2017 and 2024 were analyzed from national and international sources using Google Scholar and the Publish or Perish application. The review found that interactive learning media (such as e-modules, animations, Unity-based multimedia, and virtual classrooms) significantly enhance students' motivation, understanding, and performance in chemistry learning. Most studies demonstrated an improvement in mastery levels, motivation rates above 80%, and n-gain values categorized as high. The findings highlight that the integration of interactive media not only supports cognitive achievement but also fosters engagement and reflective learning processes. To sustain these improvements, teachers must continuously evaluate and adjust their instructional strategies. Therefore, interactive learning media serve as effective tools for optimizing chemistry education outcomes in the digital era.

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1. INTRODUCTION

Education plays a central role in developing individuals' ability to solve problems and adapt to an ever-changing world. The rapid advancement of science and technology has transformed traditional educational practices into more dynamic, technology-based systems that emphasize innovation and active learning (Wardani & Budiadnya, 2023). In recent years, the integration of technology into teaching and learning has become essential, as it enhances the accessibility of information, improves learning efficiency, and fosters students' motivation to engage in the learning process (Kartini & Putra, 2020). In chemistry education, technological innovation has introduced interactive learning media that provide a more engaging and visualized understanding of abstract and microscopic concepts, helping students move beyond rote memorization toward meaningful comprehension (Ihsan & Jannah, 2021).

Interactive learning media refer to computer-assisted instructional tools that promote active, two-way interaction between learners and content (Aqza et al., 2024). The use of such media (ranging from simulations, animations, virtual laboratories, to e-modules) allows students to explore and manipulate visual elements that represent chemical phenomena. These tools bridge the gap between theoretical content and real-world applications by visualizing processes such as chemical equilibrium, redox reactions, and molecular structures. As studies have shown, interactive media can increase learning motivation, conceptual understanding, and cognitive outcomes, making them valuable in supporting student-centered pedagogies (Mayer, 2002). However, despite their proven potential, challenges remain in adapting interactive media to diverse learning contexts, maintaining student engagement across different learning cycles, and ensuring teachers' readiness to integrate technology effectively.

Existing research indicates that interactive learning media contribute to improved academic performance when integrated with reflective and continuous instructional strategies (Harahap & Siregar, 2020; Sari & Anggraini, 2022). Yet, there remains a need to consolidate these findings to understand the extent of their impact and the mechanisms by which they enhance learning outcomes. This study addresses this gap by conducting a systematic literature review of research articles published between 2017 and 2024 on the use of interactive learning media in chemistry education. The novelty of this paper lies in synthesizing evidence from multiple studies to reveal the consistent patterns, strengths, and areas for improvement in interactive media implementation. The findings are expected to inform educators and researchers about effective strategies for optimizing student motivation and achievement in chemistry learning through the integration of digital media.

2. METHODS

This study employed a literature review design aimed at synthesizing findings from previous research related to the use of interactive learning media in chemistry education. The literature review method involves systematically collecting and analyzing existing studies to identify patterns, relationships, and implications. Data were obtained from secondary sources such as books, scientific journals, conference proceedings, and academic documents rather than direct observation.

The primary focus of this review was to evaluate how interactive learning media influence students' academic performance and conceptual understanding in chemistry. Data collection included identifying and examining research that investigated various forms of interactive media (such as virtual laboratories, e-modules, animations, and simulation-based tools) and

their effectiveness in improving learning outcomes. Each study was analyzed in terms of research objectives, media types, evaluation methods, and measured outcomes.

A content analysis approach was used to interpret and synthesize findings across studies. This involved categorizing key themes, comparing results, and determining the overall consistency of evidence supporting the effectiveness of interactive media in chemistry learning. To ensure comprehensive coverage, the literature search was conducted through Google Scholar and the Publish or Perish application during the period 2017–2024, using the keywords “interactive learning media” and “chemistry materials.” A total of ten journal articles that met the inclusion criteria were selected for detailed analysis. All selected articles were published in national academic journals and were available in full-text PDF format.

The findings derived from this method provided a synthesized overview of the effectiveness, advantages, and limitations of using interactive learning media in chemistry education, serving as the basis for drawing conclusions and recommendations.

3. RESULTS AND DISCUSSION

This section presents the synthesized findings from ten reviewed studies focusing on the application of interactive learning media in chemistry education. The analysis highlights patterns of improvement in students’ learning motivation, conceptual understanding, and academic achievement across various chemistry topics such as redox reactions, chemical equilibrium, and ionic bonding. To ensure clarity and comparability, all reviewed studies were analyzed in terms of research design, type of media used, implementation cycles, and measured learning outcomes.

3.1. Overview of Reviewed Studies

Table 1 presents a summary of the ten analyzed studies that examined the influence of interactive learning media on chemistry learning outcomes between 2017 and 2024. Each study employed a different form of interactive media and reported quantitative or qualitative evidence of its effectiveness in enhancing students’ motivation and academic performance.

Table 1. Summary of Reviewed Studies on Interactive Learning Media in Chemistry Education.

Code	Learning Media	Chemistry Topic	Key Findings	Reference
A1	Adobe Flash CS6	Chemical equilibrium	Students using Flash media scored 87.17 vs. 79.67 in control; motivation reached 94.7%.	Harahap & Siregar (2020)
A2	Interactive multimedia	General chemistry	100% of students met competency standards; continuous improvement observed up to Cycle III.	Sari & Anggraini (2022)
A3	Interactive e-module	Redox and oxidation-reduction	n-gain = 0.813 (high); overall performance improved across phases.	Erlangga & Dwiningsih (2024)
A4	Interactive animation	Redox reaction	Motivation increased from 70.6% → 81.7%; learning attitude improved from 64.8% → 80.3%.	Mulyaningsih (2019)
A5	Unity-based multimedia	Ionic bonding	n-gain between 0.8–1.0 (high category); significant improvement across indicators.	Ilyasa & Dwiningsih (2020)

Table 1 (continue). Summary of Reviewed Studies on Interactive Learning Media in Chemistry Education.

Code	Learning Media	Chemistry Topic	Key Findings	Reference
A6	Card sort strategy	Hydrocarbon nomenclature	Achievement increased from 73.3% → 85.7% by Cycle III; better participation noted.	Astuti (2018)
A7	Team Game Tournament (TGT)	Reaction rate	Learning completeness improved from 58% → 90% by Cycle II.	Sugiata (2019)
A8	Drill method with interactive strategy	General chemistry	Scores increased from 59.4 → 85.0; standard deviation reduced from 15.2 → 5.8.	Hadi (2019)
A9	Multimedia-based LKPD	Concept mastery	Mastery increased from 7.7% → 92.3% over two cycles.	Muthoharoh et al. (2017)
A10	Virtual classroom (Google Classroom)	Chemistry general topic	Student mastery improved from 70.9% → 88.9%; class completion criteria achieved.	Bintarawati & Citriadin (2020)

3.2. Trends in Student Learning Outcomes

The review reveals that all ten studies consistently reported positive effects of interactive learning media on students' chemistry learning outcomes. Most studies employed multi-cycle interventions, showing steady increases in scores, motivation levels, and mastery percentages.

In A1, the experimental class using Adobe Flash CS6 achieved higher motivation (94.7%) and an average score of 87.17 compared to 79.67 in the control class, demonstrating the potential of visual-interactive platforms to strengthen cognitive engagement. The design allowed students to manipulate equilibrium concepts visually, which supported better comprehension of chemical balancing processes. Similarly, A3 used an interactive e-module that integrated textual explanations, animations, and self-assessment features, producing a high n-gain score (0.813), signifying a large effect size on learning improvement.

For topics involving abstract concepts, such as redox reactions, the studies A4 and A5 showed that interactive animations and Unity-based multimedia significantly enhanced both conceptual understanding and learning motivation. Students' engagement rose alongside comprehension, as indicated by increases in both attitude and performance metrics. The Unity-based model in A5 achieved n-gain scores between 0.8 and 1.0, which fall into the high category, confirming that visual-spatial interactivity is effective for explaining microscopic phenomena like electron transfer and bonding structures.

3.3. Role of Learning Cycles in Performance Improvement

Several studies, including A2, A6, A7, A8, and A9, utilized iterative learning cycles (Cycle I, II, and III) to progressively refine instructional implementation and improve student outcomes. These cyclical interventions illustrate that interactive learning media are most effective when combined with reflective teaching processes and ongoing feedback loops.

For example, in A2, differentiated learning using interactive multimedia was conducted over three cycles. Each cycle incorporated refinements based on student feedback and observation, leading to full mastery (100% of students achieving competency) by the third cycle. This outcome highlights the importance of continuous adaptation to students' learning styles and prior knowledge levels. Similarly, A6 employed an active card sort strategy over three cycles, improving student completion rates from 73.33% in Cycle II to 85.71% in Cycle

III. The integration of group discussions and teacher questioning promoted more interactive classroom engagement, leading to deeper understanding.

In A7, the Team Game Tournament (TGT) model exemplified how gamified learning strategies, supported by digital interactivity, enhanced motivation and performance. The learning completeness increased from 58% in the first cycle to 90% in the second cycle. This significant improvement indicates that competition-based interactive activities can sustain students' interest and reinforce peer collaboration, especially in reaction rate topics that require repetitive practice.

Moreover, A8 showed that combining interactive strategies with the drill method not only improved average scores (from 59.4 to 85.0) but also reduced the standard deviation from 15.2 to 5.8, indicating more uniform achievement across the class. This finding suggests that interactive drill-based approaches can equalize learning outcomes among diverse student groups. Likewise, A9 demonstrated remarkable gains in concept mastery from 7.69% in the pretest to 92.31% after the second cycle through the use of multimedia-based worksheets (LKPD).

These findings collectively suggest that interactive learning media, when implemented cyclically and reflectively, promote sustained improvement in learning outcomes rather than short-term gains. The cycles enable teachers to diagnose learning barriers, modify content presentation, and improve student participation across sessions.

3.4. Digital Platforms and Virtual Learning Environments

In the context of digital transformation in education, A10 demonstrated the effectiveness of virtual classrooms in enhancing chemistry learning outcomes. Using Google Classroom as the primary platform, the study achieved an improvement in student mastery from 70.94% to 88.88% within two cycles. This success illustrates the role of online interactive tools in maintaining active learning, even in remote settings. Students benefited from flexible access to resources, immediate feedback, and collaborative discussion forums.

The integration of virtual learning aligns with the global trend toward digital pedagogy, emphasizing accessibility, adaptability, and self-regulated learning. These results reaffirm that technology-mediated environments (whether in physical classrooms or virtual spaces) can effectively replicate interactivity that supports student engagement and retention.

However, the effectiveness of virtual learning environments depends heavily on the instructor's ability to design structured, interactive tasks. The reviewed studies suggest that passive exposure to digital content does not guarantee better learning; instead, the key lies in interactive engagement, such as quizzes, simulations, and discussion forums that prompt students to construct knowledge actively.

3.5. Comparative Analysis of Effectiveness

A comparative examination across the ten studies indicates several key patterns. First, the average improvement in learning outcomes was consistently above 15–25 percentage points between the first and final cycles, or between pretest and posttest results. Second, motivation levels generally increased by 10–20%, confirming that interactivity enhances affective engagement. Third, media with visual and participatory elements (e.g., animations, simulations, gamification) yielded higher n-gain values compared to static digital resources.

These findings are supported by cognitive learning theories suggesting that dual coding (the combination of verbal and visual information) facilitates deeper understanding and retention (Mayer, 2002). Students exposed to interactive and visually enriched environments

process abstract chemistry content more effectively by connecting textual explanations with dynamic representations. Moreover, the collaborative and reflective nature of these media reinforces social learning, allowing peer discussion and feedback to complement individual understanding.

3.6. Interpretation of Learning Media Effectiveness

The reviewed studies collectively emphasize that interactive learning media act as a bridge between abstract chemical concepts and students' cognitive comprehension. Chemistry, as a discipline, often involves the visualization of submicroscopic phenomena such as molecular motion, electron transfer, or reaction equilibrium, concepts that are inherently difficult for students to imagine through text or static illustrations alone. Interactive digital media, through animation and simulation, provides dynamic representations that enhance visualization and cognitive mapping of chemical structures.

This finding supports the principles of Cognitive Theory of Multimedia Learning (CTML) proposed by Mayer (2002), which states that students learn better when information is presented through both verbal and visual channels. Interactive media facilitates dual coding, allowing learners to process information through narration and visual cues simultaneously. For instance, in the studies using Adobe Flash (A1) and Unity-based applications (A5), learners could manipulate molecular representations in real time, reinforcing their understanding through experiential learning.

Furthermore, these findings align with Constructivist Learning Theory, which emphasizes that students construct knowledge through active engagement rather than passive reception. Interactive media encourage exploration, experimentation, and immediate feedback features that make learners participants rather than observers. In the studies by Sari & Anggraini (A2) and Astuti (A6), iterative learning cycles allowed students to refine their understanding progressively, embodying the constructivist notion that knowledge develops through reflection and interaction with learning materials.

3.7. Implications

The pedagogical implications drawn from this synthesis highlight three critical roles of interactive media in chemistry education:

- (i) Facilitation of conceptual understanding through visualization and simulation;
- (ii) Promotion of motivation and engagement via interactive and gamified learning experiences; and
- (iii) Support for reflective and differentiated instruction through teacher adaptation and multi-cycle implementation.

Teachers play a pivotal role in mediating the use of interactive tools. The reviewed studies show that when instructors use media merely as a presentation aid, the learning improvement is modest. In contrast, when teachers integrate interactive tools as instructional scaffolds (encouraging dialogue, inquiry, and feedback) students demonstrate substantial gains in performance and motivation. For example, in A7 (Sugiata, 2019), the Team Game Tournament (TGT) learning model combined competition, collaboration, and technology to foster active participation. Students learned not only chemistry concepts but also teamwork, responsibility, and peer evaluation.

Moreover, differentiated instruction through interactive media allows for individual pacing and adaptive learning. A2 (Sari & Anggraini, 2022) demonstrated how students with diverse learning preferences benefited from multimedia resources that could be revisited

asynchronously. These practices align with 21st-century educational frameworks that prioritize flexibility, personalization, and digital literacy.

Interactive learning media provide numerous affordances (multimodality, interactivity, and instant feedback) that traditional instruction cannot offer. However, these advantages also present challenges regarding accessibility, technological literacy, and infrastructure. Studies such as A10 (Bintarawati & Citriadin, 2020) highlight that while virtual classrooms can enhance chemistry learning, their success depends heavily on students' internet access, device availability, and teachers' technical competence.

The diversity of technology platforms, from offline Flash-based modules to online Google Classroom systems, shows that no single solution fits all educational contexts. Therefore, the design and implementation of interactive media must consider local resources, digital readiness, and cultural factors. For developing countries, adopting low-bandwidth, offline-compatible media can ensure inclusivity and equity in access.

Another challenge involves teacher professional development. As technology evolves rapidly, educators must continually update their pedagogical and technical skills. This requirement underscores the importance of institutional support, including training programs, technical assistance, and curriculum integration of digital pedagogy. Without adequate support, even the most sophisticated tools risk being underutilized or misapplied.

The comparison of media types used in the reviewed studies reveals distinct impacts depending on the modality and interaction level.

- (i) Animation-based media (A4) enhanced conceptual visualization and engagement.
- (ii) Game-based media (A7) fostered collaboration, motivation, and affective learning.
- (iii) Simulation-based e-modules (A3, A5) improved problem-solving and conceptual reasoning.
- (iv) Virtual classrooms (A10) expanded accessibility and encouraged self-regulated learning.

These diverse impacts indicate that the most effective learning outcomes arise when interactivity, feedback, and learner control are combined. While static visualizations aid recognition, interactive simulations promote deeper cognitive processing through manipulation and hypothesis testing. The drill-based interactive method (A8) also showed a significant reduction in score variability, implying its strength in standardizing learning outcomes among students of varied ability levels.

Such differentiation is supported by Vygotsky's Zone of Proximal Development (ZPD) theory, which posits that learners benefit most when guided through challenges slightly beyond their independent capability. Interactive media effectively serve as digital scaffolds that guide students within their ZPD through hints, practice, and reinforcement, enabling steady cognitive growth.

An important dimension identified across multiple studies (A2, A6, A7, A9, and A10) is the implementation of multi-cycle learning interventions. Each cycle involved phases of planning, action, observation, and reflection, leading to gradual improvements in learning outcomes. This cyclical model resembles the Action Research framework, which promotes iterative refinement in teaching practices.

For instance, in A2, differentiated multimedia instruction underwent three cycles, with each revision informed by student feedback and observation. The process allowed teachers to identify weaknesses such as unclear instructions or insufficient interactivity and adjust subsequent lessons. Similarly, in A6, the Card Sort model evolved through continuous reflection, achieving the classical mastery threshold of 85% by Cycle III. These studies

collectively demonstrate that reflection and feedback loops are crucial for optimizing the use of interactive media.

Continuous improvement ensures that the integration of technology remains learner-centered, context-sensitive, and responsive to classroom dynamics. In the absence of reflection, interactive tools risk becoming static add-ons rather than transformative pedagogical instruments.

The outcomes of this review strongly align with United Nations Sustainable Development Goal 4 (SDG 4): Quality Education, which advocates for inclusive and equitable access to quality learning opportunities. By enhancing both cognitive achievement and digital competency, interactive learning media contribute to sustainable educational innovation.

The reviewed studies demonstrate that technology-enhanced learning can:

- (i) Promote inclusive access by offering flexible, self-paced learning opportunities through virtual and digital platforms;
- (ii) Improve learning quality by deepening understanding of complex scientific concepts through visualization and interaction; and
- (iii) Develop digital literacy among students and teachers, fostering competencies essential for participation in the modern knowledge economy.

In the broader educational context, integrating interactive media supports lifelong learning and adaptability, core principles of SDG 4. The findings indicate that digital tools, when thoughtfully implemented, not only strengthen students' academic performance but also empower them with 21st-century skills such as problem-solving, collaboration, and information management.

Despite the positive outcomes, several limitations persist. First, most studies reviewed were conducted in controlled classroom environments, which may not fully capture the variability of real-world conditions. Future research should examine long-term retention effects, cross-disciplinary applications, and scalability of interactive media in diverse educational systems.

Second, while most tools enhanced cognitive outcomes, their effects on affective and psychomotor domains remain underexplored. Chemistry learning also involves practical laboratory skills, which interactive simulations can support but not fully replicate. Future studies should integrate virtual labs with real experiments to balance theory and practice.

Third, issues of equity and digital divide must be addressed. The accessibility of devices and stable internet remains a challenge in many regions, limiting the potential reach of technology-based education. Therefore, policymakers and institutions should invest in digital infrastructure and teacher training to ensure that the benefits of interactive learning media are equitably distributed.

Finally, more meta-analytical research is needed to quantify effect sizes across broader datasets, enabling stronger evidence-based recommendations for curriculum developers and policymakers.

Overall, the synthesis of ten studies confirms that interactive learning media significantly improve students' learning outcomes in chemistry by integrating cognitive, affective, and behavioral dimensions of learning. The magnitude of improvement observed (both in scores and motivation) demonstrates that interactivity, visualization, and feedback are essential drivers of effective chemistry education in the digital era.

From a pedagogical standpoint, interactive media serve as both a tool for innovation and a vehicle for reflection. They enhance not only what students learn but also how they learn, shifting classrooms from teacher-centered to learner-centered environments. For teachers,

this transition demands continuous adaptation and technological fluency, underscoring the need for professional development aligned with digital pedagogy.

The implications extend beyond chemistry; they represent a paradigm shift toward evidence-based, technology-driven instruction that fosters curiosity, creativity, and critical thinking. By adopting interactive learning media within reflective teaching frameworks, educators contribute directly to achieving the vision of Quality Education for All.

4. CONCLUSION

This systematic review concludes that interactive learning media significantly enhance students' motivation, engagement, and learning outcomes in chemistry education. The integration of simulations, animations, e-modules, and virtual classrooms promotes deeper conceptual understanding and reflective learning processes. Sustained improvements are achieved when technology use is combined with iterative learning cycles and teacher reflection. Furthermore, interactive media contribute to achieving SDG 4 by supporting inclusive, innovative, and high-quality education. Future efforts should focus on scalability, accessibility, and the continuous professional development of educators in digital pedagogy.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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