Journal of Innovation in Educational and Cultural Research

Volume 6 Issue 2 Year 2025 Pages 450-458
ISSN 2722-9688 | e–ISSN 2722-9696
http://jiecr.org | DOI: 10.46843/jiecr.v6i2.1812

The Role of Chemistry Learning Multimedia in Enhancing Students' Cognitive Abilities and Learning Interest

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Abstract: Chemistry learning faces challenges related to students' cognitive abilities and interest in learning. One approach to address these issues is the use of multimedia in education. This study aims to analyze the role of multimedia in enhancing students' cognitive abilities and interest in learning chemistry through a systematic literature review. The review followed three stages: planning, conducting, and reporting. Data was collected from Scopus, Google Scholar, and ERIC databases, yielding 20 articles for analysis. The findings were categorized into three themes: the role of multimedia in enhancing cognitive abilities, its impact on student interest, and its integration into chemistry education. The results indicate multimedia can significantly enhance students' cognitive skills and interest in chemistry. Furthermore, various teaching approaches, such as problem-based learning, game-based learning, inquiry-based learning, cooperative TPS, and flipped classrooms, can optimize the effectiveness of multimedia in chemistry learning. This study contributes to understanding how multimedia can enhance chemistry education.

Keywords: chemistry learning; cognitive ability; learning interest; multimedia; systematic literature review

Recommended citation: Menno, A. W. M., & Prodjosantoso, A. K. (2025). The Role of Chemistry Learning Multimedia in Enhancing Students' Cognitive Abilities and Learning Interest. *Journal of Innovation in Educational and Cultural Research*, 6(2), 450-458.

INTRODUCTION

Chemistry has a crucial role in everyday life, so it is important to learn it (Byusa et al., 2022; Musengimana et al., 2021). Students' success in learning chemistry is not only related to teaching and material content but also influenced by students' cognitive and affective factors (Zhang et al., 2021). Cognitive factors relate to students' cognitive abilities such as knowledge and understanding (da Silva & de Vasconcelos, 2022; Nedungadi & Shenoy, 2023; Zhang et al., 2021), memory and abstract reasoning (Nedungadi & Shenoy, 2023), or visual-spatial abilities (Pavlin et al., 2019). In addition, the development of science and technology nowadays also requires high-level cognitive abilities such as questioning, problem-solving, decision-making, critical thinking, analytical thinking, and creative thinking to overcome these developments (da Silva & de Vasconcelos, 2022; Dewi et al., 2019; Redhana, 2019). Meanwhile, one of the affective factors that influence chemistry learning is student learning interest, which is related to students' attention or interest, motivation, and enjoyment of learning (Syafruddin et al., 2024). High student learning interest leads to student interest in actively participating in learning on an ongoing basis and exploring concepts more deeply, which affects learning success (Pavlin et al., 2019).

However, research has shown that students face significant challenges in understanding abstract chemical concepts, which are often difficult to visualize, especially at the molecular level (Astiningsih & Partana, 2020; Lipscher, 2023; Tasker, 2016). To deal with this challenge, students need the ability to visualize chemical phenomena at the molecular level, but in reality, some still have low visualization skills (Byusa et al., 2022; Pavlin et al., 2019). Pavlin et al. (2019) found that students struggled with visualizing these concepts, with achievement rates ranging from 40% to 79%. In addition, students also have difficulty learning concepts that require higher-level cognitive abilities (da Silva & de Vasconcelos, 2022; O'Dwyer & Childs, 2017). The challenges related to student interest in learning include low student interest in learning, which is indicated by a lack of enthusiasm for learning (Astiningsih & Partana, 2020; Herianto & Wilujeng, 2021; Lutfi et al., 2023). Challenges related to learning interests lead to teachers' difficulties in creating an attractive learning environment for students (Lutfi et al., 2023). Based on these challenges, some efforts should help students enhance their cognitive ability in learning chemistry concepts and increase their interest in learning.

One of the attempts that have been carried out to overcome challenges related to cognitive abilities and student interest in learning is the use of learning multimedia. Learning multimedia can help teachers present learning content more clearly and can assist students in visualizing chemical phenomena at the abstract molecular level (Tasker, 2016). Recent studies indicate that multimedia learning, specifically through interactive visual tools, can help address these issues by enabling better visualization of complex chemical processes and increasing student engagement (Klisch et al., 2012; Lutfi et al., 2023), fostering positive attitudes (Klisch et al., 2012), increasing student motivation and learning retention (Lutfi et al., 2023), and increasing student interest in studying chemistry (Yektyastuti & Ikhsan, 2016). Based on these things, it is necessary to analyze multimedia's role in increasing students' interest in learning and cognitive abilities further through a systematic review of the literature.

Several systematic literature review studies have been conducted to explore learning multimedia, including the types and applications along with their impact on chemistry learning (Abdulrahaman et al., 2020; Budiarto et al., 2024; Chiu, 2021; Djoa et al., 2021). For example, Abdulrahaman et al. (2020) discussed multimedia in the teaching and learning process. It showed that the effectiveness of multimedia used can be influenced by the technology and components such as text, images, audio, video, animation, and 3D elements, and it has the potential to enhance access to and quality of education. However, this study focused on multimedia in general education and did not specifically address its use in chemistry or its impact on students' cognitive abilities and interest in learning. Similarly, other studies have not sufficiently explored the role of multimedia in improving cognitive skills or fostering student engagement in chemistry learning. This gap highlights the need for a review that explores how multimedia can enhance cognitive abilities and student interest in chemistry education. This article aims to fill that gap by analyzing multimedia's role in enhancing students' cognitive abilities and increasing their interest in learning chemistry. This literature review aims to examine the role of multimedia in enhancing students' cognitive abilities and increasing their interest in learning chemistry. Additionally, it explores how multimedia can be effectively integrated into chemistry education. By analyzing existing studies, the review provides insights into multimedia's potential benefits in improving cognitive skills and student engagement while identifying effective strategies for integration into the chemistry curriculum.

METHODS

The systematic literature review refers to the procedures developed by Xiao and Watson (2019), including the planning, implementation, and reporting stages, which can be seen in detail in Figure 1. Searching and collecting data in this study was carried out by using Scopus, Google Scholar, and ERIC databases, with the keywords "multimedia," "cognitive ability," "learning interest," "chemistry learning," "learning outcomes," and "digital learning tools." A total of ten combinations of these keywords were used to ensure broad and relevant coverage. The initial selection of articles referred to the publication years 2014-2024, resulting in 614 articles. Then, 581 articles were obtained after screening by title and author to avoid duplication of articles. Further, through selection by reading the abstract and reviewing based on the inclusion criteria, 52 articles were produced. The systematic review procedure is presented in Figure 1.

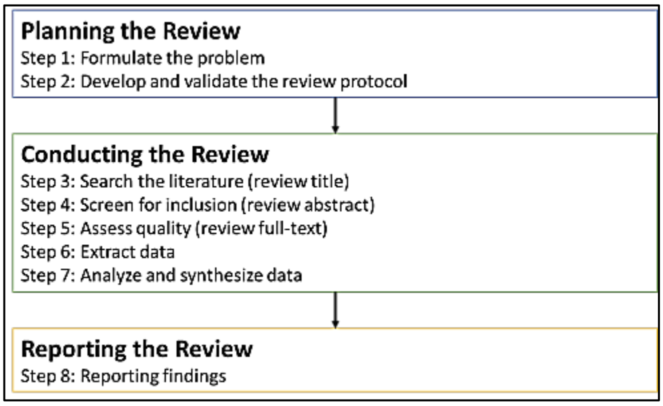

Figure 1. Systematic literature review procedures

The inclusion criteria used are (1) Research articles that focus on multimedia in chemistry learning, (2) multimedia in this context is media that consists of a combination of at least three media elements, namely audio, text, and images, for example, video, animation, virtual reality, digital games, computer-based learning media and so on, (3) examine or focus on the development of cognitive abilities and/or learning interests, (4) discuss the context of the use of multimedia in chemistry learning. An example of an article that meets the inclusion criteria is Farid and Leny (2016), which examines the impact of multimedia virtual laboratories in chemistry learning on student learning outcomes. This study also discussed the use context of the multimedia utilized in the context of problem-based learning. Articles that met the inclusion criteria were then assessed for quality by reviewing the full text of the articles. The data evaluation process is presented in Figure 2.

The 20 good-quality articles were extracted, analyzed, and synthesized to answer the research questions. Data extraction was carried out by reviewing the identity and findings in each article, which included the objectives, methods, variables, cognitive aspects and/or learning interests studied, samples or respondents, types of multimedia used, chemistry topics, integration of multimedia in learning, and conclusions of the findings related to the role of multimedia on cognitive abilities and/or learning interests. Based on the data extraction results, codes were created to obtain each article's similarities, differences, and distinctiveness and answer research questions. Articles were then analyzed and synthesized to report the results.

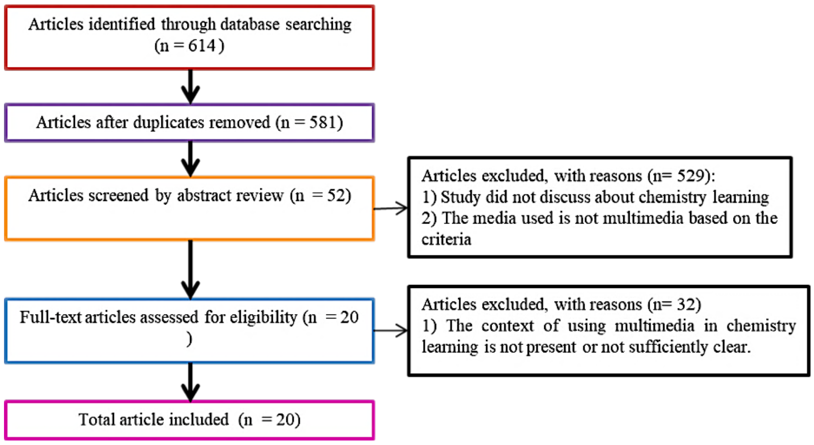

Figure 2. Data Evaluation Process

RESULT AND DISCUSSION

This study discusses the role of chemistry learning multimedia in enhancing cognitive abilities and learning interests, as well as the integration of multimedia in chemistry learning. An overview of the articles used in this study is presented in Table 1. The findings are presented into three major themes: the role of chemistry learning multimedia in enhancing cognitive abilities, the role of chemistry learning multimedia in increasing learning interest, and the integration of multimedia in chemistry learning, which are presented in Table 2, Table 3, and Table 4.

Table 1. Overview of 20 articles

ID	Authors & Year	Methods	Types of multimedia	Chemistry Topics
I	Asih, F.E., Poedjiastoeti, S., Lutfi, A., Novita, D., Ismono, I., & Purnamasari, AP. (2022)	Mixed-methods	e-module	Thermodynamics
II	Astuti, I. D., & Mulyatun (2019)	Quantitative	Multi Level Representation-based multimedia	Colloid
III	Cai, S., Wang, X., & Chiang, F.-K. (2014)	Mixed-methods	Augmented Reality (AR)	Composition of substances
IV	da Silva Júnior, J. N., Sousa Lima, M. A., Miranda, F. N., Melo Leite Junior, A. J., Oliveira Alexandre, F. S., de Oliveira Assis, D. C., & Janô Nobre, D. (2018)	Mixed-methods	Computer-based game	Nomenclature of organic compounds
V	Dwiningsih, K., & Mangengke, B. B. (2021)	Quantitative	Virtual Laboratory (VL)	Elemental chemistry
VI	Farid, M., & Leny. (2016)	Quantitative	VL	Salt hydrolysis
VII	Hoai, V. T. T., Son, P. N., An, D. T. T., & Anh, N. V. (2024)	Mixed-methods	AR	Chemical Bonding
VIII	Kim, H., Chacko, P., Zhao, J., & Montclare, J. K. (2014)	Quantitative	e-module	Molecular Structure (Lewis Dots), Chemical Equations, Nuclear Chemistry
IX	Lau, P. N., Mohammad, S. N. A. B., Low, K. N., & Chua, Y. T. (2024)	Mixed-methods	VL	Buffer
X	Lees, M., Wentzel, M. T., Clark, J. H., & Hurst, G. A. (2020)	Mixed-methods	Mobile game	Green chemistry and biorefining
XI	Liliasari, Supriyanti, S., & Hana, M. N. (2016)	Quantitative	Offline mobile application	Redox reaction

ID	Authors & Year	Methods	Types of multimedia	Chemistry Topics
XII	Newell-Caito, J., & Bernard, E. (2024)	Mixed-methods	Digital module	Fundamentals of Chemistry, Elementary Physiological Chemistry, and Organic Chemistry
XIII	Paye, C. L., Dunnagan, C. L., Tredwell, D. A., & Gallardo-Williams, M. T. (2021)	Mixed-methods	Web application	Lewis structure
XIV	Pulukuri, S., & Abrams, B. (2021)	Mixed-methods	Question-embedded videos	Fundamental organic chemistry
XV	Sari, D. S., & Sugiyarto, K. H. (2015)	Mixed-methods	Mobile application	Redox reactions
XVI	Sausan, I., Saputro, S., & Indriyanti, N. Y. (2020)	Mixed-methods	Digital simulation	Classification of matter and its changes
XVII	Sinaga, M., Situmorang, M., & Hutabarat, W. (2019)	Quantitative	e-module	Stoichiometry
XVIII	Situmorang, M., Sitorus, M., Hutabarat, W., & Situmorang, Z. (2015)	Mixed-methods	e-module	The science of matter, atoms, molecules and ions, chemical reactions, and stoichiometry
XIX	Ter Horst, N., Dietrich, J., & Wilke, T. (2024)	Mixed-methods	e-module	Acids and bases, and household cleaners
XX	Urban, S., Brkljača, R., Cockman, R., & Rook, T. (2017)	Quantitative	Videos	Organic chemistry, physical chemistry, and inorganic chemistry

Cognitive ability is important for students because it helps them understand basic concepts to complex chemical concepts and helps students apply these concepts in the real world (Hoai et al., 2024; Pulukuri & Abrams, 2021). Based on the analysis results, five codes were generated related to the role of chemistry learning multimedia in improving students' cognitive abilities, as shown in Table 2. First, multimedia in chemistry learning plays a role in helping students construct knowledge and understanding of chemical concepts. Articles that discussed the improvement of concept understanding had proven an increase in the average score of students' knowledge and/or concept understanding tests after using chemistry learning multimedia compared to before using the multimedia. For example, previous research showed that using Augmented Reality (AR) multimedia can enhance students' understanding of substance composition, even more effectively helping low-achieving students (Cai et al., 2014).

Table 2. The role of chemistry learning multimedia in enhancing cognitive abilities

Aspects	Codes	Article's ID	f	%
Concept Knowledge and understanding	Multimedia in chemistry learning plays a role in helping students build knowledge and understanding of chemical concepts.	III, X, XII, XIII, XVI-XVIII, XIX	8	42.11
Cognitive learning outcomes	Multimedia in chemistry learning plays a role in enhancing cognitive learning outcomes	II, V, VI, VIII, IX, XIV, XX	7	36.84
Cognitive abilities in general	Multimedia in chemistry learning plays an effective role in enhancing general cognitive abilities	I, VII	2	10.53
Critical thinking skills	Multimedia in chemistry learning plays a role in enhancing students' critical thinking skills	XV	1	5.26
Creative thinking skills	Multimedia plays a role in improving students' creative thinking skills	XI	1	5.26
	Total		19	100

Second, multimedia plays a role in enhancing cognitive learning outcomes. This improvement in learning outcomes is indicated by the increased results based on tests conducted on students after using multimedia. Third, multimedia also plays a role in improving cognitive abilities in general. Hoai et al. (2024) showed the improvement of students' cognitive abilities in three main components: chemical awareness, understanding the real world from a chemical perspective, and applying chemical knowledge and skills. In addition, Asih et al.

(2022) showed an improvement in students' cognitive abilities at the cognitive level of Bloom's taxonomy of analysis (C4), evaluation (C5), and synthesis (C6). This indicates that multimedia helps students understand the material and analyze, evaluate, and synthesize chemical information.

Multimedia also plays a role in enhancing students' critical thinking skills. The elements of critical thinking that can be enhanced through learning with multimedia include focusing on questions, analyzing arguments, asking and answering clarifying challenge questions, considering the credibility of a source, observing and considering the results of observations, making inductions, considering the results of inductions, making and assessing decisions, identifying assumptions, and determining an action (Sari & Sugiyarto, 2015). Lastly, multimedia plays a role in enhancing students' creative thinking skills, especially in enhancing students' fluency, flexibility, and elaboration in creative thinking. Multimedia helps students generate many ideas or solutions in a short time, view problems from various perspectives, provide innovative solutions, and the ability to develop ideas in detail and depth (Liliasari et al., 2016). These codes show five cognitive aspects that can be enhanced through multimedia in chemistry learning. From these five aspects, it can be concluded that in addition to its role in improving knowledge and understanding of concepts, learning outcomes, and cognitive abilities in general, multimedia also plays a role in the development of critical thinking and creative thinking skills that are essential to face the challenges of the modern era.

Based on the analysis results, four codes were generated related to the role of chemistry learning multimedia in enhancing students' interest in learning, as shown in Table 3. Based on these four codes, the role of chemistry learning multimedia in enhancing learning interest can be viewed from four aspects, namely student engagement, motivation, interest, and enjoyment. The enhancement of interest in learning is shown through surveys, questionnaires, and student observations. First, multimedia in chemistry learning plays a role in increasing student involvement or participation. Research by Kim et al. (2014) showed that multimedia in interactive electronic modules can enhance student engagement with higher and consistent active participation in class when studying chemistry topics. This shows that multimedia helps increase and maintain student engagement until a specific time. Second, multimedia plays a role in enhancing students' motivation to learn chemistry.

Table 3. The role of chemistry multimedia in enhancing learning interest

Aspects	Codes	Articles' ID	f	%
Engagement	Multimedia in chemistry learning plays a role in enhancing students' participation or engagement in learning.	VIII-X, XII, XX	5	33.33
Motivation	Multimedia in chemistry learning plays a role in enhancing motivation to learn chemistry.	IV, XV, XVIII, XX	4	26.67
Interest	Multimedia in chemistry learning plays a role in enhancing interest in learning chemistry.	VIII, XVI, XIX	3	20
Enjoyment	Multimedia in chemistry learning plays a role in enhancing students' enjoyment of learning chemistry.	IV, X, XII	3	20
	Total		15	100

Research has shown that students feel more motivated to learn chemistry because learning materials presented through multimedia are more interactive and engaging, such as the use of digital game multimedia (Da Silva Júnior et al., 2018), electronic modules (Situmorang et al., 2015), mobile applications (Sari & Sugiyarto, 2015), and videos (Urban et al., 2017). Da Silva Júnior et al. (2018) used computer-based games on the nomenclature of organic compounds that made chemistry learning more engaging, dynamic, and motivated students. This finding aligns with Lutfi et al. (2023), who found that multimedia can enhance students' learning motivation. Third, chemistry learning multimedia plays a role in increasing interest in learning chemistry. Multimedia, such as electronic modules (Kim et al., 2014; Ter Horst et al., 2024) and simulations (Sausan et al., 2020), make students more interested and focused on learning because the presentation of material is more interesting and easy to understand compared to traditional learning without using multimedia (Kim et al., 2014; Sausan et al., 2020; Ter Horst et al., 2024). Lastly, multimedia also plays a role in enhancing students' enjoyment of learning. For example, research by Lees et al. (2020) used mobile games to teach the principles of green chemistry and biorefinery, which can make learning more fun. In addition, Newell-Caito and Bernard (2024) applied electronic modules by incorporating elements of humor so that the multimedia used made students feel enjoyable learning.

A total of 14 codes related to multimedia integration in chemistry learning were generated, as shown in Table 4. Multimedia integration with tasks and assessments is the most common integration. In this integration, students complete tasks and quizzes integrated with multimedia to review their understanding after learning chemistry topics. For example, Sinaga et al. (2019) explain that students worked on projects with multimedia to solve problems and present the results. The following integration is the integration of multimedia with experimental activities. Multimedia integration in experimental activities is carried out to introduce experimental concepts and procedures (Asih et al., 2022; Lau et al., 2024), show the experimental process (Situmorang et al., 2015), and provide virtual experiments (Ter Horst et al., 2024). Ter Horst et al. (2024) used "Digital ChemLab," a virtual laboratory that allows students to gain practical experience despite not being in a physical laboratory, which is particularly beneficial in situations where access to a laboratory is limited or not possible.

It is possible to integrate multimedia with other media to optimize its role. One example of multimedia integration with other media is the combination of podcasts, molymod-like, and digital simulations by Sausan et al. (2020). Integration with other media can provide a more comprehensive and in-depth learning experience (Asih et al., 2022) and meet the needs of students with different learning styles (Sausan et al., 2020). Apart from being used in classroom learning, interactive multimedia can be used in learning activities outside the classroom or independent learning. Multimedia can be utilized as a learning tool that can be accessed anytime and anywhere by students so that they can enjoy a more flexible, interactive, and meaningful learning experience (Asih et al., 2022; Sinaga et al., 2019; Urban et al., 2017). This indicates that multimedia can transcend the boundaries of time and place and make learning more manageable according to each student's needs and learning pace (Lau et al., 2024).

Table 4. Multimedia integration in chemistry learning

Codes	Articles' ID	f	%
Game-based learning	IV, X	2	5.56
Inquiry learning	III	1	2.78
Problem-based learning	VI, XV	2	5.56
Think Pair Share - Cooperative learning	V	1	2.78
5E learning	IX	1	2.78
Flipped classroom	VII	1	2.78
Contextualized learning	XVII, XX	2	5.56
Asynchronous learning	I, IX, XIV, XIX	4	11.11
Bilingual learning	XVIII	1	2.78
Experiment activities	I, IX, XVII, XVIII, XIX	5	13.89
Real-time feedback	XIII, XX	2	5.56
Task and assessment	IX, XIII, XIV, XVII, XIX, XX	6	16.67
Multiple representation-based learning	I, II, XI	3	8.3
Integration with other media	I, VIII, XII, XVI, XVII	5	13.89
Total		36	100

Multimedia integration with multi-level chemical representations consisting of macroscopic, symbolic, and submicroscopic can also be done. This integration helps students connect abstract chemical concepts with more tangible and concrete visualizations so that students can build a deep and comprehensive understanding (Liliasari et al., 2016; Newell-Caito & Bernard, 2024; Pulukuri & Abrams, 2021; Ter Horst et al., 2024; Urban et al., 2017). In addition to the above integrations, multimedia can be integrated with various learning models or approaches such as problem-based, game-based, inquiry, cooperative think pair share, 5E, flipped classroom, and contextualized learning. In learning using problem-based multimedia, the syntax applied includes orientation to the problem, organizing students in learning, guiding group investigations, developing and presenting work, and analyzing and evaluating the problem-solving process. Through the use of multimedia in problem-based learning, students become more interested in actively participating in the learning process, which in turn increases their motivation, deepens their understanding of the material, and develops their thinking skills, and students feel assisted in solving problems by utilizing interactive multimedia (Farid & Leny, 2016; Sari & Sugiyarto, 2015).

Multimedia integration in game-based learning can be done by using digital multimedia games such as the mobile game "Green Tycoon" for green chemistry topics applied with role-playing games (Lees et al., 2020), and the Nomenclature Bets that helps students learn the nomenclature of organic compounds through tournament-based games (Da Silva Júnior et al., 2018). In inquiry learning, multimedia is supported with activity forms that are used in independent exploration without instruction from the teacher, so it can help students develop their understanding of the concepts learned more in-depth and interactively (Cai et al., 2014). The integration of multimedia with the Cooperative TPS learning model is applied through the stages of Think, Pair, and Share, where students are enabled to develop their initial understanding and ideas before discussing with others, allowing for the exchange of ideas, clarification of concepts, and collaboration in solving problems or answering questions, as well as helping to gather various perspectives and a more comprehensive understanding of the topic being studied (Dwiningsih & Mangengke, 2021). In 5E learning with multimedia, the stages are engage, explore, explain, elaborate, and evaluate (Lau et al., 2024). Flipped classroom learning using multimedia can be done through three phases: the first phase with online learning, the second phase with face-to-face learning, and the third phase with online learning (Hoai et al., 2024). Multimedia integration in contextualized learning is done by providing chemical multimedia content relevant to the real world of students' lives (Urban et al., 2017). In addition, multimedia can also be integrated into bilingual learning, as done by Situmorang et al. (2015). Lastly, the inclusion of immediate feedback in chemistry learning using multimedia is provided as students learn either in the form of corrections or further explanations. For example, Urban et al. (2017) combined interactive videos with real-time feedback to increase learning motivation by providing engaging content and immediate feedback to students, which helps them understand chemistry concepts better and feel more involved in the learning process. Overall, multimedia integration in chemistry learning has proven to play a positive role in improving students' cognitive ability and interest in learning.

The application of multimedia allows for more interactive, flexible, and meaningful learning. Multimedia helps students connect abstract concepts with the real world, deepen understanding, and develop skills. This shows that multimedia is an important tool in enhancing the quality of chemistry learning. In this context, the findings of this study contribute to the scientific understanding of how multimedia can influence students' cognitive abilities and learning interests in chemistry. This research provides valuable insights that can inform future educational practices and curriculum development by identifying effective multimedia tools and strategies. Furthermore, the research highlights the need for educational institutions to invest in infrastructure and teacher training to maximize the impact of multimedia in chemistry learning. The study also calls for ongoing evaluation and collaboration between researchers, educators, and technology developers to innovate and improve multimedia resources continuously. Ultimately, this research contributes to the advancement of chemistry education, offering new perspectives on how multimedia can create a more engaging and effective learning environment for students.

CONCLUSION

Based on this systematic literature review, multimedia in chemistry learning significantly improves cognitive abilities in knowledge and understanding of concepts, cognitive learning outcomes, general cognitive abilities, critical thinking skills, and creative thinking skills. Multimedia also increases student interest in learning on the aspects of engagement, motivation, interest, and pleasure. Various learning models or approaches, such as problem-based learning, game-based learning, inquiry learning, cooperative TPS, and flipped classrooms, as well as other integration ways, can be applied to optimize the role of multimedia in enhancing cognitive abilities and student interest in learning. Applying these findings can lead to more effective and engaging chemistry learning environments, improving the quality of education and student outcomes. Furthermore, integrating multimedia can help bridge the gap between abstract concepts and real-world applications, fostering a deeper understanding of chemistry. Further studies on the role of chemistry learning multimedia on students can be carried out, such as the role of chemistry learning multimedia on attitudes and other skills, to provide greater insight into the role of multimedia in chemistry learning.

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