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Interactive Multimedia and Contextual Teaching in Chemical Bonding: A Systematic Review of Motivation and Conceptual Understanding

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Abstract

Chemical bonding is one of the chemistry topics that is abstract in nature and often causes learning difficulties and misconceptions among students. Interactive multimedia combined with the Contextual Teaching and Learning (CTL) approach has the potential to help students understand concepts while increasing their learning motivation. This study aims to examine the role of CTL-based interactive multimedia in improving students' learning motivation and conceptual understanding of chemical bonding, as well as its implications for the development of chemistry e-magazines. This study employed a Systematic Literature Review (SLR) method following the PRISMA guidelines. Articles were retrieved from the Scopus, ScienceDirect, ERIC, and Google Scholar databases published between 2016 and 2025. Of the 304 records identified, 273 remained after removing 31 duplicates. Following screening, 62 reports were sought for retrieval, of which 12 could not be retrieved. Subsequently, 50 reports were assessed for eligibility, resulting in 17 included articles comprising 13 primary studies and 4 systematic reviews. The findings indicate that CTL-based interactive multimedia can enhance learning motivation through the presentation of engaging, interactive, and contextual learning materials. In addition, interactive multimedia helps students understand abstract chemical bonding concepts through clearer visualizations, thereby improving conceptual understanding and reducing misconceptions. The findings also suggest that e-magazines have the potential to become effective learning media because they can integrate interactive multimedia elements and contextual approaches within a flexible and easily accessible platform.

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Keywords: interactive multimedia, contextual teaching and learning, chemical bonding, learning outcomes, e-magazine.

1. Introduction

The development of information and communication technology has brought significant changes to the field of education. The integration of technology into the learning process is no longer an option but a necessity for creating more effective, interactive, and student-centered learning environments. However, the implementation of technology in education still faces several challenges. Many teachers have limited ability to integrate technology into teaching and learning activities due to inadequate competencies and insufficient training that supports the optimal use of technology in the classroom (Selvaganapathy, 2019). Meanwhile, today's students are accustomed to interacting with various forms of digital content in their daily lives; therefore, learning practices need to be adapted to the characteristics of this digital generation (Plass et al., 2020).

One form of technological implementation that has been increasingly developed in the field of education is the use of learning multimedia. Interactive multimedia enables information to be presented both verbally and visually, thereby simultaneously supporting students in constructing a deeper understanding of learning materials (Alemdag & Cagiltay, 2018). Based on cognitive theory of multimedia learning, meaningful learning occurs when students actively select, organize, and integrate information into their existing knowledge structures. Therefore, well-designed multimedia can help reduce cognitive load while facilitating a more effective learning process (Javora, 2020). In addition to serving as an information delivery medium, multimedia can also enhance visual appeal, foster learning motivation, and increase student engagement in the learning process through the use of animations, simulations, and various other interactive features (Javora, 2020).

In the context of chemistry learning, the use of multimedia is increasingly important due to the characteristics of chemistry, which involves many abstract concepts and microscopic representations. Chemistry is one of the scientific disciplines that plays an important role in everyday life; therefore, understanding chemical concepts is a fundamental necessity for students (Byusa et al., 2022). The success of chemistry learning is not only determined by cognitive mastery but is also influenced by affective aspects such as interest and learning motivation (Zhang et al., 2021; Syafruddin et al., 2024). Students with high levels of learning interest generally demonstrate greater activeness in participating in learning processes, exploring concepts in depth, and achieving better learning outcomes (Pavlin et al., 2019).

Despite its importance, many studies have reported that students continue to experience difficulties in understanding abstract chemistry concepts, particularly those involving particle-level and molecular representations (Byusa et al., 2022; Menno, 2025). These difficulties are associated with students' limited visualization skills in representing chemical phenomena that cannot be directly

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observed. Pavlin et al. (2019) reported that students' visualization abilities regarding chemical concepts vary considerably and are often not fully developed. Furthermore, low learning interest remains a challenge for teachers in creating engaging and meaningful learning experiences (Lutfi et al., 2023).

One chemistry topic that frequently causes learning difficulties is chemical bonding. This topic includes concepts such as ionic bonding, covalent bonding, metallic bonding, and intermolecular forces, which explain how atoms interact and form compounds (Azura & Copriady, 2017). These concepts are abstract because they involve processes occurring at the particulate level that cannot be directly observed by students (Widarti et al., 2018). At the same time, chemical bonding serves as a fundamental concept that underpins the understanding of many advanced chemistry topics. Consequently, inadequate understanding of chemical bonding concepts may lead to misconceptions that hinder learning in subsequent chemistry topics (Openhotman et al., 2017; Muderawan et al., 2019).

Interactive multimedia offers a potential solution to these challenges. By integrating text, images, animations, videos, simulations, and interactive assessments, multimedia can help students visualize abstract concepts while increasing their engagement in the learning process (Abdulrahaman et al., 2020; Tasker, 2016). The effective use of multimedia can also transform teacher-centered instruction into student-centered learning, thereby promoting active participation, increasing learning motivation, and strengthening conceptual understanding (Coleman et al., 2016). Therefore, the development of interactive multimedia represents a promising alternative for teaching chemical bonding.

To make learning more meaningful, interactive multimedia needs to be combined with a learning approach that can connect scientific concepts with students' real-life experiences in their daily lives. One appropriate approach is Contextual Teaching and Learning (CTL). The CTL approach focuses on the relationship between learning materials and everyday life situations, enabling students to develop a deeper conceptual understanding that can also be applied in real-world contexts. Through this approach, abstract concepts in chemical bonding can be linked to phenomena that are close to students' experiences, making the learning process more meaningful and easier to understand.

One form of interactive multimedia that has the potential to support the CTL approach is the e-magazine. An e-magazine is a digital learning medium that can integrate various multimedia elements, such as text, illustrations, animations, videos, hyperlinks, and interactive activities, into a single learning platform. These characteristics enable chemical bonding materials to be presented in a more engaging, contextual, and learner-centered manner. Furthermore, e-magazines provide flexible learning experiences because they can be accessed anytime and anywhere through digital devices.

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Although numerous studies have investigated interactive multimedia and contextual learning separately, research specifically examining the integration of both approaches in chemical bonding instruction remains limited. In addition, only a few studies have explored the application of these findings to modern learning media such as e-magazines (Linda et al., 2021). Therefore, this Systematic Literature Review (SLR) was conducted to synthesize and integrate previous research findings on CTL-based interactive multimedia in chemical bonding learning. This study aims to examine how this combination can improve students' learning motivation and conceptual understanding, as well as its implications for the development of chemistry e-magazines.

2. Methods

This study employed a descriptive qualitative approach using a Systematic Literature Review (SLR) design structured based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol. SLR is a literature review method that follows specific procedures and standards (Xiao & Watson, 2019), aimed at identifying and evaluating findings from relevant studies (Suparwati, 2022). The implementation of SLR consists of five stages, namely developing the research question, developing the search strategy, applying selection criteria to determine appropriate articles, conducting data evaluation and analysis, and interpreting the findings (Thovawira et al., 2021).

Based on the objectives of this study, three research questions (RQs) were formulated to guide the systematic literature review:

RQ1: What are the characteristics of the reviewed studies in terms of country, educational level, research design, and learning media?

RQ2: How do interactive multimedia and contextual learning approaches support students' learning motivation and conceptual understanding in chemistry education?

RQ3: What are the implications of interactive multimedia and contextual learning approaches for the development of chemistry e-magazines?

2.1. Data Sources

A comprehensive literature search was conducted using four academic databases: Scopus, ScienceDirect, ERIC, and Google Scholar. The search strategy was designed to identify studies relevant to the research topic using the following keywords:

("interactive multimedia" OR "multimedia learning") AND ("contextual teaching and learning" OR "context-based learning") AND ("chemical bonding" OR "chemistry education") AND ("learning motivation" OR "conceptual understanding" OR "learning outcomes") AND ("e-magazine chemistry")

2.2. Inclusion and Exclusion Criteria

To ensure the relevance and eligibility of the reviewed studies, the following inclusion and exclusion criteria were applied.

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Inclusion Criteria:

- Articles published between 2016 and 2025.
- Full-text research articles published in peer-reviewed scientific journals or conference proceedings.
- Studies focusing on the use of interactive multimedia or contextual-based approaches in chemistry learning.
- Studies reporting data related to conceptual understanding, learning motivation, learning interest, or learning outcomes.

Exclusion Criteria:

- Articles not written in English or Indonesian.
- Conference abstracts, short papers, book reviews, and other non-research publications.

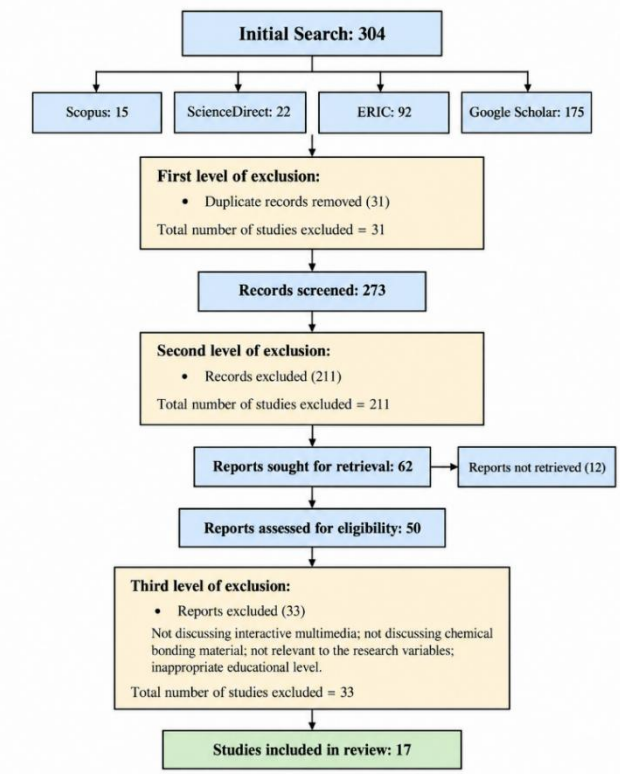
2.3. Procedure

The document selection process followed the PRISMA framework and consisted of four stages:

1. Identification Stage
   A total of 304 articles were identified through database searches, including Scopus (15 articles), ScienceDirect (22 articles), ERIC (92 articles), and Google Scholar (175 articles).
2. Duplicate Removal Stage
   Thirty-one duplicate articles were removed, resulting in 273 remaining articles.
3. Screening Stage
   Screening based on titles and abstracts excluded 211 articles that were not specifically related to interactive multimedia, chemical bonding, or contextual-based learning. As a result, 62 articles remained for further review.
4. Eligibility Stage
   Of the 62 articles sought for full-text retrieval, 12 articles could not be retrieved, leaving 50 articles for eligibility assessment. After full-text assessment, 33 articles were excluded because they did not meet the inclusion criteria, including studies that did not focus on interactive multimedia, chemical bonding, relevant research variables, or the specified educational levels. Consequently, 17 articles met the eligibility criteria and were included in the final review.
   The 17 selected articles were analyzed descriptively by examining their publication characteristics, research designs, educational levels, types of learning media, and main findings. The findings were then organized and synthesized thematically to identify patterns related to students' learning motivation, conceptual understanding, and the implications for the development of chemistry e-magazines.

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Figure 1. PRISMA Flow Diagram of Systematic Literature Review



3. Result and Discussion

3.1. Reviewed Articles

Based on the literature search and analysis, a total of 17 scientific articles published between 2016 and 2025 met the inclusion criteria and were selected for review. The findings indicate that research on the use of interactive multimedia in chemistry education has continued to grow over recent years. This trend is driven by the increasing demand for digital learning environments, particularly following the COVID-19 pandemic and the growing emphasis on technology-enhanced learning in education.

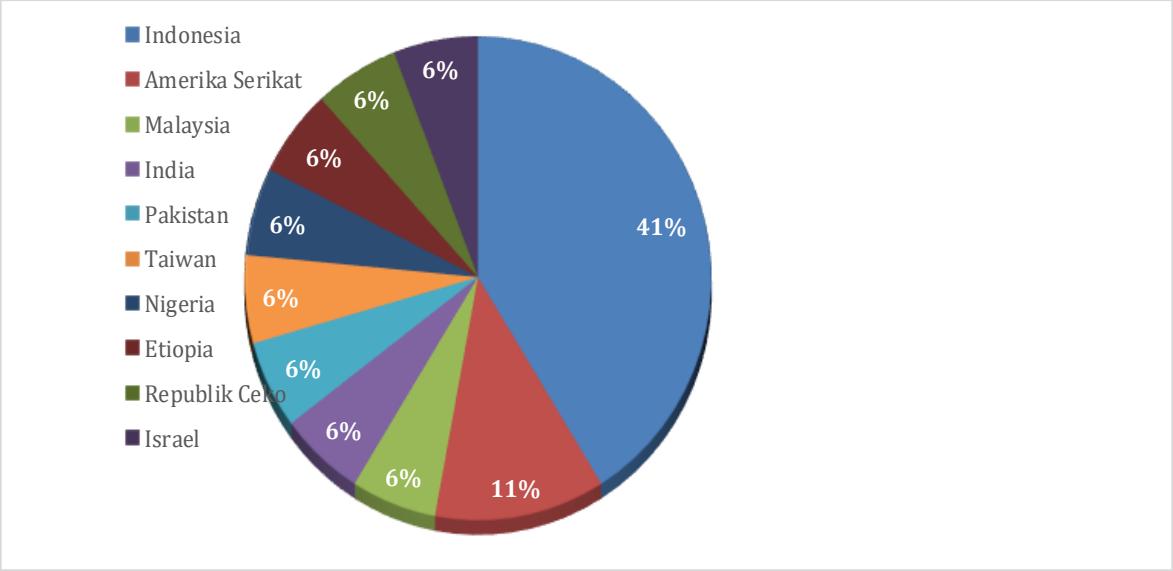
Based on the mapping of the 17 selected articles, studies related to the development of learning media, educational technology, contextual approaches, and visualization in science and chemistry education have been conducted across various countries. Indonesia contributed the highest number of publications, accounting for seven articles (Ambarukma & Sulistina, 2025; Iwan et al., 2025; Linda et al., 2018; Menno & Prodjosantoso, 2025; Sary & Jahro, 2022; Suyanti & Sormin, 2016; Yovanie, 2024). Similar studies were also identified in several Asian countries, including Taiwan

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(Yang & Wang, 2023), Malaysia (Kuit & Osman, 2021), India (Selvaganapathy & Benjamin, 2019), and Pakistan (Rahman et al., 2024).

Outside Asia, two studies were conducted in the United States (Casselman et al., 2021; Zhang & Fiorella, 2019). In addition, one study each was identified from Nigeria (Abdulrahaman et al., 2020), Ethiopia (Demelash et al., 2023), the Czech Republic (Javora et al., 2020), and Israel (Dori et al., 2018). This broad geographical distribution suggests that the development of multimedia-based and contextual learning approaches for science and chemistry education has attracted considerable attention worldwide. The country distribution of the reviewed studies is presented in Figure 2.

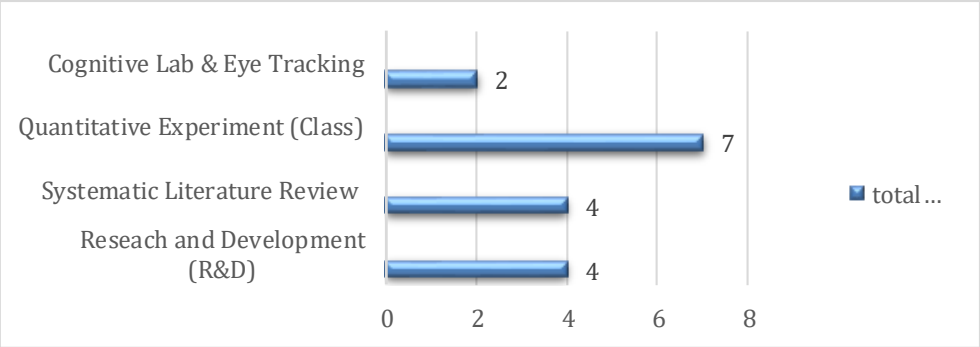
Figure 2. Distribution of selected studies by country of origin



The dominance of publications from Indonesia indicates the high level of attention given by researchers to the use of technology-based learning media to support chemistry learning. This condition indicates a strong need for learning media that can help students understand abstract chemistry concepts.

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Figure 3. Distribution of Reseach Methods in 17 Analysed Articles



In terms of research methods, the most frequently used method was quantitative experiments (in-class), followed by Research and Development (R&D) using development models such as ADDIE, Plomp, and 4-D, as well as Systematic Literature Review (SLR). Systematic review articles were included in this study because they can provide summaries and syntheses of findings from previous studies, thereby helping to strengthen the analysis and provide a more comprehensive overview of research developments on the topic under investigation. The research subjects generally consisted of Grade X and XI senior high school students and pre-service teacher students. The learning media developed were also diverse, including interactive e-modules, Lectora Inspire-based multimedia, Android applications, and technologies based on Augmented Reality (AR) and the Metaverse. These various learning media were combined with the Contextual Teaching and Learning (CTL) approach to help students understand the abstract nature of chemical bonding concepts. The analyzed articles are presented below:

Tabel 1. Article Analysis

No.	Author, Year	Educational Level & Reseach Method	Media type & CTL	Main Focus & Findings for E-Magazine Implications
1	Roza Linda, et al. (2018)	Grade XI Senior High School / Research and Development (R&D – Plomp Model)	Interactive Chemistry Magazine E-Module (Electronic Chemistry Magazine).	The magazine-based media was proven to be highly valid (91–94%) and practical for independent chemistry learning.
2	Iwan, Eny E., & Masriani (2025)	Grade XI Senior High School / Research &	Computer/Android-based Interactive Multimedia on Chemical Bonding	The media validity reached 94.17%. Macroscopic and sub-microscopic visualizations

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No.	Author, Year	Educational Level & Reseach Method	Media type & CTL	Main Focus & Findings for E-Magazine Implications
		Development (R&D - ADDIE).		helped students understand covalent bonding concepts.
3	Putri Y. Sary & Iis S. Jahro (2022)	Grade X Senior High School / Research & Development (R&D - 4D)	Lectora Inspire-based Interactive Multimedia on Chemical Bonding.	The media feasibility was above 90%. The interactive Lectora design was effective in reducing students' boredom while learning Lewis structures.
4	Wahyuni A. & Oktavia S. (2025)	Senior High School / Research & Development (R&D).	Chemistry E-Magazine integrated with Ethnoscience and Green Chemistry.	The integration of local cultural contexts (ethnoscience) in the electronic magazine was proven to increase students' learning interest.
5	Retno D. S. & Efrida S. (2016)	Grade X Senior High School / Quasi-Experimental.	Inquiry-Based Interactive Multimedia (CTL Syntax: Investigating).	The experimental class using multimedia showed a significant improvement in learning outcomes (Gain = 0.69) compared to the conventional class.
6	Vui K. Kuit & Kamisah O. (2021)	Senior High School / Quasi-Experimental.	CHEMBOND3D e-Module integrated with web-based visualization (Molview).	The integration of 3D visualization in the e-module improved spatial-visual ability and reduced misconceptions in chemical bonding.
7	Hameedur R., dkk. (2024)	Secondary Education / R&D and Experimental.	Metaverse- and GBL-Based Virtual Chemistry Classroom (VC3B).	Immersive game-based learning involving molecular reconstruction significantly increased motivation for distance.
8	R. Selvaganapathy & A. Edward (2019)	Grade XI Senior High School / Experimental.	E-Content / Multimedia Courseware.	udent-controlled learning (user-controlled multimedia) improved students' understanding of abstract chemistry materials on an individual basis.

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No.	Author, Year	Educational Level & Reseach Method	Media type & CTL	Main Focus & Findings for E-Magazine Implications
9	Yehudit J. Dori, dkk. (2018)	Senior High School / Conceptual Experiment.	Context-Based Learning accompanied by metacognitive guidance in scientific texts.	Connecting chemistry texts with real-life contexts improved critical thinking skills and textual understanding.
10	Fang-Ying Y. & Hui-Yun W. (2023)	Grade X Senior High School / Experimental (Eye-Tracking).	Augmented Reality (AR)-Based 3D Visualization.	Visual attention analysis showed that 3D AR visualization greatly helped students with low academic achievement (low achievers).
11	Ondřej Javora, dkk. (2020)	Basic and Secondary Education / Experiment	Contextual Animation in Educational Games.	Contextual background animations enhance students' affective-motivational aspects without increasing cognitive load.
12	Matthew D. C., dkk. (2021)	Undergraduate (Chemistry Students) / Experiment	Embodied Learning Tools (Virtual Models vs Plastic Physical Models).	Virtual computer-based models are as effective as physical models in transferring understanding of spatial concepts (stereochemistry).
13	Qian Zhang & Logan F. (2019)	Undergraduate / Experiment	Visual Learning Tools (Provided Images vs Student-Generated Images).	The combination of observing visualizations and asking students to reconstruct them produces the highest learning transfer scores.
14	Abdulrahaman et al. (2020)	Universal /Systematic Literature Review	Multimedia tools (e-books, simulations, videos) integrated with self-paced learning accessibility within students' daily learning ecosystem.	This study reviews the role of multimedia in overcoming limited access to quality education in developing countries. It was found that multimedia effectively simplifies abstract material and reduces cognitive load.

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No.	Author, Year	Educational Level & Reseach Method	Media type & CTL	Main Focus & Findings for E-Magazine Implications
15	Demelash et al. (2023)	Universal/ Systematic Literature Review	Digital/printed teaching materials (story-based modules, popular articles) that purely apply a Context-Based Approach (connecting chemistry with social, industrial, environmental issues, and real-life contexts).	This study evaluates the impact of context-based approaches on chemistry learning outcomes. The findings consistently show that this approach improves conceptual understanding and makes science more meaningful.
16	Menno & Prodjosantoso (2025)	Senior High School/MA and Higher Education / Systematic Literature Review	Interactive multimedia (Android applications, contextual videos, molecular animations) integrated with active contextual learning models (Inquiry and Problem-Based Learning).	This study analyzes the role of multimedia in improving cognitive abilities and motivation in learning chemistry. Multimedia has been shown to simultaneously enhance academic performance and interest through visualization.
17	Yovanie(2024)	Senior High School / Systematic Literature Review	Interactive visual media, 3D representations, and conceptual macromedia to bridge students' understanding of real-world concrete contexts.	This study identifies difficulties, misconceptions, and media-based solutions in Chemical Bonding material. It is concluded that this topic contains many misconceptions due to its abstract nature, but these can be effectively reduced through interactive visual media.

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3.2 Interactive Multimedia and Contextual Learning in Supporting Students' Learning Motivation and Conceptual Understanding

The findings of this review suggest that interactive multimedia and contextual learning approaches have the potential to support students' learning motivation and conceptual understanding in chemistry education. Multimedia is a combination of various media elements, such as text, images, audio, video, animation, and simulations, that are integrated to support the learning process (Guan et al., 2018). The interactive nature of multimedia enables students not only to receive information passively but also to participate actively throughout the learning process. The integration of visual and verbal representations can increase students' attention, interest, and engagement in learning activities (Alemdag & Cagiltay, 2018).

Various studies have shown that the use of interactive media can support students' understanding of chemistry concepts. Media such as three-dimensional visualization-based e-modules (Kuit & Osman, 2021), interactive multimedia (Iwan et al., 2025; Sary & Jahro, 2022), and Augmented Reality (Yang & Wang, 2023) provide opportunities to represent abstract concepts in more concrete and understandable forms. Through these visualizations, students can explore molecular representations and develop a clearer understanding of concepts that are difficult to observe directly. These findings highlight the potential of visual and interactive media to support conceptual understanding, particularly in learning abstract chemistry concepts.

The increase in learning motivation through interactive multimedia can be explained by its ability to present complex concepts in a more engaging and understandable manner. Abdulrahaman et al. (2020) stated that multimedia can transform abstract concepts into more concrete forms, present information more efficiently, and stimulate students' interest in learning. In addition, the use of electronic content in chemistry education has been shown to improve learning achievement and encourage students to learn independently according to their interests and abilities (Selvaganapathy & Benjamin, 2019). This indicates that digital media does not merely function as a tool for delivering information, but also provides a more flexible and meaningful learning experience for students.

The role of multimedia in supporting conceptual understanding can also be examined through studies involving visual attention. Yang and Wang (2023) and Javora et al. (2020) utilized eye-tracking technology to investigate how students interact with visual representations during learning. Their findings provide insights into students' attention to visual information and the role of multimedia design in supporting learning processes. Although visual attention does not necessarily indicate conceptual understanding, these studies highlight the importance of designing visual materials that help students focus on relevant information. Such considerations are particularly important in chemistry education, where students need to interpret abstract molecular representations.

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Furthermore, the effectiveness of multimedia in enhancing learning motivation becomes more optimal when combined with the CTL approach. CTL emphasizes the relationship between learning materials and real-life contexts, enabling students to understand the relevance and usefulness of what they learn (Demelash, 2023). In chemical bonding instruction, abstract concepts can be connected to phenomena that are familiar to students' daily experiences, making the material easier to understand. This approach is consistent with social constructivist theory, which views students as active constructors of knowledge through their experiences and interactions with the surrounding environment (Demelash, 2023). When students are able to recognize the connection between chemistry concepts and everyday life, their motivation to learn tends to increase because learning becomes more meaningful rather than merely memorizing concepts.

Overall, the reviewed studies suggest that interactive multimedia and contextual learning approaches offer complementary contributions to chemistry education. Interactive multimedia supports the representation and exploration of abstract concepts, while contextual learning helps connect scientific knowledge with students' everyday experiences. Together, these approaches provide a potential foundation for designing learning environments that support students' motivation and conceptual understanding. However, the reviewed evidence does not establish that their combined implementation consistently produces improvements in both outcomes across all educational contexts.

3.3. Implications for the Development of Chemistry E-Magazines

The findings from the 17 reviewed articles provide strong implications for the development of chemistry e-magazines as learning media based on interactive multimedia and Contextual Teaching and Learning (CTL). An e-magazine is a digital instructional material in the form of an interactive e-module that can be accessed through various electronic devices, such as computers, laptops, tablets, and smartphones, both online and offline (Linda et al., 2018). The main advantage of this medium lies in its ability to integrate various multimedia components, including text, images, audio, video, animation, and interactive links within a single learning platform. This integration enables abstract chemical bonding concepts to be presented in a more concrete and engaging manner, thereby helping students develop a deeper understanding of the subject matter.

In addition to supporting classroom learning, e-magazines provide flexibility for students to learn independently according to their individual needs and learning pace. The availability of digital devices among students, reaching 81.92%, indicates significant potential for implementing e-magazines in chemistry education (Linda et al., 2018). Furthermore, the validation results reported by Linda et al. (2018) demonstrated that the interactive chemistry magazine e-module met excellent criteria in terms of content substance, instructional design, visual presentation, and software utilization, in accordance with the guidelines for ICT-based instructional material development. Similarly, Ambarukma and Sulistina (2025) developed a chemistry e-magazine integrating ethnoscience and green chemistry in reaction rate learning. Therefore, e-magazines based on

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interactive multimedia and CTL have the potential to become effective learning media for enhancing students' learning motivation while helping them understand the abstract concepts of chemical bonding.

Based on these findings, the development of a CTL-based interactive chemistry e-magazine should consider several important aspects, including the integration of molecular visualizations, interactive learning activities, and contextual examples related to students' everyday experiences. For chemical bonding material, these elements could be designed to help students connect observable phenomena with submicroscopic representations and symbolic explanations. In addition, the e-magazine should provide clear content organization, accessible navigation, and opportunities for independent learning. Therefore, integrating interactive multimedia and contextual learning principles into chemistry e-magazines represents a promising direction for supporting students' learning motivation and conceptual understanding. Nevertheless, further development and empirical testing are required to determine the effectiveness of such e-magazines specifically in chemical bonding instruction.

4. Conclusion

Based on the Systematic Literature Review of 17 articles published between 2016 and 2025, the reviewed studies employed various research methods and learning media, with Indonesia contributing the largest number of publications. The findings suggest that interactive multimedia and Contextual Teaching and Learning (CTL) approaches have the potential to support students' learning motivation and conceptual understanding in chemistry education. Interactive multimedia facilitates the visualization of abstract concepts, while contextual learning helps students connect scientific knowledge with everyday experiences, making learning more meaningful. These findings also provide a foundation for the development of chemistry e-magazines that integrate interactive multimedia elements, contextual examples, and flexible digital learning features. However, further empirical research is needed to evaluate the effectiveness of CTL-based interactive e-magazines in improving students' learning motivation and conceptual understanding specifically in chemical bonding instruction.

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