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The Effectiveness of Learning Media on Atomic Structure Material: A Literature Review

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ABSTRACT

This literature review aims to evaluate the effectiveness of various learning media in facilitating the understanding of atomic structure material in chemistry education. The research was conducted by analyzing 10 research articles published between 20215 and 2025, gathered from SCOPUS and SINTA database. The review identified several innovative learning media that have been implemented, including e-Modules, Animated Videos, and educational Games. An analysis of the strengths and weaknesses of each media revealed a consistent finding: all these innovative media were significantly more effective in improving the learning outcomes of 10th-grade students compared to the use of conventional media like whiteboards. The primary advantage of these innovative media lies in their ability to visualize abstract atomic concepts into more tangible and interactive forms, thereby directly enhancing student comprehension and visual memory. Based on this review, it is concluded that there is a pressing need to develop and adopt chemistry learning media that are not only innovative and practical but also capable of transforming abstract learning into an immersive visual experience, enabling students to more easily understand and remember complex concepts in atomic structure.

INTRODUCTION

Chemistry education still faces major challenges related to the abstract nature of its basic concepts, such as atomic structure, chemical bonds, periodic systems, and chemical equilibrium. The complexity of the material that demands the connection between macroscopic, microscopic, and symbolic representations often causes conceptual difficulties for students (Wijaya & Premono, 2020). Macroscopic representation in chemistry is a concrete level at which students can observe phenomena that occur directly, either through experiments or phenomena that occur in daily life (Chusnah et al., 2020; Wilandari et al., 2018). Submicroscopic representation is an aspect that shows chemical characteristics that are memorable abstract which are used to explain macroscopic phenomena (Imaduddin, 2018). The submicroscopic aspect provides an explanation by using an image in the form of atoms, molecules, or ions, so that the phenomenon that occurs cannot be directly observed (Hatimah & Khery, 2021). In contrast, the symbolic domain serves to illustrate macroscopic phenomena through the utilization of atomic symbols, molecular and chemical equations, mathematical representations, graphical models, reaction mechanisms, as well as various analogies. Based on the data of the results of daily tests provided by chemistry teachers, data was obtained that 86% of class X students had not completed understanding the material of atomic structures. The data is also strengthened by information provided by chemistry

teachers who teach at the school, chemistry teachers stated that students are less able to connect chemistry concepts to solve the problems obtained. The low learning outcomes are also because students' interest in learning chemistry is still lacking, students often think that chemistry materials are not in accordance with their needs, not in accordance with their abilities, and their skills, so students feel compelled to learn them.

Learning resources have a crucial role in supporting learning success. According to Novallyan & Gusfarenie (2020), learning resources include information, educators, hardware, software, and learning environments that can support the process of conveying messages. However, the results of the initial questionnaire at SMAN 4 Surabaya show that the learning resources used by teachers and students are still dominated by printed materials. More than 70% of students stated that chemistry textbooks felt confusing and uninteresting, so they failed to foster interest in learning, especially in atomic structure materials (Nadia Salsabila & Nurjayadi, 2019). The development of educational technology offers an opportunity to present chemical materials in a more interesting and interactive way. Gabby et al. (2016) stated that technology can be used to deliver material according to the needs of students, while Linda et al. (2018) added that technology integration can produce learning media that is easy to understand, interactive, and widely accessible.

A number of studies have developed various innovations in chemistry learning media. Animated video media has proven to be effective in facilitating the understanding of abstract concepts through concrete visualization (Wijaya & Premono, 2020; Putri, Taufik, & Qurniati, 2022). The transformative learning approach is considered to be able to build cognitive competencies as well as 21st century character and skills (Rahmawati, 2018). In addition, virtual laboratories support practicum learning through experimental simulations (Dwiningsih et al., 2018), while augmented reality technology is effective in increasing student involvement in learning atomic structures (Aris, Fitria, & Ihtisyamuddin, 2020). The pandemic has also encouraged the use of e-modules (Mufida, Subandowo, & Gunawan, 2022) and web-based media (Widiyaningtyas & Widiatmoko, 2014) as distance learning solutions. Interactive multimedia-based media has also been proven to increase student motivation and learning outcomes (Harahap & Siregar, 2020).

Despite this, most teachers still rely on conventional media such as PowerPoint and LCD projectors, while the use of Android-based digital media is still relatively low due to limited technical skills (Yudha, Nurfajriani, & Silaban, 2023). Furthermore, previous studies tended to only test the feasibility and effectiveness of media separately without comparing the advantages and disadvantages of each type of media in the context of chemical learning. Addressing this need, This study aims to conduct a systematic review and analysis of the effectiveness of different learning media designed to facilitate the teaching and learning of atomic structure concepts.. This

investigation will critically appraise the advantages and drawbacks of these media as reported in the literature. By doing so, this research aims to contribute to the enhancement of chemistry learning by demonstrating how technology can be utilized to boost student involvement, ability, and comprehension of this fundamental topic.

RESEARCH METHOD

This study uses the literature review method (Cohen, Manion, & Morrison, 2018). This method involves a systematic review and analysis of previously published research findings. The approach used is a descriptive analysis to synthesize the characteristics and results of the selected literature. The focus of this literature review is on the use of learning media, especially on the topic of atomic structure. The literature search strategy was carried out through Scopus and Sinta, covering the publication time range of 2015 to 2025. Searches using instructional media and chemical elements keywords yielded a total of 10 journal articles. The selected articles are in the form of PDF files and meet the criteria for publication in national and international journals.

RESULTS AND DISCUSSION

Table 1 provides an overview of the publications identified in indexed journals, and Table 2 reports the results of the analysis performed through a systematic review of the literature, namely

Table 1. indexed Journal Publication

Year.	Journal Name	Number Of Articles	Type Of Publication
2024	Development of a mobile learning network for science with augmented reality and its impact on students' literacy and numeracy	1	Scopus Q4
2022	Development Of Chemical Learning Media Based On Video Animation To Increas Learning Motivation Of Students Of SMAN 1 Wanasaba	1	Sinta 2
2022	Development of articulate-storyline-3-based digital learning media on the subject of atomic structure	1	Sinta 3
2021	Development of android based chemical comics integrated Qur'ani values in the main structure of atomic for high schools	1	Scopus Q4
2021	eS2MART Teaching and learning material in chemistry: Enhancing spatial skills thru augmented reality technology	1	Scopus Q4
2020	Understanding the Concept of Atomic Structure After Learning	1	Sinta 2

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Table 2. Research Articles Analysis Result

No.	Writer	Method	Research Findings
1.	(Cahyana et al. 2024)	Research and Development (R&D)	Based on this study, the data collected concluded that the use of MLNFS-AR significantly improves students' literacy and numeracy skills compared to conventional learning methods. If calculated using the *Normalized Gain (N-Gain)* formula with an estimate based on the average increase in score (maximum score = 15), the N-Gain value for the experimental group in Lombok ≈ 0.45 (medium category) and in Yogyakarta ≈ 0.33 (medium category). This value showed a moderate but consistent increase in learning outcomes in the two study sites.
2.	(Putri, Taufik, and Qurniati 2022)	Research and Development (R&D)	The development of the animated video-based chemistry learning media was evaluated on three key metrics. First, validator assessment resulted in a high average validity score of 0.900884, categorizing the media as highly feasible. Second, student questionnaire responses supported this finding, showing an 81.16% eligibility rate and indicating no need for revision. Finally, the media's effectiveness was confirmed through an N-Gain analysis, which produced a score of 0.5, denoting a moderate increase in student learning motivation.
3.	(Pratiwi, Sudyana, and Fatah 2022)	Research and Development (R&D)	He results indicate that the initial design of the PERISA media achieved a content conformity level of 82.9%. Following expert evaluation, several revisions were made to ensure complete alignment with the established competency standards (KD) and learning objectives. This iterative refinement process highlights the responsiveness of the media development to expert input, thereby strengthening its instructional validity. Furthermore, the feasibility validation yielded a score of 86.5%, suggesting that the PERISA media is highly appropriate for classroom application without the need for further modification. The obtained n-gain score of 0.536 demonstrates a high level of effectiveness in improving students' understanding of the learning material. This finding implies that the integration of PERISA media contributes significantly to conceptual mastery. Additionally, the positive student response rate of 82.05% reinforces the practicality and appeal of the media,

			indicating that learners found it engaging and supportive in facilitating the learning process.
4.	(Montalbo 2021)	Teaching and Learning Material (TLM)	The results revealed that both the pretest and posttest employed a standardized spatial skills assessment comprising seven items from the Purdue Spatial Visualization Test (PSVT) and thirteen content-specific items administered before and after the implementation of the eS2MART TLM. Based on the Hake factor analysis, the normalized gain score on the PSVT was 0.50, indicating a moderate improvement in students' spatial visualization abilities. In contrast, the Content-Specific Spatial Skill Test yielded a higher normalized gain value of 0.76, demonstrating a substantial enhancement in content-related spatial understanding. These findings suggest that the eS2MART TLM effectively supports the development of both general and context-specific spatial skills. Furthermore, the incorporation of augmented reality into the eS2MART TLM was associated with highly positive student learning experiences, as evidenced by a composite mean score of 3.54, indicating strong engagement and favorable perceptions toward the learning process.
5.	(Aulia, Darmana, and Nugraha 2021)	Research and Development (R&D)	The effectiveness test results indicated a significant improvement in student learning outcomes. The experimental class, which utilized Android-based chemical comic media, demonstrated a marked increase from a mean pretest score of 55.17 to a posttest score of 85.17. In comparison, the control class showed an increase from 58.17 to 80.00. Analysis of the normalized gain (N-Gain) revealed a moderate increase of 0.50 for the control group, compared to a higher gain of 0.68 for the experimental group. An independent samples t-test confirmed a statistically significant difference in the improvement between the two groups ($p = 0.002$). These findings substantiate that the Android-based chemical comic media is more effective than conventional methods in enhancing students' understanding of atomic structure
6.	(Salkind 2020)	Research and Development (R&D)	The research findings demonstrate a significant enhancement in students' conceptual understanding following the implementation of the Discovery Learning model assisted with Student Worksheets (LKS). The mean pretest score, initially at a low 17.86%, rose substantially to 73.86% in the posttest, which is categorized as good. This improvement was quantified using a normalized gain (N-Gain) calculation,

	yielding an average score of *g* = 0.67, which falls within the medium-to-high category. These results indicate that the guided discovery activities were highly effective in fostering a deeper comprehension of atomic structure concepts among students.

Based on Table 2, the analysis of six research articles regarding the development and effectiveness of various chemistry learning media shows that all the developed media are proven to be able to significantly improve student learning outcomes. The six studies consist of: (1) MLNFS-AR by Cahyana et al. (2024), (2) chemistry animation videos by Putri, Taufik, and Qurniati (2022), (3) PERISA media by Pratiwi, Sudyana, and Fatah (2022), (4) *Augmented* Reality-based *Teaching and Learning Material* eS2MART by Montalbo (2021), (5) Android-based chemistry comics by Aulia, Darmana, and Nugraha (2021), and (6) *Discovery Learning* assisted by LKS by Salkind (2020). All of these studies use *the Research and Development (R&D) approach*, except for the research of Montalbo (2021) which focuses on the development and trial *of Teaching and Learning Material (TLM).*

Research conducted by Cahyana et al. (2024) shows that the application of *Mobile Learning with Numbered Formula Structure – Augmented Reality (MLNFS-AR)* media significantly improves students' literacy and numeracy skills compared to conventional learning. Based on the calculation of *Normalized Gain (N-Gain),* the increase in learning outcomes in the two study locations showed a moderate category, namely 0.45 in Lombok and 0.33 in Yogyakarta. This value confirms that the integration of AR technology is effective in clarifying abstract concepts of chemistry with the help of three- dimensional visualization and interactive narratives

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Meanwhile, research by Putri, Taufik, and Qurniati (2022) showed that chemistry learning media based on animated videos had a very high level of validity with a score of 0.900884, as well as the feasibility of student responses of 81.16%. The effectiveness of the use of this media on students' learning motivation shows a moderate category with an *N-Gain* value of 0.5. This shows that video animation plays an important role in increasing the appeal and understanding of chemical concepts, but its improvement is still limited to motivational aspects and learning engagement.

Similar results were also found in the research of Pratiwi, Sudyana, and Fatah (2022) who developed the PERISA media. The validation of the content and feasibility of the media showed an excellent value, which was 86.5%, while the effectiveness of the media was shown by an *N-Gain* value of 0.536 (high category). The positive response of students which reached 82.05% shows that this media is not only academically feasible, but also liked by students because it is relevant to competency-based learning needs. Montalbo's research (2021) showed the findings revealed notable enhancements in spatial ability, evidenced by an N-Gain score of 0.50 on the general spatial visualization assessment and 0.76 on the content-specific spatial test, both of which indicate a high level of improvement. Through the application *of Augmented Reality-based* Teaching and Learning Materials (TLM), students can visualize abstract concepts in real life, such as the shape of molecules and atomic structures, so that the learning experience becomes more concrete and meaningful. The average composite score of student satisfaction of 3.54 indicates a positive perception of the use of AR in learning. Furthermore, research by Aulia, Darmana, and Nugraha (2021) show the integration of Android-based chemical comic media was found to significantly enhance student learning outcomes, as evidenced by an average N-Gain score of 0.68 in the experimental group compared to 0.50 in the control group. Statistical analysis using a t- test confirmed the significance of this improvement, yielding a p-value of 0.002, which is well below the 0.05 threshold. These findings prove that interactive comic-based media can be an effective alternative to learning abstract concepts such as atomic structures, as they are able to combine visual, narrative, and interactive aspects in one engaging learning medium.

Finally, Salkind (2020) demonstrated a substantial improvement in students' conceptual understanding through the implementation of the Discovery Learning model supported by LKS, with average scores rising from 17.86% to 73.86%. The calculation *of an N-Gain* of 0.67 shows a significant improvement in the student's conceptual ability towards atomic structure. These findings confirm that an invention-based learning approach with the support of structured media is able to encourage students to actively build their own knowledge.

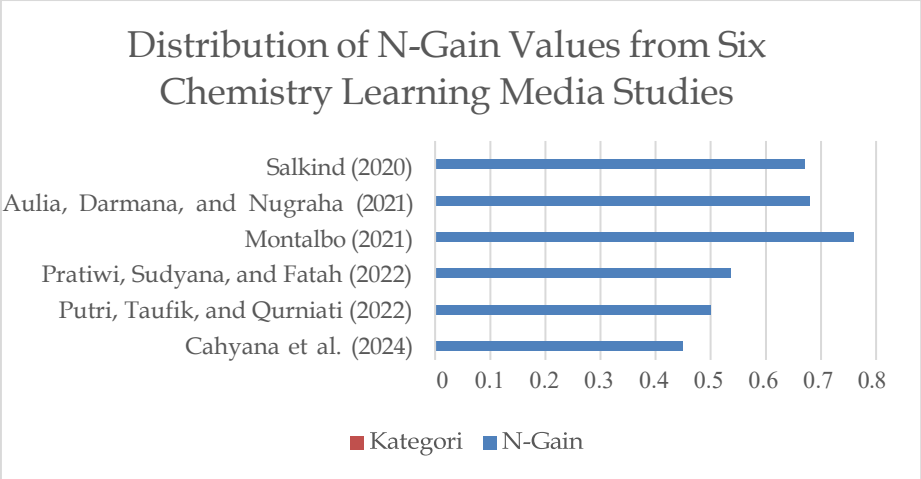

Figure 1. Distribution of *N-Gain* Values from Six Chemistry Learning Media Researches Based on figure 1. that *Augmented Reality media* (Montalbo, 2021) provides the highest increase in learning outcomes compared to other media. Meanwhile, animated video- based media (Putri et al., 2022) and interactive e-modules (Pratiwi et al., 2022) showed stable results with moderate to high levels of effectiveness. These results strengthen the argument that the level of interactivity and visualizability are the main factors in the effectiveness of chemical learning media. Media that is able to present complex visual representations dynamically and support dual cognitive pathways (visual and auditory) has proven to be more efficient in aiding the understanding of abstract chemical concepts. Thus, Analysis of the data in Table 2 and Figure 1 indicates that all forms of technology-enhanced instructional media demonstrate a positive impact on student learning outcomes, confirming their overall effectiveness in educational settings. *Augmented Reality-based media* stand out in terms of improving spatial and conceptual understanding, while animated videos and digital comics excel in motivational aspects and student engagement. These findings are in line with a constructivist approach that emphasizes active, visual, and contextual learning as the key to increasing the effectiveness of chemistry learning.

CONCLUSION

The synthesis of findings from six studies indicated that the various chemistry learning media developed were effective in enhancing students' learning outcomes, as reflected in N-Gain values ranging between 0.33 and 0.76, which fall within the medium to high improvement categories. *Augmented Reality-based media* shows the highest effectiveness in strengthening spatial and conceptual understanding, while animated videos, e- modules, and digital comics are effective in increasing student motivation and engagement. Thus, the integration of interactive technology in chemistry learning has been proven to be able to optimize the learning process through engaging and hands-on experience-based visualization.

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