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Innovation in Augmented Reality-Based Chemical Bonding Learning Media to Support Interactive Learning

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ABSTRACT

Purpose of the study: This study aims to determine students' responses toward an interactive learning media based on augmented reality technology on chemical bonding material, focusing on usability, visualization, material benefits, language clarity, and potential impact in supporting interactive learning experiences.

Methodology: This study employed the Warsita development model consisting of design, production, and evaluation stages. The developed media included an augmented reality application integrated with a marker book. Data were collected through a structured questionnaire consisting of 40 items administered to 40 students. Validation involved media and subject experts, and data were analyzed using percentage techniques and interpretation criteria.

Main Findings: Students showed positive responses toward the augmented reality-based interactive learning media, categorized as good overall. High acceptance was reflected in usability and illustration aspects, while material benefits, grammar, and future impact were also positively rated. The media demonstrated feasibility for classroom use with minor improvements needed for long-term learning engagement.

Novelty/Originality of this study: This study presents an augmented reality-based interactive learning media specifically designed for chemical bonding with integrated marker books and application features. It emphasizes students' response evaluation across multiple aspects, providing empirical insight into user acceptance and contributing to the development of more effective and engaging chemistry learning media.

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1. INTRODUCTION

The development of information and communication technology has brought significant changes to the world of education, particularly in the classroom learning process [1], [2]. The use of digital technology has become a strategy to improve the quality of learning, making it more effective and engaging for students [3], [4]. In the context of 21st-century learning, technology integration is no longer an option but a necessity [5], [6]. This encourages educators to continuously innovate in developing interactive and adaptive learning media. One form of this innovation is the use of augmented reality technology in learning.

Augmented reality is a technology capable of combining virtual objects with the real world in real time [7], [8]. This technology provides a more concrete and interactive visual experience than conventional learning media. In science learning, particularly chemistry, augmented reality has great potential to help students understand abstract concepts [9], [10]. The visualizations produced by augmented reality can increase student interest and engagement in the learning process [11], [12]. Therefore, the use of augmented reality is an alternative solution to overcome the limitations of traditional learning media.

Chemical bonding is a crucial topic in chemistry learning that is often considered difficult by students [13], [14]. This is because the concept of chemical bonding is abstract and cannot be directly observed [15], [16]. Students are required to understand the interactions between particles at the microscopic level, which are often difficult to visualize [17], [18]. As a result, many students struggle to grasp these concepts in depth. This situation highlights the need for learning media that can present concepts in a more concrete and understandable way.

Interactive learning media based on augmented reality can be a solution to this problem [19], [20]. With the help of augmented reality, students can see visual representations of molecular structures and the process of chemical bond formation in a more realistic manner [21], [22]. The interactivity offered allows students to actively participate in the learning process [23], [24]. This can increase learning motivation and optimize conceptual understanding. Thus, augmented reality has the potential to be an effective innovation in chemistry learning [25], [26].

The development of augmented reality-based learning media focuses not only on the technological aspect but also on the response and acceptance of the users, namely students. Student responses to learning media are a crucial indicator in assessing the success of an innovation [27], [28]. Visually appealing media is not necessarily effective if it does not elicit a positive response from students. Therefore, evaluating student perceptions and experiences in using augmented reality media is necessary [29], [30]. This aims to ensure that the developed media truly meets students' learning needs.

Several previous studies have shown that the use of augmented reality technology can increase student interest and engagement in learning [31], [32]. However, further study is needed to determine students' responses to this technology, particularly in chemical bonding. Each learning context has unique characteristics, so research results cannot always be generalized. Therefore, this study is crucial in providing an empirical overview of the use of augmented reality in chemistry learning. The primary focus of this research is on student responses as direct users of the learning media.

This research has a novelty in the development of interactive learning media based on augmented reality specifically designed to visualize the abstract concept of chemical bonds through the integration of AR applications and bookmarks. Not only focusing on the product development aspect, this research also emphasizes the comprehensive evaluation of student responses based on several important aspects such as usability, illustrations, material usefulness, grammar, and future impacts. This approach provides new contributions in the form of empirical data regarding user acceptance of AR media in the context of chemistry learning at the secondary school level. The urgency of this research is based on the need for innovative learning media that can increase student engagement and understanding of material that is difficult to visualize. Thus, this research is expected to be an alternative solution while enriching studies on the integration of augmented reality technology in chemistry education.

Based on this description, this study aims to determine student responses to interactive augmented reality-based learning media for chemical bonding. The results are expected to contribute to the development of more innovative and effective learning media. Furthermore, this research can serve as a reference for educators integrating augmented reality technology into the learning process. With interactive media, chemistry learning is expected to become more engaging and easier to understand. Ultimately, this innovation is expected to improve the quality of learning and student learning outcomes.

2. RESEARCH METHOD

2.1. Research Methods

This research uses the development model proposed by Warsita as the primary reference in the media development process. The model consists of three interrelated and systematic main stages. The first stage is media design, which includes the development of the initial concept and design of the learning media. Next, the media production stage is carried out to realize the design into an interactive learning product based on augmented reality [19]. The final stage is evaluation, which aims to assess the feasibility and effectiveness of the augmented reality learning media that has been developed for the chemical bonding material.

2.2. Research Design

This research employed the Warsita development model, beginning with the design stage as the initial phase in developing the learning media. This stage aimed to prepare a prototype of the augmented reality-based interactive learning media and to define the learning problems to ensure a clear development direction. The activities included needs analysis, preparation of a content outline, and development of a media script. Needs analysis was conducted through field surveys and questionnaires to collect data related to students, teachers, and the availability of instructional media. The results of this stage were used to determine learning objectives and design media content aligned with the chemical bonding material.

The next stage was the production stage, which focused on transforming the design into a functional learning product. This stage consisted of preparation, implementation, and completion processes. It involved the development of an augmented reality application integrated with a marker book as a supporting learning tool. Technical aspects such as layout design, font selection, content organization, and file format integration were carefully considered. The output of this stage was an interactive augmented reality-based learning media on chemical bonding, which was ready for limited implementation in the classroom.

The final stage was evaluation, which aimed to assess the feasibility of the developed media and to identify students’ responses as the main research focus. Evaluation was carried out through expert validation and limited trials involving 40 students of class X science 4. Data were collected using a structured questionnaire covering usability, future impact, benefits of the material, use of illustrations, and grammar aspects [33]. The collected data were analyzed using percentage techniques and interpretation criteria to determine the level of student acceptance toward the developed media. This stage emphasized measuring user responses rather than learning outcomes.

2.3. Research Subjects

The subjects of this study were 10th grade science 4 students at State Senior High School 7 in South Tangerang City, who served as respondents in the limited trial phase. The students provided feedback on the developed learning media to assess its acceptability and effectiveness..

2.4. Data Collection Instruments and Techniques

The data collection technique used in this study was a student response questionnaire. The questionnaire was used as an instrument to determine student responses after using interactive augmented reality-based learning media in chemical bonding lessons. The outline of the student response questionnaire can be seen in Table 1.

Table 1. Student Response Questionnaire Grid

No.	Indicator	Statement		Question Number	Amount
		(+)	(-)		
1.	Usability	6	2	1,2,3,4,5,6,7,8	8
2.	Future Impact	3	4	9,10,11,12,13,14,15	7
3.	Benefits of the Material	7	2	16,17,18,19,20,21,22,23,24	9
4.	Use of Illustrations	7	4	25,26,27,28,29,30,31,32,33,34,35	11
5.	Grammar	1	4	36,37,38,39,40	5
		Amount			40

2.5. Data Analysis Techniques

The data generated from the questionnaire responses were then tabulated, presented, and analyzed. Afterward, researchers were able to determine whether the development of this augmented reality-based learning media fell into the categories of very good, good, sufficient, poor, or very poor. The criteria for interpreting the questionnaire scores used can be seen in Table 2.

Table 2. Score Interpretation Criteria

No.	Interval	Category
1.	81 – 100%	Very Good
2.	61 – 80%	Good
3.	41 – 60%	Fair
4.	21 – 40%	Poor
5.	0 – 20%	Very Poor

3. RESULTS AND DISCUSSION

The developed media products were then tested on students to obtain data in the form of user responses to the interactive learning media based on augmented reality technology. Student response data was collected through the distribution of questionnaires after students used the developed media. The trial subjects in this study were 40 students of class X science 4 at State Senior High School 7 South Tangerang. The questionnaire aimed to measure students' perceptions of the quality and effectiveness of the learning media used. The questionnaire instrument covered five assessment aspects, namely usability, future impact, use of illustrations, material usefulness, and grammar. The data obtained from the media product trial can be seen in Table 3.

Table 3. Results of Student Response Questionnaire

No.	Aspect	Percentage (%)	Criteria
1.	Usability	85.75	Very Good
2.	Future Impact	74.57	Good
3.	Benefits of the Material	79.64	Good
4.	Use of Illustrations	81.80	Very Good
5.	Grammar	77.20	Good
Average Percentage (%)		79.78	Baik

Based on the data in the table, it can be seen that student responses to the interactive augmented reality-based learning media were generally in the good category, with an average percentage of 79.78%. This indicates that the developed media has been quite positively received by students as a supporting tool for learning about chemical bonds. Although it has not yet reached the "very good" category overall, these results indicate that the media is of sufficient quality for use in the learning process. Furthermore, the average score approaching the "very good" category indicates potential for further development to optimize the media. Therefore, this media can be considered suitable for use with some improvements in certain aspects.

Regarding usability, the percentage obtained was 85.75%, categorized as "very good," indicating that the media is easy to use and understand for students. This indicates that the interface design and navigation within the media are sufficiently intuitive to avoid difficulties for users. This ease of use is a crucial factor in increasing the effectiveness of technology-based learning. Meanwhile, the use of illustrations also received a "very good" category, with a percentage of 81.80%, indicating that the visualizations presented are able to help students understand the abstract concept of chemical bonds. Engaging and representative visuals have been shown to contribute to increased student engagement.

The benefits of the material aspect achieved a score of 79.64%, categorized as good, indicating that the material presented in the media is quite useful in aiding student understanding. This indicates that the developed content is relevant to learning needs, although it still has room for improvement. Furthermore, the grammar aspect achieved a score of 77.20%, categorized as good, indicating that the language used in the media is clear and understandable to students. However, there is still room for improvement in the clarity and accuracy of the language used. Improvements in this aspect are crucial to prevent misconceptions in learning.

Meanwhile, the future impact aspect achieved the lowest score, at 74.57%, categorized as good. This indicates that while the media is considered beneficial when used, its long-term impact or sustainability of learning still needs improvement. Students may not yet fully appreciate the potential of this media to support ongoing learning. Therefore, further development needs to focus on increasing the media's appeal and sustainability. Overall, these results indicate that augmented reality-based learning media has good prospects, but still requires refinement in several aspects to achieve a more optimal impact.

Student responses indicate that augmented reality-based learning media has been able to provide a relatively accessible and user-friendly learning experience. Ease of use reflects the fact that the interface design and navigation flow have been designed with user characteristics in mind, allowing students to focus more on understanding the material rather than on the technical aspects of using the media. This aligns with the principle that good learning media should be user-friendly so as not to hinder the process of knowledge construction. Furthermore, ease of use also contributes to increasing student confidence in exploring the material independently. Thus, usability is one of the main strengths of the developed media.

In terms of visualization, the use of illustrations in augmented reality media has proven to be a significant contribution in helping students understand the abstract concept of chemical bonding. Interactive visual representations allow students to observe the structure and process of bond formation more concretely [34]. This supports cognitive learning theory, which emphasizes the importance of visualization in strengthening understanding of complex concepts. Furthermore, the integration of visual elements with augmented reality technology can also increase student engagement and attention during the learning process [35], [36]. Thus, the use of illustrations serves not only as a supplement but also as a central component in delivering material.

However, in terms of the usefulness of the material, there is still room for further development so that the content presented can have a deeper impact on student understanding. The material presented needs to be continuously tailored to students' learning needs and linked to real-life contexts for greater meaning. Reinforcement in this aspect can be achieved by adding examples of concepts applied in everyday life or interactive exercises that encourage critical thinking. Furthermore, the material's complexity should be considered to align with students' cognitive abilities [37]. By optimizing content, media should be not only visually appealing but also substantively strong.

From a linguistic perspective, clarity and accuracy of language use are crucial factors in supporting the effectiveness of learning media. Communicative and easily understood language will help students absorb information without creating ambiguity. Therefore, improvements in grammar need to be directed at simplifying sentences, choosing appropriate terms, and consistently using scientific terminology. This is especially important in chemistry learning, which has a wealth of specialized terminology. With better language use, the potential for misconceptions can be minimized.

Meanwhile, from a long-term impact perspective, efforts are needed to increase the appeal and sustainability of media use in the learning process. Innovative media is expected to be effective not only once used but also encourage students to continue using it as a source of independent learning [38]. Integrating additional features such as interactive evaluation, direct feedback, or further content development can be strategies to increase sustainability. Furthermore, teacher support in integrating media into learning activities is also crucial [39], [40]. With continued development, augmented reality media has the potential to become an integral part of the broader digital learning ecosystem.

4. CONCLUSION

Based on the results of the research that has been conducted, it can be concluded that the interactive learning media based on augmented reality technology on chemical bonding material in the form of applications and marker books that were developed received a positive response from students of 79.78% and is included in the good category.

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AUTHOR CONTRIBUTIONS

Conceptualization, A.I.N. and F.A.; Methodology, A.I.N.; Software, T.D.; Validation, F.A., T.D. and T.S.; Formal Analysis, A.I.N.; Investigation, A.I.N.; Resources, T.S.; Data Curation, T.D.; Writing – Original Draft Preparation, A.I.N.; Writing – Review & Editing, F.A.; Visualization, T.D.; Supervision, F.A.; Project Administration, A.I.N.; Funding Acquisition, T.S.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

Not applicable.

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