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DEVELOPMENT OF HOLOKUL: 3D HOLOGRAM LEARNING MEDIA ON MOLECULAR STRUCTURE

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Abstract: Learning media refers to equipment designed and developed to convey information, facilitating the effective transmission of knowledge. Molecular structure is a complex chemical concept containing abstract ideas, which can challenge student comprehension. To address this, the development of 3D hologram learning media for molecular structures aims to provide students with a visual representation for enhanced understanding. This research aims to (1) understand the process of developing 3D hologram learning media for molecular structures via the ADDIE development model and (2) assess the validity and practicality of the developed media. The supporting instruments for this research include product and instrument validation sheets, product readability questionnaires, and question items. The study involved six students from the 12th grade. Descriptive analysis of the data reveals that the developed product aligns with the ADDIE model, achieving a validation rate of 90%. The practicality of the product is determined to be 89%. Therefore, the developed product can be utilized as a learning media for molecular structures via 3D holograms.

Keywords: 3D Holograms; Learning Media; Molecular Structure

Abstrak: Media pembelajaran adalah alat yang diciptakan untuk mengkomunikasikan informasi secara efektif, mempermudah proses penyaluran pengetahuan. Salah satu konsep kimia yang rumit adalah struktur molekul, yang penuh dengan gagasan-gagasan abstrak dan sering kali sulit dipahami oleh siswa. Untuk mengatasi kesulitan ini, pengembangan media pembelajaran menggunakan teknologi hologram 3D tentang struktur molekul bertujuan untuk memberikan representasi visual yang jelas dan memudahkan pemahaman siswa. Penelitian ini memiliki dua tujuan utama: (1), untuk memahami secara mendalam proses pengembangan media pembelajaran hologram 3D struktur molekuler dengan menggunakan model pengembangan ADDIE; (2), untuk mengevaluasi kevalidan dan kepraktisan media yang telah dikembangkan. Instrumen penelitian meliputi lembar validasi produk dan instrumen, kuesioner keterbacaan produk, serta butir soal. Penelitian ini melibatkan partisipasi dari enam siswa kelas 12. Hasil analisis deskriptif menunjukkan bahwa produk yang dikembangkan sesuai dengan model ADDIE, dengan tingkat validasi mencapai 90%. Sementara itu, tingkat kepraktisan produk adalah 89%. Oleh karena itu, dapat disimpulkan bahwa produk yang telah dikembangkan memiliki potensi untuk digunakan sebagai media pembelajaran efektif dalam mempelajari struktur molekuler menggunakan teknologi hologram 3D.

Kata kunci: 3D Hologram; Media pembelajaran; Struktur molekul

INTRODUCTION

Chemistry is the study of the structure, composition, properties, and changes in matter and the reactions that occur (Chang, 2005). Most chemistry learning involves abstract concepts and phenomena that cannot be observed directly by humans, leading students to often struggle with understanding the science of chemistry (Rahmawati et al., 2021). Therefore, in the process of learning chemistry, there is a need for image representation or practical applications (Magwilang, 2016).

Since the COVID-19 outbreak, teaching systems and strategies have shifted, requiring teachers to master technology for learning (Purnasari & Sadewo, 2020). Courduff and Szapkiw (2015) explained that the application of technology in learning can motivate students to actively participate in the learning process. Technology has the potential to positively impact the learning experience by offering support, but it should not be considered a substitute for teachers. Teachers play a crucial role in integrating technology into instruction, encouraging and motivating students to grasp new knowledge. Technology serves as a tool for teachers to enhance instruction, making it more accessible and fostering greater interest in learning among students (Jhurree, 2005). The incorporation of technology in education has numerous advantages in terms of instructional methods, providing an effective learning environment. Fernandez (2016) revealed that students express a desire for increased technology use to make learning more enjoyable. Integrating technology, which is aligned with multiple intelligences, into lessons enhances children's motivation and concentration. This approach is further supported by the implementation of the 2013 curriculum, which places the chemistry learning process at the center of students' active engagement, enabling them to better understand chemical concepts (Setiawan et al., 2018). To enhance students' understanding, the abstract concepts of chemistry should be visualized through learning media. Learning media are equipment designed for delivering information and fostering interaction. They are designed on the basis of students' needs to convey all knowledge effectively and efficiently (Yaumi, 2018). Hence, there is a need for media that can assist students in comprehending chemistry concepts, rendering them engaging through the utilization of virtual reality technology (Langitasari et al. 2022).

One type of chemical material in high school with abstract concepts is the molecular structure. The molecular structure is a material in which many abstract forms are found that are composed of atoms in molecules in certain patterns. Molecular structure studies the impact of lone pairs of electrons and bonding electron pairs on the shape of a molecule (Gillespie & Popelier, 2001). In molecular structure learning, the conventional approach involves representing three-dimensional molecules by illustrating them in a two-dimensional format on paper or a whiteboard/screen. Nevertheless, the critical shift in understanding from a two-dimensional to a three-dimensional perspective, known as spatial ability, holds significant importance in comprehending chemistry concepts. Many students find this transition challenging, underscoring the necessity for them to engage in regular practice in visualizing representations of atoms, molecules, and reaction mechanisms (Gilbert et al., 2008; Wu et al., 2001).

The utilization of learning media for molecular structure materials aids students in visualizing the bonding shape of molecules. Various learning media have been developed, including physical products and technology-based products. Three-dimensional hologram technology is among the widely developed learning media. A hologram is a product of holography, a technique that records light from a scattered object and reconstructs it, allowing the 3D object to appear in the same position as the recording media. On a hologram, there is a collection of information in the form of images, scenes, or animations. 3D holograms not only present information in the form of 3D objects but also integrate captivating audio–visual elements.

Several studies, including the research of Safitri and Djuniadi (2021), have explored the development of 3D holograms as learning media, particularly for introducing the benefits of coconut plants to kindergarten children. An analysis of the pretest and posttest results indicates an improvement in students' learning outcomes when this media is used, demonstrating its practical utility in the teaching and learning process. Another study by Abdul (2016) involved creating an introduction to ancient animals via a captivating 3D hologram display, which successfully increased public enthusiasm for studying dinosaurs and other ancient creatures.

Another study demonstrated the implementation of three-dimensional hologram (3DH) technology in an educational setting and evaluated its impact on student learning. The results of the achievement tests clearly show that the use of 3DH significantly enhances students' learning outcomes and overall achievement levels. The success of 3DH animations in capturing students' attention and improving their comprehension is conclusive evidence of their effectiveness. The findings strongly suggest that this technology contributes to creating a realistic and motivating learning environment for students (Hoon & Shaharuddin, 2019; Olsson & Broman, 2020).

In response to the challenges of teaching abstract molecular shapes, this research introduces 3D hologram-based learning media for high school chemistry. The novelty of this study lies in its development of innovative media, a format not widely explored in chemistry education, and its assessment of the product's validity and practicality through limited school trials.

METHOD

This research adopts a developmental research design using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) to create and evaluate 3D hologram learning media for molecular structure materials. This study employs qualitative and quantitative approaches to assess the validity and practicality of the developed product (Lee & Owens, 2004). Data collection involved expert validation, student feedback, and observations of student interactions with the media. The data were analyzed descriptively, with validation scores averaged and categorized to determine the validity of the data. The practicality of the product was assessed by calculating the average percentage scores from the questionnaire responses. The research procedures follow the ADDIE development model, which is broken down into the following stages.

Analysis

Material analysis is performed to identify the material that will be loaded, namely, the molecular structure of the material. Needs analysis is derived from interviews containing the main problems of learning chemistry, especially concerning the material of the molecular structure. These analyses were performed through interviews with high school chemistry teachers.

Design

The design stage involves designing a description of the 3D hologram product. This stage includes (1) molecule making; (2) molecule video making; (3) molecule formation video making; (4) audio recording; (5) final video making; (6) card making; (7) hologram projector box making; and (8) sticker making. The development of this 3D hologram product involved the use of primary applications, such as Avogadro and PhET, along with supporting applications such as Canva, CapCut, YouTube, Google Forms, and Adobe Photoshop.

Development

The next stage is development, which combines all the compiled parts from the previous stage. Additionally, during the development stage, activities were conducted to measure product validation and validate the product readability questionnaire. Three validators conducted validation activities. The validation results were used to improve the product according to the suggestions of each validator. At this stage, several instruments, including product and instrument validation sheets, which experts used to assess the validity of the media, were utilized. The validity assessment uses a Likert scale with ratings ranging from 1 to 4. The scores given by the validators are subsequently calculated to determine a percentage, following the formula provided below.

$$V = \frac{f}{P} \times 100\%$$

Description: V = percentage, f = the total score obtained, P = the maximum score

The validation process of the product's language, media, and content is determined by the criteria outlined in Table 1. After expert validation, the product is revised as needed.

Table 1. Validity Category (Sugiyono, 2013)

Score	Category
85,01 – 100%	Highly valid
70,01 – 85%	Moderate
50,01 – 70%	Less valid
1,00 – 50,00%	Not valid

Implementation

The implementation stage involves the application of products that have been developed. To assess the practicality of the product, testing activities were conducted on students at El Sadai Magelang High School during the implementation stage, ensuring that the developed product aligns with its intended function (Baharuddin, 2018). Product readability questionnaires were administered to gauge students' perceptions of the clarity, design, and usability of the media. The results from the product readability questionnaire were analyzed by determining the average rating from respondents after using 3D hologram media. This product's practicality level was obtained by calculating the overall score on the questionnaire via the same validity formula and compared against the criteria specified in Table 2.

Table 2. User responses (Riduwan, 2011)

Score	Category
81 – 100%	Highly Practical
61 – 80%	Practical
41 – 60%	Moderately Practical
21 – 40%	Less Practical
0 – 20%	Not Practical

Evaluation

The final evaluation stage involves reviewing the results, including suggestions from the validator and the respondents. Feedback from both the validator and product users is utilized to revise the product iteratively until the final version is obtained. This stage emphasizes the importance of feedback from the validator and students (Anwar & Muharram, 2019).

RESULTS AND DISCUSSION

The development research uses the ADDIE development model (Lee & Owens, 2004), which consists of five stages: analysis, design, development, implementation, and evaluation. These stages aim to produce an improved product. The results of the analysis include material, needs, and environmental analyses. The material analysis focused on molecular structure material, which is part of the high school chemistry curriculum. The activities involved studying 14 molecular shapes on the basis of VSEPR theory, enabling students to analyze the number of electron pairs around an atom to predict the shape of a molecule. After interviewing a chemistry teacher at Bentara Wacana Muntilan High School, the needs analysis revealed that students struggle to understand and visualize the shape of molecules in real life.

The results of the product design stage in this research include 3D hologram video designs, projector boxes (or media boxes), and molecule cards. Three types of 3D hologram videos are used: product usage procedure videos, molecule videos, and question practice videos. The product usage procedure video explains the parts of the developed product and demonstrates how to use it. Molecule videos provide a brief explanation of 14 molecular shapes, each created via Avogadro and PhET applications, as illustrated in Figure 1. The researchers recorded audio explanations for each molecule. Each video depicting molecular structures contains audio containing brief explanations covering the number of bonding electron pairs and lone electron pairs, molecular notation, example molecules, molecular angles, boiling points, freezing points, types of bonds, hybridization, and polarity.

After the video and audio recordings were obtained, the video was edited via the CapCut application, as shown in Figure 2. In the video, molecule audio, animations, and background music were added to make the resulting video more engaging. All final videos that were created were then uploaded via YouTube and converted into QR code format. The created video is displayed in Figure 3.

The projector box design, as shown in Figure 4, is customizable and features adjustable lids on the front and back to support product use. It also includes a small drawer at the bottom for storing molecule cards, a designated space on top for a cell phone supported by an acrylic base to fit all phone sizes, and mica mounted at a 45° angle in the center to reflect light from the phone.

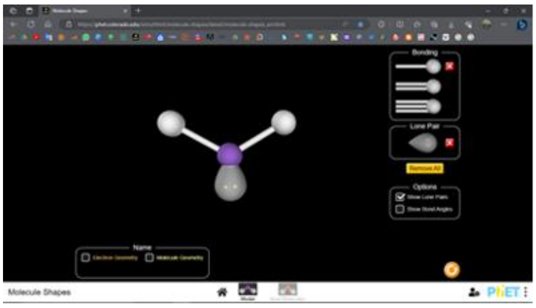

Figure 1. Making molecular structures via Avogadro and PhET applications

Figure 2. Editing video using Capcut

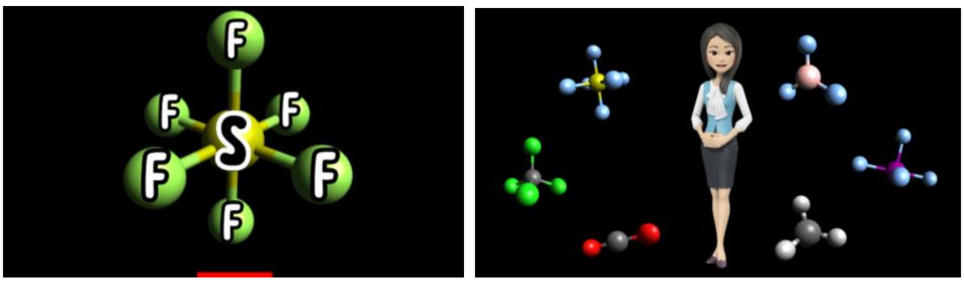

Figure 3. 3D Hologram Video Display

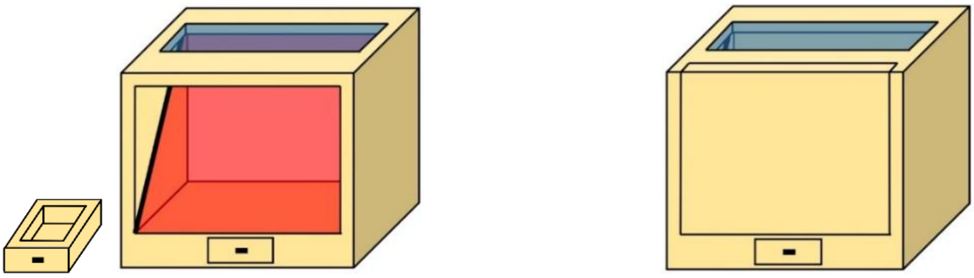

Figure 4. Projector Box Design

The product includes 15 cards—14 molecule cards and 1 question exercise card. The card design is shown in Figure 5. There are two sections on the card: the front and the back. The back of the card features the product name Holokul (Molecular Structure Hologram). Below the product name, there is an image illustrating the 3D hologram technology. In front of the practice card, various information about sample compounds for each molecule is provided, including compound images, chemical formulas, molecular notations, molecular shapes, and a QR code. The practice card's front also includes a QR code containing video questions. The designed cards incorporate QR codes with design components compatible with 3D hologram technology. Each card provides brief information on a molecular structure and includes a QR code linked to an explanatory video.

The next stage, development, aims to enhance the product's attractiveness on the basis of the components created earlier. Notably, as shown in Figure 6, the 3D hologram learning media in this study is box shaped, offering users a wider view, unlike the pyramid-shaped media commonly found. The product was validated by three validators to ensure its feasibility.

Figure 5. Card Design

Figure 6. 3D Hologram Development Result

The implementation stage involved a limited trial at El Sadai Magelang High School with six students. The validity, effectiveness, and practicality of the developed product have been validated (Akker et al., 2007). Validity was confirmed through assessments and validation results obtained from three validators.

The aspects evaluated during the media product validation process included audio–visual clarity and product display. A summary of the results of the media and material product validation is presented in Table 3. According to the validation results, the material aspect achieved an average score of 94.5%, placing it in the high validity category (Sugiyono, 2013). The media aspect received an average score of 85.5%, also falling within the high validity category. Consequently, the overall validation results for the product categorize it as having high validity, with an average score of 90%. The next step involves revising the product on the basis of feedback from the validators. Following these revisions, the product can proceed to testing with students.

Table 3. Product Validity Results

Assessment of Product Quality/Student Response	Assessment Aspects	Score	Average	Category
Material Expert	Suitability with concept	89%	94.5%	High Validity
	Language usage	100%		
Media Expert	Audio Visual Clarity	88%	85.5%	High Validity
	Product Display	83%		
Student	Design	83%	89%	High practicality
	Content	92%		
	Language	92%		

The practicality of the product was gauged by analyzing students' feedback on the product readability questionnaire. The assessment covered various elements, such as the design, content, and language of the product, revealing an average of 89%, placing it in the very practical category (Riduwan, 2011).

The evaluation stage involved feedback from both validators and product users, contributing to the revision of the product until its final form. There are several suggestions from each validator regarding the development of this product. The validator recommends adding instructions for placing the smartphone to ensure that the video display is not inverted when the phone is placed, as shown in Figure 7. A red line at the bottom of the video is created to help users distinguish the bottom position. When the phone is placed in the projector box, users can ensure that the red line is at the bottom, minimizing the possibility of inverted video positions. This instruction is also explained in the product usage video.

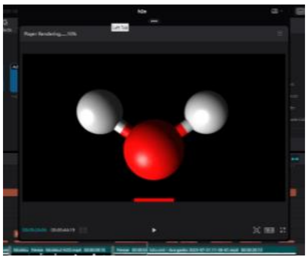

Figure 7. Revised video

A validator also suggests replacing mica with flatter mica so that during product use, the video can be visible. The validator also advises adding explanations to the product usage procedure regarding the use of the box lid, which can be used as a cover for the top part of the phone. This is done to prevent light from entering through the gaps around the phone, thus avoiding interference with the video playback process. This suggestion has been implemented by adding an explanatory video to the product usage procedure. The 3D hologram learning media was evaluated as good and feasible for use in learning chemistry on molecular shapes.

During product testing at El Sadai Magelang High School, six students with varying cognitive levels participated. Users expressed high satisfaction, with 66.67% strongly agreeing that the product facilitated understanding and 41.67% strongly agreeing on its impact resistance and ease of storage. The students reported a fully engaging experience, noting that the holographic 3D molecule seemed genuinely present in the room. They highlighted the particular benefit of this experience in aiding their visualization in three dimensions. Additionally, they emphasized that the 3D object conveyed a greater amount of information than did a two-dimensional representation. Fuadi and Listyorini (2018) noted that 3D hologram media can increase user enthusiasm and increase the desire to learn.

In line with Ninkovic & Adamov's (2023) research, three-dimensional holograms prove to be valuable visualization tools, and their incorporation into chemistry instruction can enhance learning outcomes. The data collected indicate that students hold a positive view of their application. Consequently, the research findings suggest that teachers should integrate 3D holograms into chemistry classes. Moreover, students believe that the implementation of 3D holograms would prove beneficial across various chemical materials, such as the polarity of molecules and general chemistry. Notably, the students expressed an interest in acquiring skills to create 3D holograms themselves.

CONCLUSION

The development of 3D holographic learning media for molecular structure materials, following the ADDIE model, demonstrated high validity, with a score of 90%, and practicality, with a score of 89%, confirming that it is a highly practical and effective tool for teaching chemistry. However, the study faced limitations, such as a small sample size of 6 students and a focus solely on molecular structure, which may restrict the broader application of the findings. The reliance on specific devices and the short implementation period also limit the generalizability and long-term evaluation of the results. Despite these limitations, the findings suggest that 3D hologram media can significantly enhance the learning of abstract concepts, making chemistry more engaging. However, this also emphasizes the need for teacher training in integrating such technologies into their teaching strategies. Future research should involve larger, more diverse samples, explore wider content applications, consider long-term effects, and strive to make the technology more accessible, particularly for underresourced schools.

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