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# Development of Google Sites-based Multiple Representations Learning Media on Benzene and Its Derivatives Topic

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## Abstract

COVID-19 pandemic accelerated the transformation of education and forced the digitalization of education to create effective learning. The understanding of complex chemical structures and reactions holds great significance in the realm of chemistry education. Benzene and its derivatives are particularly challenging topics that require a robust representation approach. The research aims to develop and assess the feasibility of Google Sites-based multiple representations learning media on benzene and its derivatives material. The research utilized the Research and Development (R&D) approach, adhering to the ADDIE (analysis, design, development, implementation, and evaluation) development model. The research was carried out until the development stage. The developed learning media effectively integrated three levels of chemical representation for benzene and its derivatives, utilizing various features such as text, animation, video, 3D molecular simulation, and images. The validation conducted by subject matter and learning media experts indicated that the learning media is valid with scores of 95.8% and 92.5%, respectively, with excellent category. Furthermore, the product quality assessment conducted by teachers and students' responses showed that media could be used practically, with percentages of 95% and 95% as excellent categories. These findings confirm the suitability of the developed learning media for facilitating students' understanding of benzene and its derivatives during the learning process.

Keywords: benzene derivatives, google sites, learning media, multiple representations

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## 1. Introduction

The COVID-19 pandemic has brought about a pivotal educational transformation (Firmansyah et al., 2021). A remarkable transformation is transitioning from conventional in-person instruction to online distance learning (Putri et al., 2021). This change, known as digitization, has transformed how we learn using digital methods and concepts. Digitization allows students to access learning materials from anywhere and offers a variety of digital resources for education (Dilmaç, 2020; Ngongo et al., 2019). Even after the pandemic, digitalization in education will continue to progress, highlighting the importance of digital literacy. Incorporating technology in learning can provide interactive and engaging materials, enhancing the learning experience.

Information and communication technology (ICT) plays a vital role in education by serving as a tool, a source of knowledge, and both a material and tool for learning (Agustian & Salsabila, 2021; Ramli, 2012). It enables collecting, storing, processing, and transmitting information and data through computer networks and the Internet (Kwartolo, 2010). Using technology, we can create interactive learning materials that make learning more exciting and enjoyable (Kaur et al., 2022).

Learning media serves as a tool to convey messages and enhance students' cognitive abilities, attention, and motivation, thereby supporting learning objectives (Suprihatiningrum, 2013). Utilizing technology as a medium for delivering educational content holds greater appeal as it can depict abstract concepts more tangible, potentially influencing student learning outcomes positively (Listantia et al., 2015). Chemistry, a discipline with numerous abstract concepts and topics, challenges learners. It primarily focuses on concepts like molecular structure, chemical reactions, and atomic properties, which are not readily observable (Upahi & Ramnarain, 2019). Consequently, students may face difficulties in comprehending these concepts. One particularly challenging topic in chemistry is benzene and its derivatives, as indicated by studies (Davis, 2010; Isnaini & Ningrum, 2018) and interviews with high school chemistry teachers who acknowledged the need to improve students' understanding of the subject. Students' low test scores further support this observation.

Benzene and its derivatives are essential, particularly in organic chemistry, which focuses on studying their structure, nomenclature, properties, and applications (Harta, 2019). However, the depth of teaching this topic in high school chemistry courses is often inadequate, and some chemistry textbooks for grade XII students contain misconceptions (Topal et al., 2007). Difficulties in understanding organic chemistry arise from challenges in converting molecular formulas (symbolic representations) into accurate three-dimensional molecular structures (submicroscopic representations) based on specific configurations or rules (Isnaini & Ningrum, 2018). Sitorus (2022) has identified issues in the learning process of benzene and its derivatives, encompassing challenges in memorization and applying chemical reactions. The complexity of the structures and reaction mechanisms associated with benzene and its derivatives necessitates strong chemical representation skills (Davis, 2010). A comprehensive understanding of the multiple representations, namely macroscopic, submicroscopic, and symbolic, improves practical chemistry education, particularly in benzene and its derivatives (Kapici, 2023). Therefore, employing multiple representations in learning is crucial to facilitate students' development of a comprehensive understanding of chemistry (Zamhari et al., 2021).

Chemical representations are formulated based on observed phenomena, reaction equations, and models of atoms, molecules, and symbols (Gilbert & Treagust, 2009). However, many students struggle with integrating macroscopic, submicroscopic, and symbolic representations (Isnaini & Ningrum, 2018). To enhance the study of benzene, visualization-based learning tools should be employed. These tools connect different representations, enabling students to observe phenomena, collect data, analyze them, and draw conclusions. This approach facilitates a deeper understanding of concepts beyond mere memorization. Visual-based media effectively improves students' comprehension of submicroscopic representations and their connection to the macroscopic and symbolic levels (Dutton & Loader, 2005; Abdinejad et al., 2021). Previous research on learning media for benzene and its derivatives is limited. Khairiah (2017) developed module-based learning media, which, although an alternative, lacks interactivity and has static visuals. Furthermore, it lacks digital accessibility anytime and anywhere, which is crucial in the current era of digitalization. Sholihah (2021) developed a puzzle educational game for benzene and its derivatives that operates on the Android platform. However, this approach is restricted to Android devices. It lacks compatibility with other devices, such as laptops or PCs, limiting learning flexibility for students without Android devices or with difficulties using them. These issues can be addressed through visual learning media based on Google Sites, offering a solution that overcomes these limitations.

Google Sites is a freely available platform for creating websites suitable for personal and business purposes. It allows users to easily share information with others and collaborate on content, including attachments and data from other Google applications like Docs, Sheets, Forms, and Calendars. Additionally, Google Sites offers up to 100 MB of free online storage and can be searched using the Google search engine. The platform is accessible from various internet-connected devices such as smartphones, tablets, laptops, and computers (Arief, 2017; Azis, 2019). According to Japrizal and Irfan (2021), using Google Sites as a learning media positively impacts students' learning outcomes. This learning media has proven valid, practical, and effective in improving students' academic achievements. Teachers can use Google Sites to offer students a unified and seamless learning experience in education. They can incorporate images, sounds, animations, simulations, and graphics into teaching materials and assignments to make learning more engaging and enjoyable (Wu et al., 2018). Visual elements can facilitate the integration of macroscopic, submicroscopic, and symbolic representations, promoting a meaningful understanding of concepts (Azhar et al., 2019; Dutton & Loader, 2005). This approach helps prevent student disengagement and boredom, creating a more comfortable and enjoyable learning environment (Salic-Hairulla et al., 2020).

The research background highlights the need to investigate learning media development using Google Sites with a multiple representation approach for benzene and its derivatives. The research aims to develop and assess the feasibility of learning media utilizing Google Sites, incorporating multiple representations for benzene and its derivatives. Classroom teachers can use this learning media to facilitate students' understanding of benzene and its derivatives through visualizations of macroscopic, submicroscopic, and symbolic content. Furthermore, it is anticipated that this learning media will enhance student motivation and ultimately improve their learning outcomes in studying benzene and its derivatives.

## 2. Research Method

The research methodology employed in this study follows a research and development (R&D) approach, which aims to create and evaluate a specific product. The product development stages based on this model, as outlined by Siswono (2019), encompass analysis, design, development, implementation, and evaluation. However, this research focuses on the development stage, followed by expert validation, assessment conducted by teachers and students' responses. The developed product in this study is a learning media based on Google Sites, explicitly focusing on benzene and its derivatives and incorporating multiple representations. The product development process is described in detail below.

### 2.1. Analysis

The analysis stage serves as the initial phase in learning media development. Various analyses were conducted, including needs analysis, availability analysis, student analysis, and learning topic analysis. Data for this stage were collected through interviews with high school chemistry teachers in Yogyakarta and an extensive literature review.

### 2.2. Design

The design stage involves the creation of the learning media prototype, encompassing the overall design of the media. In this stage, a prototype of the learning media was developed.

### 2.3. Development

The development stage focuses on transforming the design into the actual product. The product was created following the design established in the previous stage.

### 2.4. Expert Validation

The expert validation process aims to assess the validity of the learning media in conveying chemistry topics. The validation involves subject matter and learning media experts. The subject matter expert is a chemistry lecturer with extensive knowledge of benzene and its derivatives topic, while the learning media expert is an expert who has a good understanding of learning media based on Google Sites. The validation is conducted using a Likert scale questionnaire (Table 1). These experts provided feedback and evaluated the developed learning media based on predefined criteria. The learning media is deemed valid if it meets the established criteria.

### 2.5. Product Assessment

The product was assessed by five chemistry teachers from high schools in Yogyakarta, Indonesia. Additionally, the product was tested on ten students in the twelfth grade from high schools in Yogyakarta, Indonesia, to evaluate its user-friendliness and suitability. Product quality assessment was conducted using a Likert scale questionnaire (Table 1), while student responses were obtained through a Guttman scale questionnaire (Table 2). The assessment results are converted into quantitative data presented as scores. The ideal percentage (%) is calculated using formula (1), while the average score is computed using formula (2), with ΣX representing the total score and N indicating the number of assessors. The average score is used to categorize the eligibility of the media. (Table 3).

$$\% = \frac{The\ average\ score}{The\ highest\ ideal\ score} \times 100\% \quad (1)$$

$$\bar{X} = \frac{\sum X}{N} \quad (2)$$

**Table 1. Guideline for Converting Categories Likert Scale into Scores**

| No | Category | Score |
|---|---|---|
| 1 | Excellent | 4 |
| 2 | Good | 3 |
| 3 | Poor | 2 |
| 4 | Very Poor | 1 |

**Table 2. Guideline for Converting Categories Guttman Scale into Scores**

| No | Category | Score |
|---|---|---|
| 1 | Yes | 1 |
| 2 | No | 0 |

**Table 3. Guidelines for Converting Average Scores into Categories**

| No | Formula | Category |
|---|---|---|
| 1 | $X \geq \bar{X}i + 1.SBi$ | Excellent |
| 2 | $\bar{X}i + 1.SBi > X \geq \bar{X}i$ | Good |
| 3 | $\bar{X}i > X \geq \bar{X}i - 1.SBi$ | Poor |
| 4 | $X < \bar{X}i - 1.SBi$ | Very Poor |

**Ideal average score**
$\bar{X}i$ = 1/2 (ideal max score + ideal min score)
**Ideal standard deviation**
$SBi$ = 1/6 (ideal max score – ideal min score)

## 3. Result and Discussion

### 3.1. Analysis

Based on the needs analysis conducted with high school chemistry teachers in Yogyakarta, it has been identified that students need to enhance their understanding of benzene and its derivatives. The interviews revealed low test scores and highlighted common challenges faced by students in grasping fundamental organic chemistry concepts, comprehending molecular structures, and describing molecules. Consequently, there is a pressing need for the development of learning media to facilitate quicker and more enjoyable comprehension of these topics.

The analysis of availability revealed that teachers had limited utilization of instructional media when teaching the topic of benzene and its derivatives. They acknowledged the existence of digital learning media but lacked the knowledge and understanding of how to create and utilize it effectively. Instead, teachers mainly relied on traditional teaching methods such as lectures and blackboards. Teachers expressed their challenges in explaining benzene and its derivatives concepts due to the lack of visualizations that could enhance students' understanding. Previous research on learning media for benzene and its derivatives was limited. Khairiah (2017) developed module-based learning media, which although providing an alternative, lacked interactivity and had static visuals. Moreover, it was not accessible digitally anytime and anywhere, which is crucial in the digitalization era. Sholihah (2021) developed a puzzle educational game for benzene and its derivatives that operates on the Android platform. However, this approach had limitations as it could only be accessed via Android devices and excluded other devices such as laptops or PCs, reducing flexibility for students without Android devices or those who face difficulties using them. Based on the literature review, interactive learning media with dynamic visuals that can be accessed digitally anytime and anywhere have not been developed for benzene and its derivatives. To address this gap, the proposed solution is to develop learning media based on Google Sites, which offers interactivity, accessibility, and flexibility.

The student analysis results indicate that students have diverse learning style preferences, emphasizing the need for learning approaches to accommodate various learning styles. Multiple representation learning can cater to the needs of students with different learning styles and bridge the gap between teachers' and students' representations, which conventional teaching methods may not achieve (Mallet, 2007). In the context of benzene and its derivatives, there are challenges in the chemistry learning process, including difficulties in memorization and applying chemical reactions (Sitorus, 2022). This topic requires proficiency in chemical representation skills due to the intricate structures and reaction mechanisms involved (Davis, 2010). Hence, incorporating multiple representations in the learning process is crucial to foster students' understanding of benzene and its derivatives. By employing multiple representations, students can engage with the topic from various perspectives, enhancing their comprehension and facilitating the development of a robust understanding of benzene and its derivatives.

The analysis of learning topics in this study was conducted based on the 2017 revised edition of the 2013 curriculum. The learning topics centered explicitly around the comprehensive examination of the structure, nomenclature, properties, and applications of benzene and its derivatives. This analysis aimed to ensure that the developed learning media aligned with the specific content requirements outlined in the curriculum. The learning media could effectively support students' understanding and mastery of the subject by focusing on these critical aspects of benzene and its derivatives. Through this analysis, the researchers aimed to develop a learning resource that covered the essential topics and provided comprehensive and engaging content to enhance students' learning experiences in chemistry.

### 3.2. Design

The design stage of the learning media development process involves developing a website prototype. This stage encompasses various elements, such as planning the website structure, layout, navigation, and content to be presented. The website structure is divided into several pages: the homepage, competencies, learning topics, practice questions, grades, and reference sources. The homepage serves as an introduction to the website, providing information about its purpose and a navigation menu to facilitate user access to other sections. The competencies page presents the intended learning objectives and details the indicators of achievement and skills users are expected to acquire through the learning media. The learning topics page focuses on the specific content related to benzene and its derivatives. It utilizes a combination of text, animation, video, 3D molecular simulation, and images to enhance users' understanding of the topics. Application examples are also included to illustrate the practical aspects of the concepts being taught. The practice questions page offers a set of 20 multiple-choice questions designed to help users reinforce their understanding of the topics. Detailed explanations are provided for each question to clarify any misconceptions. The grades page displays users' performance results after completing the practice questions. It presents the scores obtained and includes a graph to visualize the progress made in each exercise. The reference sources page contains a compilation of the sources used to develop the learning topics. This section ensures the accuracy of the information presented on the website. During the planning phase, a wireframe or rough sketch is developed to outline the website's appearance and functionality (Figure 1). This visual representation is generated using Figma software. Subsequently, the visual design stage involves finalizing the website's visual elements, including color schemes, font choices, and selecting appropriate images (Figure 2). The website design was also developed using Figma software.

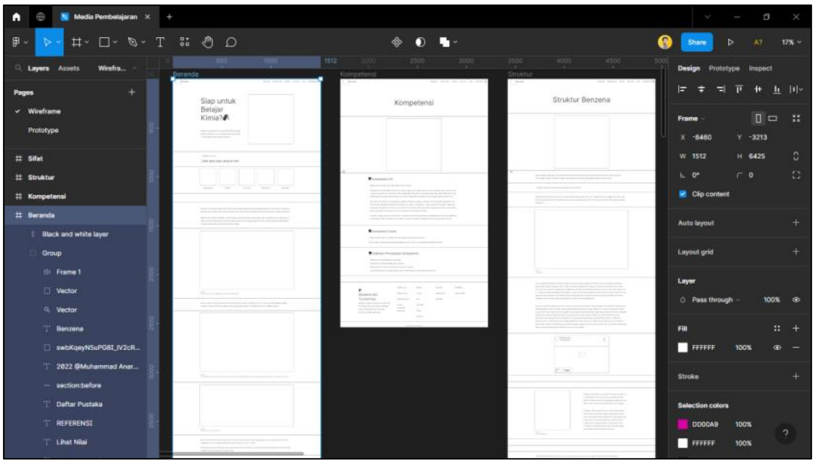


**Figure 1. Development of Website Wireframes Using Figma**

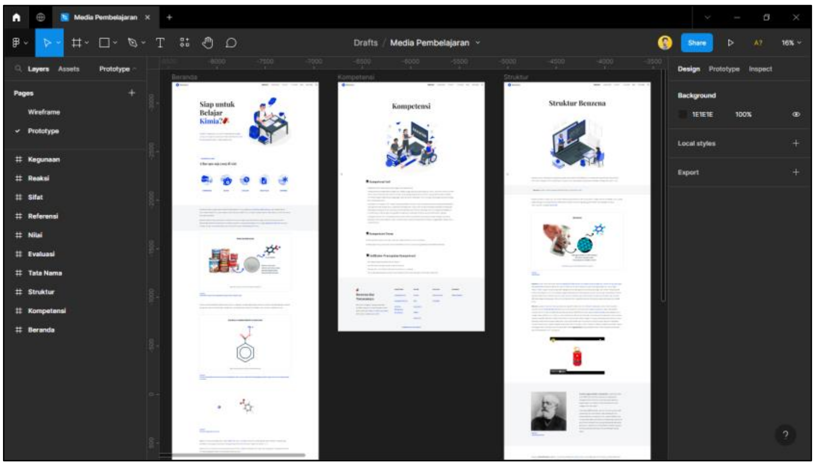


**Figure 2. User Interface Design for Website Using Figma**

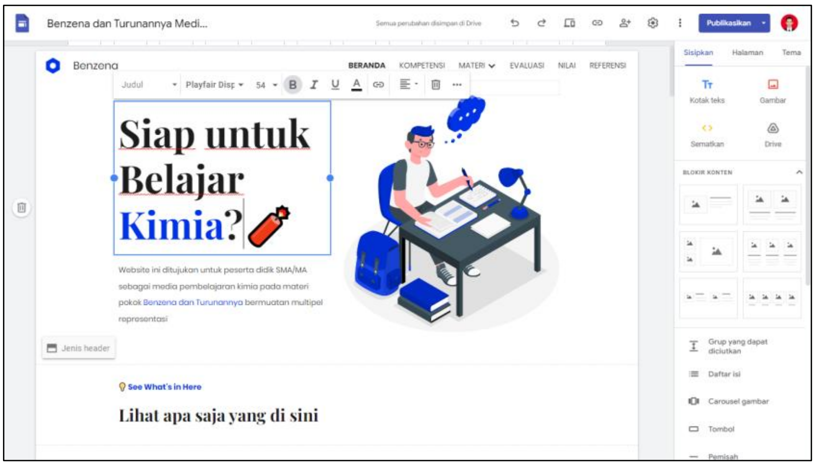


**Figure 3. Website Development on Google Sites**

### 3.3. Development

The development stage involves translating the previously designed prototype into the actual product. In this case, the website was developed using Google Sites, which can be accessed directly through the website address https://sites.google.com/new. Google Sites provides a user-friendly interface for website creation. Developing a website on Google Sites is a straightforward process. The website design will automatically arrange itself neatly by clicking, dragging, or dropping the desired content. All elements of the website, including text, images, and multimedia components, can be easily positioned, resized, or rearranged to achieve the desired layout and organization (Figure 3).

### 3.4. Multiple Representation

The learning media developed on Google Sites incorporates multiple chemical representations engagingly and interactively. These representations are presented through various visualizations, including images, animations, videos, and 3D molecular simulations. By employing multiple representations, students are provided with different perspectives and ways of understanding the topic of benzene and its derivatives.

Macroscopic representation describes phenomena based on human visual perception. Submicroscopic representations depict the arrangement and motion of particles on a scale that is not directly observable, encompassing entities such as molecules, atoms, ions, and electrons. Symbolic representation represents phenomena using symbols, formulas, or equations (Gkitzia et al., 2011).

On the webpage dedicated to the structure of benzene, a macroscopic representation is used to explain that benzene is a clear liquid, colorless in appearance, with a gasoline-like smell. It is also highlighted that benzene is flammable and can evaporate (Figure 4). The submicroscopic representation of benzene showcases the arrangement and motion of particles, including molecules, atoms, ions, and electrons, at a scale that cannot be directly observed. Specifically, the submicroscopic representation reveals a hexagonal ring comprising six carbon atoms, with hydrogen atoms bonded to each carbon atom (Figure 5). The electrons in chemical bonding are distributed and delocalized around the carbon ring, forming pi and sigma bonds (Figure 6). This depiction effectively demonstrates the dynamic movement of these particles, such as the vibrational motion of atoms and the continuous shifting of electron positions within the benzene molecule. Furthermore, a video is utilized to visualize resonance structures, which depict the movement of electrons within compounds, indicating that no single structure can fully describe the compound. It is due to delocalized or moving double bonds (Figure 7). The learning media also includes a 3D simulation of the molecule to support the submicroscopic representation further. Users can manipulate the simulation by rotating, zooming, and exploring various aspects of the benzene molecule, including the carbon-hydrogen bonds and the positions of the atoms. This interactive simulation aims to enhance students' visual understanding of the benzene molecule's structure and its derivatives (Figure 8). Symbolic representation is employed to explain the chemical structure of benzene through its Formula (Figure 9). The symbolic representation includes the chemical Formula $C_6H_6$ and the structure of the benzene ring, represented as a hexagon with a circle inside.

An additional instance of multiple representations can be observed on the web page dedicated to the application of benzene and its derivatives. One of the applications of benzene derivatives is the use of phenol. The macroscopic representation depicts the application of phenol from a perspective visible to the naked eye (Figure 10). Phenol is used as a chemical in the industry for producing phenol-formaldehyde resins in manufacturing plywood and composite materials. In the pharmaceutical industry, phenol produces certain drugs and antiseptics. In medicine, phenol is commonly employed as a local antiseptic and anesthetic. Additionally, phenol finds application in the production of plastics, including polycarbonates and epoxies. Phenol is a colorless-to-white solid when pure. The commercial product is a liquid. Phenol has a distinct odor that is sickeningly sweet and tarry. The submicroscopic representation depicts the application of phenol from the perspective of molecular structure and intermolecular interactions (Figure 10). Phenol possesses hydroxyl (-OH) groups that form hydrogen bonds with other molecules. The hydroxyl groups in one phenol molecule can interact with hydroxyl groups or oxygen atoms in other phenol molecules. The hydroxyl groups (-OH) in the phenol structure also influence its reactivity, enabling its use in various chemical synthesis reactions. The benzene ring structure in phenol provides additional stability to its derivatives, making it suitable for synthesizing various essential chemical compounds. The symbolic representation of phenol employs chemical formulas and molecular formulas to depict the composition and structure of the compound symbolically (Figure 11). The chemical formula of phenol is $C_6H_5OH$, which describes the exact composition of the phenolic compound. By incorporating multiple representations (macroscopic, submicroscopic, and symbolic), the learning media offers students a comprehensive and multi-dimensional understanding of benzene and its derivatives. These representations cater to different learning styles and facilitate a more engaging and practical learning experience.

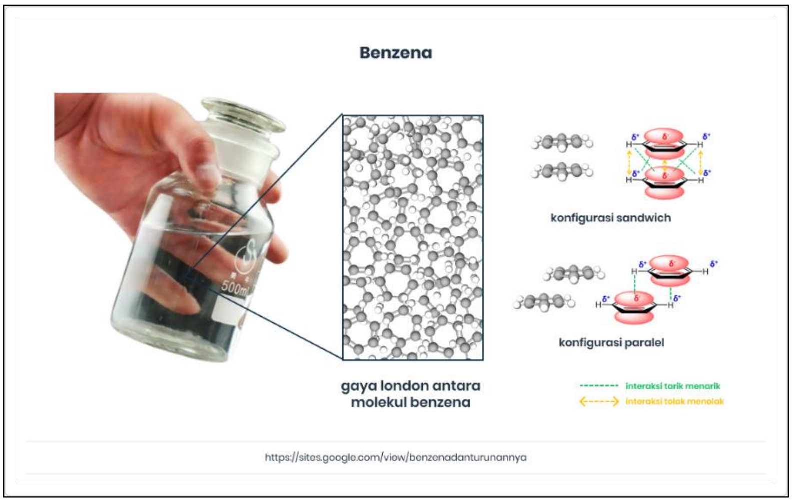


**Figure 4. Macroscopic Representation on The Benzene Structure Page: Benzene Has a Clear Liquid, Colorless in Appearance, With a Gasoline-Like Smell**

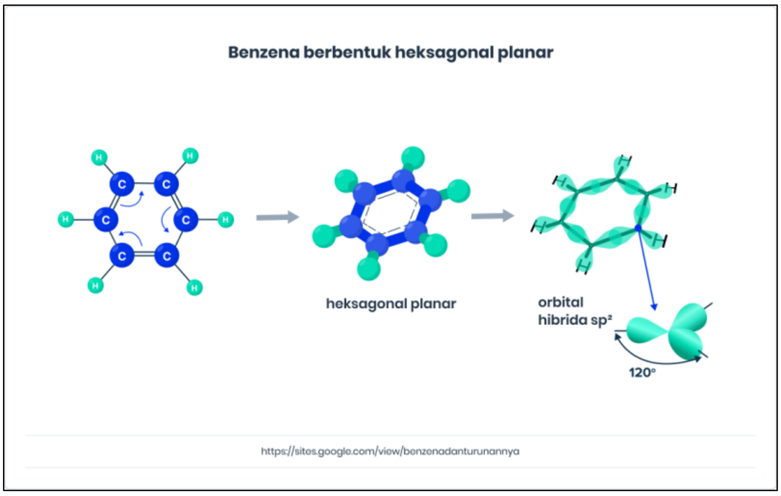


**Figure 5. Submicroscopic Representation on The Benzene Structure Page: Benzene Has a Hexagonal Ring Consisting of Six Carbon Atoms, With a Hydrogen Atom Bonded to Each Carbon Atom**

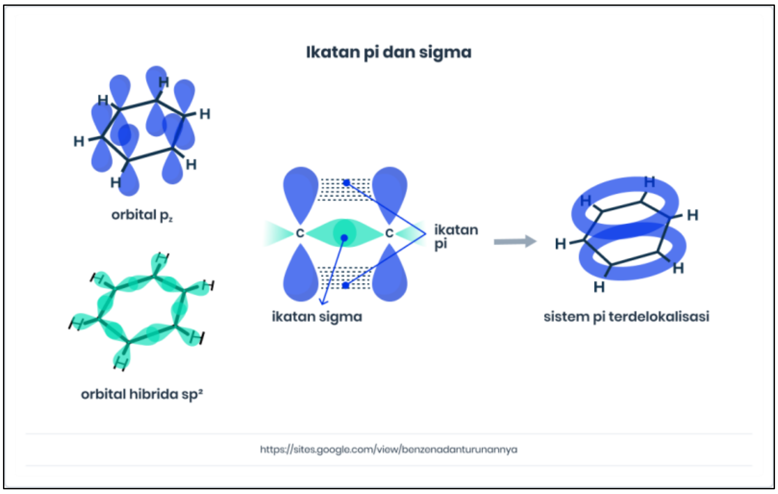


**Figure 6. Submicroscopic Representation on The Benzene Structure Page: Benzene Has Pi and Sigma Bonds**

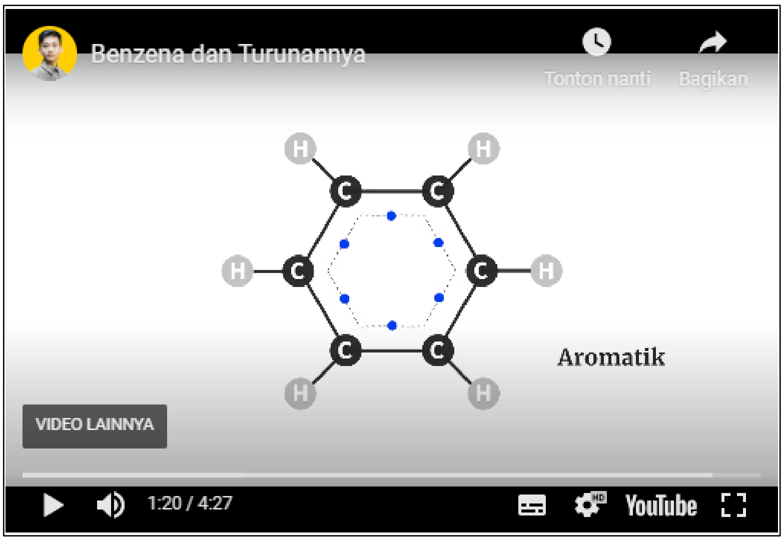


**Figure 7. Submicroscopic Representation on The Benzene Structure Page: Video to Visualize The Movement of Electrons Within Compounds**

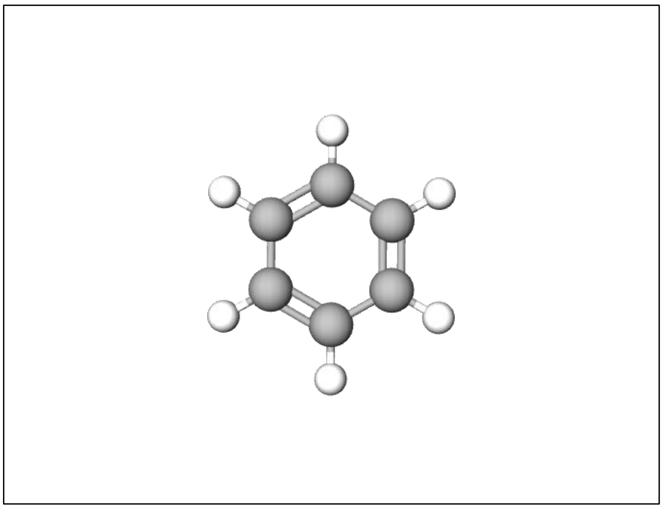

**Figure 8. Submicroscopic Representation on The Benzene Structure Page: 3D Molecular Simulation to Enhance The Visual Understanding of The Structure of The Benzene Molecule**

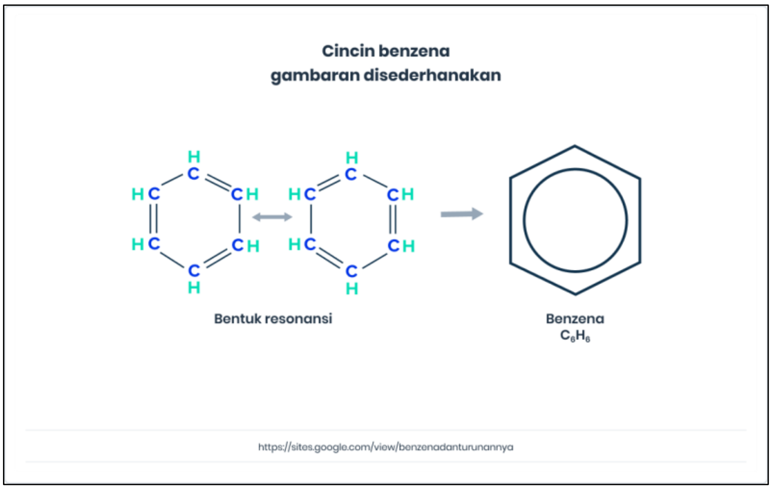


**Figure 9. Symbolic Representation on The Benzene Structure Page: Benzene Has The Chemical Formula $C_6H_6$ and a Benzene Ring Structure, Represented as a Hexagon With a Circle Inside**

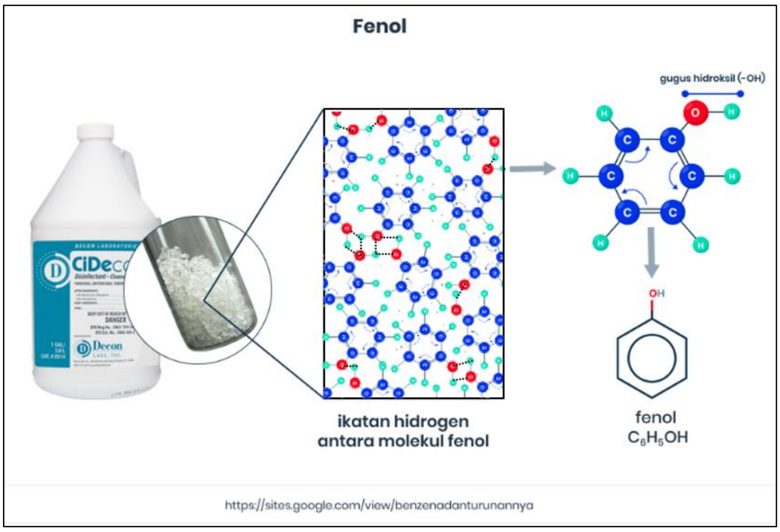


**Figure 10. Macroscopic, Submicroscopic, and Symbolic Representations on The Applications of Benzene and Its Derivatives Page: The Use of Phenol**

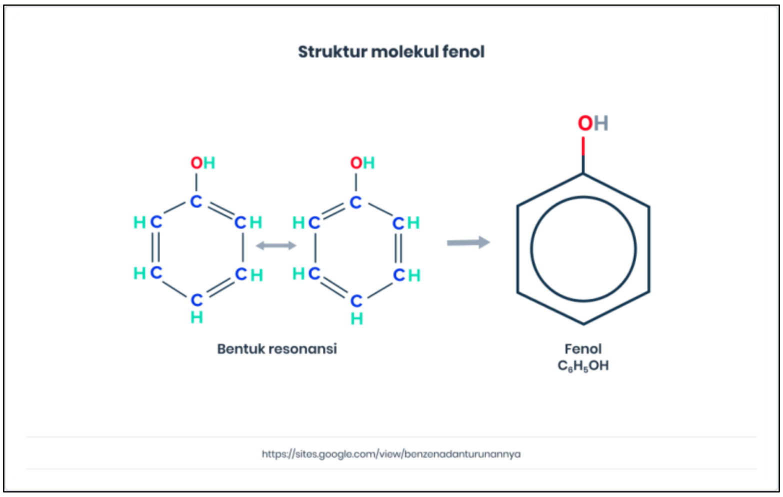


**Figure 11. Symbolic Representation on The Applications of Benzene and Its Derivatives Page: Phenol Has The Chemical Formula $C_6H_5OH$ and Consists of a Benzene Ring Structure With a Hydroxyl Group (-OH) Attached to One of The Carbon Atoms**

### 3.5. Expert Validation

The validation results conducted by subject matter and learning media experts are presented in Figure 12. Subject matter expert lecturers conducted product validation based on their expertise in the subject matter. The validation focused on aspects of content and multiple representation aspects. The overall assessment by the subject matter expert resulted in an ideal percentage of 95.83%, categorizing the learning media as excellent. Similarly, learning media expert lecturers conducted product validation based on their expertise in learning media. The validation focused on utility, navigation, and appearance aspects. The overall assessment by the learning media expert resulted in an ideal percentage of 92.50%, categorizing the learning media as excellent. These assessment outcomes demonstrate that the learning media product is valid for conveying chemistry topics.

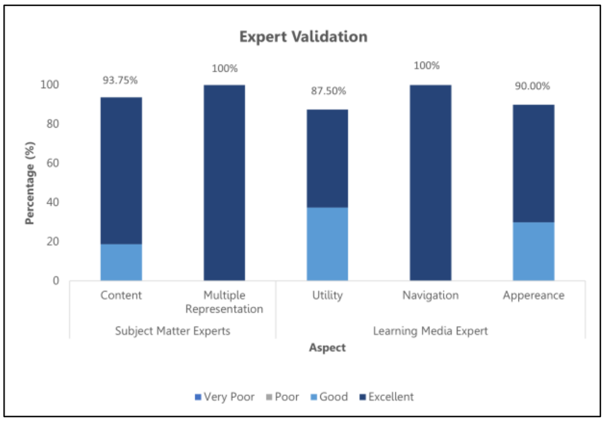


**Figure 12. Expert Validation by Subject Matter Experts and Learning Media Experts**

### 3.6. Product Assessment and Student Response

The product assessment involved five high school chemistry teachers who completed a product assessment questionnaire, while the student response questionnaire was distributed to 10 class XII high school students. The assessment covered various aspects, including content, multiple representations, navigation, utility, and appearance. The evaluation results of the learning media product and the student's responses are presented in Figures 13 and 14.

The assessment results from the high school chemistry teachers yielded an ideal percentage of 95.00%, placing the product in the excellent category. Furthermore, the high school students provided positive responses, achieving an ideal percentage of 95.00%. These outcomes indicate that the learning media product is user-friendly and can be practically applied in the learning process.

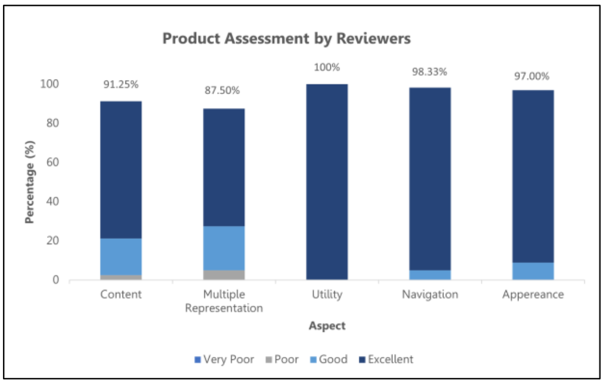


**Figure 13. Product Assessment by Reviewers**

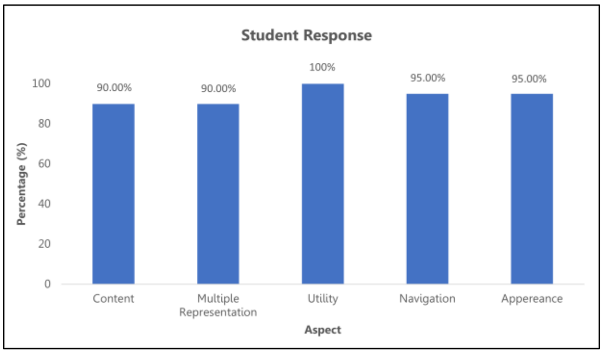


**Figure 14. Student Response**

## 4. Conclusion

The study has successfully developed learning media using Google Sites for benzene and its derivatives, incorporating multiple representations. This learning media encompasses the topic of benzene and its derivatives at macroscopic, submicroscopic, and symbolic levels, utilizing diverse visualizations such as images, animations, videos, and 3D molecular simulations. The learning media product has been deemed suitable for implementation, meeting the criteria for an excellent quality category. This media is considered valid and practical to facilitate students' understanding of benzene and its derivatives during the learning process.

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