

Augmented Reality-Based LKPD Innovation Using Assemblr Edu for Atomic Structure Content

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ABSTRACT: Teaching chemistry on the topic of atomic structure still faces challenges due to its abstract nature and the limitations of teaching materials in visualizing the concept. The use of Assemblr Edu, which provides interactive AR-based three-dimensional (3D) visualizations that are easily accessible via mobile devices, offers an alternative solution. However, previous studies generally still use AR as a standalone medium and have not yet integrated it into structured teaching materials such as student worksheets. This study aims to develop and determine the validity and practicality of AR-integrated LKPD based on Assemblr Edu for atomic structure material. This study is a research and development project using the ADDIE model, limited to the development stage. The research subjects consisted of 1 chemistry teacher, 2 expert validators (content and media), and 20 10th-grade students at SMA N 2 Langsa for the 2024/2025 academic year. The instruments included a needs analysis questionnaire, expert validation, practicality assessment, and validated student response data. Data were analyzed using Aiken's V index and percentages. The results indicate that the worksheets possess high validity with Aiken's V values of 0.86 and 0.88, as well as practicality rates of 90.6% (teacher) and 84.4% (students), both falling into the "very practical" category. Thus, the AR-integrated LKPD based on Assemblr Edu is suitable and practical for use. The novelty of this study lies in the integration of AR into structured instructional materials. This study is limited to testing validity and practicality; therefore, its effectiveness on learning outcomes has not yet been examined.

Keywords: Assemblr Edu, augmented reality, development, LKPD

INTRODUCTION

Technological advancements and innovations in the field of education play a crucial role in the renewal and development of education within a country. With the availability of technology, learning can be tailored to the needs and characteristics of students, making it more effective in achieving learning objectives. The primary goal of learning is to help students achieve competencies through appropriate learning tools, one of which is instructional materials. A teaching resource that can be used to holistically develop students' abilities is the student worksheet (LKPD). LKPDs serve not only as learning guides but also as tools to help students understand concepts independently. The use of well-designed LKPDs allows students to practice critical thinking, problem-solving, and collaboration skills. Furthermore, LKPDs combined with modern technology can increase student engagement in learning, especially in chemistry, which is often considered difficult [1].

Chemistry is a branch of the natural sciences that plays a vital role in the advancement of science. Chemistry involves concepts, reactions and calculations of an abstract nature [2], making it difficult for students to concentrate and understand the subject matter. One such abstract topic is atomic structure, where students are required to be able to accurately depict the structure of an atom. Technological advancements in education, particularly in the use of educational media, have had a significant impact on the teaching and learning process. Technological advancements in education are characterized by the use of various digital educational media, such as computers, the internet, e-learning, and social



media, as well as the latest innovations in mixed reality, virtual reality, and augmented reality (AR). However, learning media utilizing AR are more feasible for implementation in school settings, as AR learning media can be used simply by employing a mobile phone [3].

Augmented reality (AR) significantly enhances chemistry education by transforming abstract concepts into interactive three-dimensional visualizations. This technology allows students to engage with both physical and digital elements, facilitating a deeper understanding of complex topics such as atomic structure and molecular interactions [4]. The integration of AR into educational settings has shown promising results in increasing student engagement and understanding, making learning more dynamic and effective [5]. AR can also visualize complex concepts in real time and promises an engaging and immersive learning experience by combining virtual elements with the real world [6].

One platform that can support the development of Augmented Reality (AR)-based teaching materials is Assemblr Edu. Assemblr Edu is an application designed to help teachers and students create more interactive learning experiences through AR technology [7]. Through this platform, users can create and display three-dimensional (3D) objects and add information or multimedia elements that support the delivery of learning materials [8]. These features allow abstract concepts to be visualized more concretely, thereby making it easier for students to understand the material being studied. Furthermore, the user-friendly interface allows both teachers and students to create AR content without requiring complex programming skills [9]. Consequently, the use of Assemblr Edu serves as a relevant alternative learning medium to support the integration of AR technology into teaching materials, including the development of AR-based worksheets.

Various previous studies have shown that the use of Augmented Reality (AR) in chemistry education can improve students' conceptual understanding and engagement [10]. AR has proven effective in helping to visualize abstract concepts through three-dimensional representations and in enhancing students' motivation to learn. AR allows students to visualize molecular structures and atomic arrangements in three dimensions, making abstract concepts more concrete and easier to understand [11, 12]. Research conducted by Mahendra [13] indicates that approximately 65% of students reported very high levels of learning motivation following the use of AR in instruction. These findings are supported by the results of Son et. al [14], which demonstrate that the use of AR can enhance student engagement and interest in learning, thereby making the learning process more engaging and enjoyable. However, most of these studies still utilize AR as a learning medium that functions as a tool for visualizing concepts [15]. The integration of AR into structured instructional materials, such as student worksheets (LKPD), remains very limited and has not yet been systematically developed. This gap indicates a need for innovative instructional materials that not only utilize AR as a visualization tool but also integrate it into structured learning resources.

Based on the results of a needs analysis conducted through interviews at SMAN 2 Langsa, it was found that the learning process remains conventional, with teaching materials dominated by printed textbooks as the primary source. The learning media used are also limited to PowerPoint presentations and images, making them less effective at capturing students' interest, particularly regarding atomic structure—a topic that requires a high degree of visualization. This situation highlights the need for innovative teaching materials capable of enhancing student engagement and understanding.

Therefore, this study aims to develop augmented reality (AR)-based worksheets using the Assemblr Edu platform for atomic structure material. Unlike previous studies that merely utilized AR as an additional medium or visualization tool, this study integrates AR technology into the worksheets in a structured manner as an integral part of the learning process. Furthermore, the effectiveness of the developed instructional materials will be evaluated through tests of validity, practicality, and student responses. Thus, this study is expected to contribute to the development of innovative instructional materials that integrate technology and pedagogy more comprehensively.

RESEARCH METHODS

Research and Development Methods

This study is a research and development (R&D) project that employs the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation. The ADDIE model was chosen because its systematic and structured stages facilitate the researcher's ability to design, develop, and evaluate learning products in a step-by-step manner [16]. Additionally, this model is flexible and adaptive, making it suitable for developing technology-based instructional materials such as augmented reality [17]. However, this study is limited to the development stage, focusing on the

development and validation of the product. The product developed in this study is an augmented reality-based student worksheet using the Assemblr Edu platform on the topic of atomic structure. The research was conducted at Langsa State High School 2 during the 2024–2025 academic year. The research subjects consisted of 20 tenth-grade students and one chemistry teacher. The sampling technique used was purposive sampling, in which the sample was selected based on specific considerations, particularly students studying atomic structure.

The instruments used in this study included a needs analysis questionnaire, a media and materials expert validation sheet, and a practicality questionnaire. The needs analysis questionnaire used a Guttman scale (Yes/No) to identify the initial learning conditions and the students' needs. Meanwhile, the validation and practicality instruments used a 4-point Likert scale (1–4) to obtain more detailed assessments and avoid neutral responses. The rating scale for the Likert scale is as follows: 4 (strongly agree), 3 (agree), 2 (somewhat disagree), and 1 (disagree).

All research instruments were first validated by expert lecturers to ensure the clarity of the statement items, alignment with the measured indicators, and the appropriateness of their content and construction, so that the instruments could accurately measure the aspects under study. Product validation was conducted by 2 media experts and 2 content experts who are lecturers with expertise in Chemistry Education and learning media. The same validators assessed both aspects to maintain consistency in the evaluation.

The data analysis technique used was quantitative descriptive analysis. Validity was tested using Aiken's V formula, as shown in Equation 1.

$$V = \frac{\sum s}{[n(c-1)]} \quad \text{where } s = r - l_o \dots\dots (1)$$

Notes:

- s = the score assigned by the validator minus the lowest score used
- r = the validator's selected category score
- l_o = the lowest score in scoring category (1)
- n = the number of validators
- c = the number of categories selected by the validator

Aiken's V was calculated for each item and then averaged to obtain the overall validity score. This results were then interpreted into validity categories according to Table 1 [18].

TABLE 1. Criteria Based on the Aiken'V Scale

Aiken'V Scale	Category
$V \leq 0,4$	Invalid / Unreliable
$0,4 < V \leq 0.8$	Valid/Reliable
$0.8 < V$	Highly Valid/Highly Reliable

The practicality analysis was conducted by calculating the percentage of scores obtained from the teacher and student response questionnaires by using the percentage formula in Equation 2 [19].

$$P = \frac{f}{N} \times 100\% \dots\dots (2)$$

Notes:

- P = Percentage of respondents
- f = Number of responses received
- N = Total number of respondents

The percentage results were then interpreted based on practicality criteria according to Table 2 [20].

TABLE 2. Practical Interpretation Criteria

Percentage (%)	Interpretation criteria
81 – 100	Very practical
61 – 80	Practical
41 – 60	Quite practical
21-40	Less practical
0-20	Impractical

Materials and Tools

The materials used were drawn from university textbooks and chemistry textbooks for students. Microsoft Word was used to create the storyboard; the worksheets were designed using Canva; the augmented reality content was developed using the Assemblr Edu platform; and data processing was performed using Microsoft Excel.

Development Procedure

Analysis

At this stage, the main activity carried out is analyzing the needs for the development of teaching materials in accordance with the learning objectives [21]. This involves analyzing materials relevant to the needs of the students and the current curriculum, which includes analyzing needs with chemistry teachers to identify learning obstacles regarding atomic structure, the students' level of understanding, as well as the teaching materials used and the need for more interactive teaching materials. Subsequently, the determination of content, the formulation of instructional objectives, and the development of indicators referencing learning outcomes serve as the basis for the development of the AR-integrated worksheets to support innovative and contextual learning.

Design

The design of worksheets involves drafting worksheets, which includes determining the layout and presentation of learning materials. The worksheet design incorporates engaging images and materials to stimulate students' interest in learning. The design process is guided by the learning materials, learning outcomes, and learning objectives. At this stage, AR content is also designed using the Assemblr platform. The AR content is designed to visualize abstract concepts in atomic structure material in the form of three-dimensional (3D) objects. The design process also includes the creation of a storyboard to serve as a guide in product development. All completed designs are then reviewed and approved by the supervising instructor before proceeding to the development stage.

Development

At this stage, the approved design is developed into a complete student worksheet. The AR content designed using Assemblr Edu is then integrated into the worksheet in the form of a barcode or QR code, allowing students to easily access the AR visualization via mobile devices. The developed product is then tested for suitability by subject matter experts and media experts using a validation questionnaire to determine the level of validity and to serve as a basis for product improvements. Subject matter expert validation focuses on the relevance, accuracy, and depth of the content. Media expert validation emphasizes visual presentation, usability, and technical quality. Subsequently, the product was revised based on the validators' critiques and suggestions to meet feasibility standards. After being deemed feasible and printed, a practicality test was conducted by distributing questionnaires to teachers and conducting a small-scale trial with students to determine the practicality of the developed worksheets.

RESULT AND DISCUSSION

Analysis Stage

The first step in this study was to analyze the needs of chemistry teachers regarding AR-based worksheets integrated with Assembler Edu on the topic of atomic structure. The results of the needs analysis are shown in Table 3.

TABLE 3. Results of the Chemistry Teacher Needs Analysis

Question	SMAN 2 Langsa
1 - 16	100%
Total	100%
Interpretation Criteria	Highly Needed

Based on Table 3, the results of the needs analysis indicate that chemistry teachers have a high need for teaching materials in the form of AR-integrated worksheets based on Assembler Edu, with a 100% percentage falling under the "highly needed" category. The results of the needs analysis indicate that the primary teaching materials used are printed textbooks. Teachers also use PowerPoint presentations and visual aids. However, the use of these media and teaching materials fails to capture students' interest, particularly regarding abstract atomic structure material that requires a high level of visualization.

Teachers need teaching materials that can visualize atomic structure material so that students can more easily and with greater interest understand atomic structure material using AR technology based on Assemblr Edu. The use of AR is expected to increase interest in learning about atomic structure and enhance students' cognitive abilities. This aligns with the findings of Nasution [22], which states that teaching materials must be well-designed and supplemented with content and illustrations to capture students' attention and encourage them to utilize the materials as learning resources. The availability of teaching materials can support the learning process and serve as a medium for interaction between educators and students. Therefore, the development of AR-integrated worksheets based on Assemblr Edu is needed in the chemistry learning process, particularly for atomic structure material. This aligns with the research by Laila [23], which states that the use of Augmented Reality technology in chemistry learning can enhance cognitive engagement and learning motivation, as well as help students understand abstract chemistry concepts through interactive visualization.

Design Stage

During the design stage, the researcher identifies and collects references to be used in developing the worksheets. These references are drawn from various sources, such as university chemistry textbooks, relevant journals, and high school chemistry textbooks that align with the content used in the development of the worksheets. In designing the worksheets, the content is structured based on the Competency Standards and Learning Outcomes for Phase E of the curriculum.

The researchers also collected images to compile and supplement the worksheets. The images are intended to clarify the material described in the worksheets and to capture students' interest [24]. Therefore, the researchers identified, organized, and systematically detailed the appropriate concepts to be taught using the Assemblr Edu -based AR-integrated LKPD for the Atomic Structure material.

Next, the initial design of the LKPD was created. The templates within the LKPD were designed using the Canva application. The use of Canva enhances the design of the LKPD, making it more visually appealing [25]. The template serves as a framework for creating the LKPD front cover, preface, table of contents, instructions for using the LKPD, learning outcomes, learning objectives, content, and bibliography, all organized in the form of a storyboard. The storyboard serves as an initial design to visualize the flow of material presentation and the structure of the learning media so that the process of developing teaching materials can be carried out systematically and purposefully [26].

Development Stage

During the development stage, several steps must be taken, including the development of the worksheets, their validation by experts, and their distribution to chemistry teachers and students to assess their practicality and the students' responses to the worksheets. The results of the development process are shown in Figure 1.

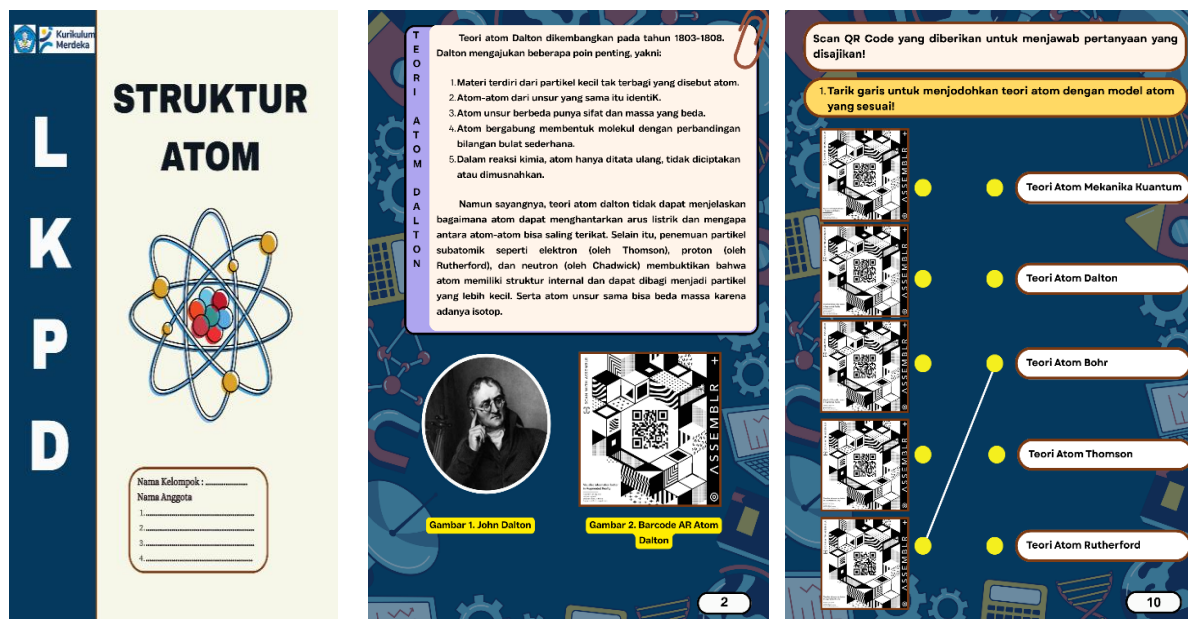


FIGURE 1. Display of the Developed Worksheet

Next, subject matter and media expert validations were conducted to determine the suitability of the AR-based Integrated LKPD using Assemblr Edu for atomic structure content. The results of the subject matter expert validation are shown in Table 4, and the results of the media expert validation are shown in Table 5.

TABLE 4. Material Expert Validation Results

Indicator	Aiken'V Ratings	Category
Material Suitability	0.83	Highly Valid
Content	0.89	Highly Valid
Average Percentage	0.86	Highly Valid

TABLE 5. Media Expert Validation Results

Indicator	Aiken'V Ratings	Category
Design	0.83	Highly Valid
Display	0.92	Highly Valid
Object Balance	0.83	Highly Valid
Sensitive Marker	1.00	Highly Valid
Benefits of Learning	0.83	Highly Valid
Average Percentage	0.88	Highly Valid

Based on the results of the content validation in Table 4, an average Aiken's V score of 0.86 was obtained, indicating that the product falls into the "highly valid" category. Similarly, the results of the media expert validation indicate that the instructional materials possess significant validity, with an average Aiken's V score of 0.88, as presented in Table 5, which falls into the "highly valid" or "highly suitable" category.

Based on the above results of content and media expert validation, the developed worksheets have met the criteria for suitability and can be effectively used because they facilitate students' understanding of the material and enhance their learning motivation. These findings align with the research by Apertha [1], which explains that one of the functions of worksheets is to increase students' interest in learning, facilitate understanding of the material, and capture attention during the learning process. Regarding the visual aspect, after revisions were made, an Aiken'V score of 0.92 was obtained, meeting the "highly valid" criterion, meaning the worksheets have an attractive layout, appropriate color schemes, and easily understandable images. This is also supported by the research by Lestari [27], which states that the selection of attractive designs and colors can enhance students' motivation in participating in learning activities. Next is the level of practicality of the developed worksheets. The practicality results can be seen in Table 6.

TABLE 6. Practicality Results Data

Indicator	Percentage (%)	Category
Design	87.5	Very Practical
Contents	100	Very Practical
Suitability of the material	75	Practical
Material accuracy	87.5	Very Practical
Presentation technique	100	Very Practical
Presentation of learning	75	Practical
Language Rules	100	Very Practical
Benefits	100	Very Practical
Average Percentage	90.6	Very Practical

Based on Table 6, the practicality results indicate that the AR-integrated worksheets based on Assemblr Edu fall into the "highly practical" category, making them suitable for use as instructional materials. The high level of practicality of these worksheets is supported by systematic presentation techniques, an attractive design, and the use of clear and easy-to-understand language. Additionally, the integration of augmented reality via barcodes/QR codes enables quick access to visualizations without requiring complex additional devices. Thus, the use of the Assemblr Edu platform contributes to the ease of implementing the worksheets in the learning process.

This aligns with the findings of Heni [28] and Tanjung [29], who state that instructional materials are considered practical if they receive a “good” rating and are easy for users to use. This practicality is reflected in ease of use, clarity of instructions, and the smooth operation of the worksheets when implemented in the classroom. Thus, the developed worksheets are not only valid but also practical in supporting more effective and interactive learning.

Furthermore, the level of student response to the AR-integrated worksheets based on Assemblr Edu on atomic structure material can be seen from the results of the student response questionnaire, which consists of statements regarding the worksheets developed by the researcher. The results of the student responses can be seen in Table 7.

TABLE 7. Data on the Results of Student Response Assessment

Indicator	Percentage (%)	Category
Guidelines for the Use of Teaching Materials	83	Very Practical
LKPD	86	Very Practical
<i>Assemblr Edu</i>	81	Very Practical
Benefits	87.5	Very Practical
Average Percentage	84.4	Very Practical

Based on Table 7, the Assemblr Edu-based AR-integrated worksheets on atomic structure were rated as highly practical, with an average score of 84.4%. This positive response from students indicates that the developed worksheets are engaging and easy to use in the learning process. The integration of AR in the form of interactive visualizations provides a more engaging learning experience, thereby increasing student engagement in the learning process. This finding aligns with the view that the practicality of instructional materials is directly related to their effectiveness in helping students understand the subject matter. Materials with an appealing design and user-friendly interface provide a more enjoyable learning experience, making it easier for students to grasp the concepts being taught [30].

The high practicality and validity of the worksheets can be explained through multimedia learning theory and dual coding theory, which emphasize the importance of integrating visual and verbal elements in learning. AR enables 3D visualization that aids in the formation of mental representations of abstract concepts. AR combines visual elements with textual information, which can improve understanding and retention of complex subjects such as science [31, 32].

The results of this study align with various previous studies that have developed Augmented Reality (AR)-based chemistry instructional materials. Research by Yamtinah [33], Tuta [34], Kartini [35] indicates that AR-based instructional materials have a very high level of validity, with validation scores falling into the “highly valid” category, exceeding 0.90. These findings are consistent with the results of this study, where the developed worksheets also demonstrated a high level of validity based on Aiken’s V. Additionally, the use of the Assemblr Edu platform in chemistry education has been studied by Oktaviani [36], and Pamenang [37] indicating that AR-based learning media are not only practical to use but also support learning in abstract subjects. These results align with this study, which shows that AR-integrated worksheets possess a high level of practicality.

Furthermore, the use of AR in chemistry learning contributes to increased motivation, learning interest, and students’ multirepresentational abilities. Although this study has not yet tested these aspects of effectiveness, the findings regarding high validity and practicality demonstrate the potential of AR-based worksheets to support more interactive and meaningful learning [38, 39, 40].

Assemblr Edu makes a significant contribution to the visualization of atomic structures through the use of Augmented Reality technology, which presents interactive and dynamic three-dimensional (3D) models. This allows students to observe, manipulate, and explore atomic representations directly in three-dimensional space, which ultimately helps improve understanding of abstract chemical concepts and encourages engagement and spatial reasoning in the learning process [41, 42]. This demonstrates that Assemblr Edu functions not only as a visualization tool but also as a medium supporting experiential learning [43].

This study makes a new contribution to the development of chemistry teaching materials by integrating Augmented Reality (AR) technology into Student Worksheets (LKPD) in a structured manner using the Assemblr Edu platform. Unlike previous studies, which generally utilized AR as a standalone

learning medium, this study positions AR as an integral part of learning activities within the LKPD. This integration allows students not only to access visualizations of abstract concepts but also to engage in a systematic learning process through guided activity stages. Furthermore, this study specifically developed AR-based LKPDs on atomic structure material at the secondary chemistry education level, which has long been known for its high level of abstraction. Thus, this study expands the approach to utilizing AR in chemistry education from merely a visualization medium to an integrated pedagogical component within instructional materials.

This study has several limitations. First, this study was conducted on a limited scale with a relatively small number of respondents, so the generalizability of the results remains limited. Second, this study focused on product development and testing the validity and practicality of the worksheets; therefore, it did not examine the effectiveness of the worksheets in improving students' learning outcomes and motivation. Therefore, future research is recommended to conduct a large-scale pilot study involving more subjects and using an experimental design to comprehensively test the effectiveness of augmented reality-based worksheets in improving students' learning outcomes and motivation.

CONCLUSION

This study aims to develop augmented reality-based worksheets using the Assemblr Edu platform for atomic structure material. The results show that the developed worksheets have a high level of validity based on expert assessment, with Aiken's V values of 0.86 and 0.88, which fall into the "highly valid" category. Additionally, the practicality test results indicate that the worksheets fall into the "highly practical" category based on feedback from teachers and students. These findings suggest that the developed AR-based worksheets are suitable for use as instructional materials in chemistry education, particularly for abstract topics like atomic structure. The contribution of this study lies in the development of instructional materials that integrate augmented reality technology into worksheets in a structured manner, thereby supporting more interactive presentation of chemistry content. However, this study has limitations because it has not yet tested the effectiveness of the worksheets on student learning outcomes. Therefore, future research is recommended to examine the influence of using AR-based worksheets on improving student learning outcomes and critical thinking skills through a more comprehensive experimental design.

Authors' contribution

- **Conceptualization:** Shayda Agustina; Hasby; Cyndi Prasetya
- **Data curation:** Shayda Agustina
- **Formal Analysis:** Shayda Agustina; Hasby; Cyndi Prasetya
- **Funding acquisition:** Shayda Agustina
- **Investigation:** Shayda Agustina
- **Methodology:** Shayda Agustina; Hasby; Cyndi Prasetya
- **Project administration:** Shayda Agustina
- **Resources:** Shayda Agustina
- **Software:** Shayda Agustina
- **Supervision:** Hasby; Cyndi Prasetya
- **Validation:** Hasby; Cyndi Prasetya
- **Visualization:** Shayda Agustina
- **Writing – original draft:** Shayda Agustina
- **Writing – review & editing:** Hasby; Cyndi Prasetya

All authors have read and agreed to the published version of the manuscript.

Ethics Statement

This research involved human subjects who had given informed consent to participate. All participants received treatment in accordance with their rights, dignity, and applicable research ethics principles.

Data availability statement

All data sets were generated or analyzed in the current study.

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Conflicts of Interest

The authors declare no conflicts of interest.

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