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Development of VIRUSCAPE learning media: learning viruses through scrapbooks, augmented reality, and crossword puzzles

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Article

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Abstract

This study aimed to develop VIRUSCAPE (Virus Scrapbook, Augmented Reality, and Crossword Puzzle) as an innovative multimodal learning medium for virus material in senior high school biology learning. The study employed a Research and Development (R&D) approach using the 4D model consisting of Define, Design, and Develop stages. The developed media integrated scrapbook-based visual learning, Augmented Reality (AR)-assisted visualization, and crossword puzzle educational games into one instructional framework. Data were collected through interviews, questionnaires, and expert validation sheets involving one material expert and one media expert. Quantitative data were analyzed descriptively using feasibility percentage calculations, while qualitative data from validator suggestions were analyzed descriptively for product improvement. The results demonstrated that VIRUSCAPE obtained a material expert validation score of 95.45% and a media expert validation score of 84.72%, both categorized as "Very Feasible." The findings indicate that the developed media successfully fulfilled important instructional criteria, including scientific accuracy, visual attractiveness, interactivity, and curriculum relevance. The integration of visual, digital, and game-based learning components effectively supported students' conceptual understanding and engagement in learning abstract virus concepts. The novelty of this research lies in the integration of scrapbook media, AR technology, and crossword puzzle activities into a single multimodal biology learning medium. This study contributes to science education literacy by providing an innovative instructional alternative capable of improving meaningful learning experiences, student participation, and conceptual understanding in biology education.

INTRODUCTION

The rapid development of educational technology and the demands of 21st-century learning require educators to design innovative instructional media capable of improving student engagement, conceptual understanding, and learning motivation. In science education, particularly biology, instructional media play a crucial role in facilitating the delivery of abstract concepts that cannot be directly observed by students. Effective learning media not only support the transfer of knowledge but also help learners construct meaningful understanding through visual, interactive, and contextual learning experiences. Biology learning frequently involves microscopic and complex concepts that are difficult to comprehend through conventional teaching methods alone, making media integration increasingly essential in modern classrooms [1].

One of the biology topics considered difficult for high school students is virus material. Viruses are microscopic entities with complex structures, classifications, and replication mechanisms that cannot be observed directly without technological assistance. The topic includes several abstract subtopics, such as viral structure, viral morphology, and replication processes involving lytic and lysogenic cycles. These concepts often create misconceptions and learning difficulties among students when instruction relies primarily on textbooks, lectures, or static presentation slides. Traditional instructional approaches tend

to limit students' opportunities to visualize biological processes dynamically, resulting in low conceptual understanding and reduced learning interest [2].

Previous studies have shown that students frequently experience difficulties distinguishing between lytic and lysogenic replication cycles because both processes involve invisible and sequential biological mechanisms. In addition, limited use of interactive instructional media contributes to passive learning behavior and low classroom participation. Conventional media such as PowerPoint presentations and printed textbooks are often insufficient to facilitate deep conceptual understanding because they provide limited opportunities for active interaction and visualization. Consequently, students tend to rely solely on imagination when studying virus-related concepts, leading to fragmented understanding and decreased motivation toward biology learning. These findings indicate the importance of developing innovative and interactive learning media capable of visualizing abstract biological processes and improving students' active engagement during science learning activities [3].

To address these challenges, educational researchers have increasingly explored the integration of visual and digital technologies in science learning. One technology that has gained significant attention is Augmented Reality (AR). AR enables the integration of virtual two-dimensional or three-dimensional objects into real-world environments in real time through digital devices such as smartphones or tablets. In biology education, AR has been reported to improve students' conceptual understanding, motivation, and engagement because it allows learners to visualize microscopic or abstract biological phenomena more concretely. Research conducted demonstrated that AR-based learning environments positively influence student interaction and conceptual comprehension in science learning [4]. Similarly, previous studies have found that AR technology supports immersive and interactive learning experiences, thereby enhancing students' understanding of scientific concepts [5].

In addition to digital technology, visual-based printed media also contribute significantly to improving biology learning. Scrapbook-based instructional media have been identified as effective tools for presenting learning content through attractive combinations of images, illustrations, colors, and concise explanations. Such media facilitate information processing through visual representation and help students retain information more effectively. Previous research revealed that scrapbook media can increase student interest and motivation because of their creative and engaging presentation style [6]. Furthermore, game-based learning approaches, such as crossword puzzles, have been widely recognized for their ability to reinforce conceptual understanding while creating enjoyable learning experiences. Game-based instructional activities can improve students' engagement, motivation, and active participation during learning through interactive problem-solving experiences [7]. Educational games such as crossword puzzles encourage active participation and improve biology learning outcomes by supporting collaborative and problem-solving learning activities [8].

Several previous studies have independently examined the effectiveness of AR, scrapbook media, and crossword puzzles in educational settings. Developed AR-based biology learning media for virus materials and reported high feasibility and effectiveness in improving conceptual understanding [9]. Another study demonstrated that scrapbook media were valid and practical as supplementary instructional tools for virus learning [10]. Meanwhile, crossword puzzle media effectively increased student participation and reinforced understanding through educational games [11]. However, most previous studies focused on a single type of instructional media and rarely integrated multiple learning modalities into one comprehensive instructional system.

Despite the growing number of studies on AR and visual learning media, a significant research gap remains regarding the integration of multimodal instructional media that simultaneously combine printed visual materials, digital interactive visualization, and game-based evaluation within biology learning. Existing studies generally examine AR, scrapbook media, or educational games separately, resulting in limited exploration of how multimodal integration can optimize conceptual understanding and student engagement simultaneously. Moreover, limited studies specifically address virus learning

through integrated multimodal approaches that focus on visualizing lytic and lysogenic cycles, which are consistently identified as the most difficult concepts for students.

Based on these considerations, this study aimed to describe the development process of VIRUSCAPE (Virus Scrapbook, Augmented Reality, and Crossword Puzzle) as an integrated multimodal learning medium for biology learning on virus materials for senior high school students. VIRUSCAPE combines scrapbook-based visual learning, AR-assisted three-dimensional visualization, and crossword puzzle activities into a single instructional framework. This integration is intended to provide a more interactive, meaningful, and student-centered learning experience while facilitating students' conceptual understanding of abstract virus concepts.

The novelty of this research lies in the integration of three different instructional approaches—scrapbook visual media, Augmented Reality technology, and crossword puzzle-based educational games—into a single multimodal biology learning medium specifically designed for virus materials. Unlike previous studies that focused on only one instructional medium, VIRUSCAPE provides a comprehensive learning environment that integrates visual representation, digital interaction, and game-based reinforcement simultaneously. This study therefore contributes a novel multimodal instructional innovation that addresses conceptual difficulties in virus learning while enhancing student engagement and learning motivation in biology education.

RESEARCH METHOD

This study employed a Research and Development (R&D) approach using the 4D development model [12]. The 4D model consists of four stages: Define, Design, Develop, and Disseminate. However, this study was limited to the Develop stage due to time and resource constraints, with the primary focus directed toward producing a valid and feasible learning medium for biology instruction. The research aimed to develop and validate VIRUSCAPE (Virus Scrapbook, Augmented Reality, and Crossword Puzzle) as an innovative multimodal learning medium for teaching virus material in senior high school biology.

The study was conducted from January to April 2026 at a senior high school in East Java, Indonesia. The research subjects consisted of expert validators selected purposively based on their academic expertise and professional experience. The validators included one biology education expert and one educational media expert. The object of the study was the VIRUSCAPE learning media developed for Grade X biology learning on virus materials. The development procedure followed the stages of the 4D model as follows:

Define Stage

The define stage was conducted to identify instructional problems and determine the learning needs that formed the basis for developing VIRUSCAPE. Several analyses were carried out at this stage, including curriculum analysis, learner analysis, concept analysis, and needs analysis. Curriculum analysis was performed by reviewing the biology curriculum related to virus material for senior high school students to identify relevant learning objectives and competencies. Learner analysis was conducted to identify students' characteristics, learning preferences, and learning difficulties in studying virus concepts. Concept analysis focused on identifying essential concepts related to virus structure and replication processes that would be integrated into the learning media. Needs analysis was conducted through interviews with biology teachers and classroom observations to identify problems encountered during biology learning activities and the need for interactive instructional media.

Design Stage

The design stage focused on planning the structure and instructional components of the VIRUSCAPE learning media based on the results obtained from the define stage. At this stage, the learning materials, media layout, visual appearance, navigation flow, and instructional activities were systematically designed. The media framework consisted of scrapbook-based visual learning content,

Augmented Reality (AR)-assisted slide cards, and crossword puzzle activities. In addition, the storyboard and prototype design of the media were prepared to guide the product development process. Research instruments, including expert validation sheets and user response questionnaires, were also designed during this stage.

Develop Stage

The develop stage involved the process of producing, validating, and revising the VIRUSCAPE learning media. The initial product prototype was developed according to the design specifications prepared in the previous stage. The scrapbook component was developed using visual learning principles, while the AR component was designed to provide three-dimensional visualizations related to virus structures and replication processes. Crossword puzzle activities were prepared as game-based evaluation tools to support conceptual reinforcement.

After the product prototype was completed, expert validation was conducted to evaluate the feasibility of the developed media. The validation process involved one material expert and one media expert. The material expert assessed aspects related to scientific accuracy, curriculum relevance, language clarity, and appropriateness of the learning content. Meanwhile, the media expert evaluated the visual design, technical quality, navigation consistency, interactivity, and usability of the media. Feedback, suggestions, and comments obtained from the validators were subsequently used as references for revising and improving the product before the final version of the media was produced.

Research Instruments

The instruments used in this study consisted of needs analysis questionnaires, material validation sheets, and media validation sheets. The instruments were developed based on instructional media evaluation criteria adapted from previous educational media studies and relevant literature. The material validation instrument included five assessment aspects [13]: (a) content feasibility, (b) depth and breadth of material, (c) scientific accuracy and up-to-dateness, (d) integration of material with media components, and (e) language and readability. The instrument consisted of 11 statement items measured using a four-point Likert scale. The media validation instrument included five assessment aspects: (a) visual design and appearance, (b) technical quality, (c) interactivity and attractiveness, (d) navigation consistency, and (e) suitability of media with learning objectives. The instrument consisted of 11 statement items measured using a four-point Likert scale. The scoring rubric used in both validation instruments is presented in Table 1.

Table 1. Likert Scale Scoring Rubric for Expert Validation Instruments

Score	Category
4	Very Good
3	Good
2	Poor
1	Very Poor

Data Collection Techniques

Data were collected through interviews, questionnaires, and expert validation sheets. Interviews with biology teachers were conducted during the needs analysis stage to identify learning difficulties and instructional media needs. Quantitative data were obtained from expert validation scores, while qualitative data were obtained from comments, suggestions, and recommendations provided by validators.

Data Analysis Techniques

The collected data were analyzed using descriptive quantitative and qualitative techniques. Quantitative data from validation sheets were analyzed by calculating the percentage of feasibility using the following formula:

$$P = \frac{\sum X}{\sum Xmax} \; x \; 100\%$$

Where:

P = Feasibility percentage
∑X = Total score obtained
∑Xmax = Maximum possible score

The feasibility percentages were interpreted using the criteria adapted [14], as presented in Table 2.

Table 2. Feasibility Criteria for Learning Media Validation

Percentage	Feasibility Category
85% - 100%	Very Feasible
70% - 84%	Feasible
55% - 69%	Moderately Feasible
<55%	Not Feasible

Qualitative data obtained from validator comments and suggestions were analyzed descriptively and used to improve the quality of the developed learning media. The validity of the findings was strengthened through triangulation of quantitative validation results and qualitative feedback from expert validators to ensure consistency and credibility of the evaluation process.

RESULTS AND DISCUSSION

Results

This study successfully developed VIRUSCAPE (Virus Scrapbook, Augmented Reality, and Crossword Puzzle) as an innovative multimodal biology learning medium for virus material in Grade X senior high school. The development process employed the 4D model consisting of the Define, Design, and Develop stages. The resulting product integrated scrapbook-based visual learning, Augmented Reality (AR)-assisted visualization, and crossword puzzle educational games into one comprehensive instructional medium.

At the define stage, preliminary analysis revealed several instructional problems in virus learning. Based on interviews with biology teachers and observations during classroom learning, students experienced difficulties understanding abstract concepts related to virus structures, classifications, and replication mechanisms, particularly the lytic and lysogenic cycles. The learning process was still dominated by lecture-based instruction and textbook usage, causing students to become passive during learning activities. Similar findings, who emphasized that abstract scientific concepts require interactive visualization to facilitate meaningful learning experiences [15].

The needs analysis also showed that students preferred learning media containing visual illustrations, digital interaction, and game-based activities. Therefore, VIRUSCAPE was designed as an integrated multimodal learning medium capable of accommodating various student learning styles through visual, technological, and interactive learning components (Figure 1).

During the design stage, the structure and components of the media were systematically arranged. The scrapbook component was designed to present concise virus material accompanied by attractive illustrations and colorful visual layouts (Figure 2). The AR component was developed through marker-based slide cards that displayed three-dimensional visualizations of virus structures and replication processes when scanned using smartphones (Figure 3). Meanwhile, crossword puzzle activities were developed as educational games to reinforce students' conceptual understanding and learning motivation (Figure 4).

Figure 1. VIRUSCAPE: Integrated Scrapbook, Augmented Reality, and Crossword Puzzle Learning Media for Virus Material

VIRUSCAPE Scrapbook Media

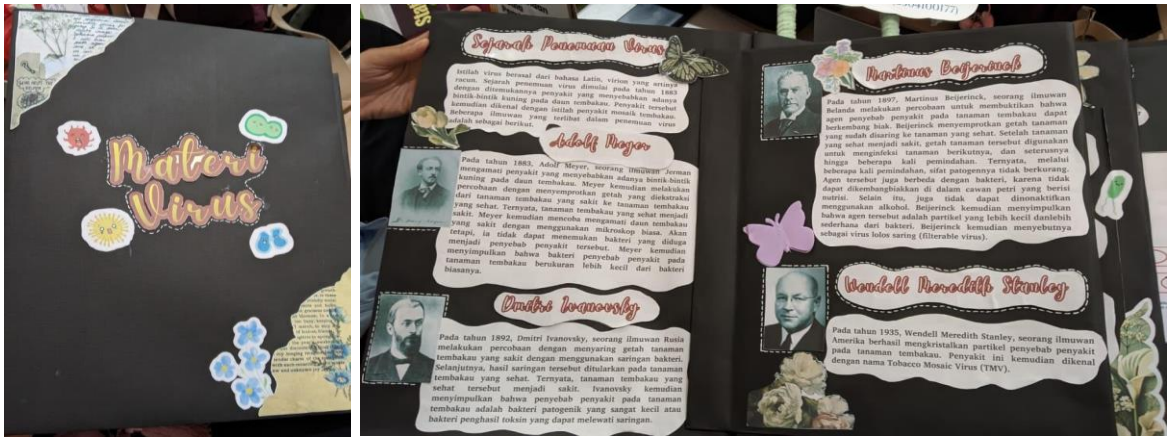

Figure 2. VIRUSCAPE Scrapbook-Based Learning Media

The scrapbook component presented virus material through visual explanations, diagrams, pop-up illustrations, and concise conceptual summaries. The media was designed to increase students' interest and facilitate understanding through visual representation. Scrapbook-based learning media can improve student motivation and conceptual retention because visual information is processed more effectively compared to text-only instructional materials [6].

VIRUSCAPE Augmented Reality (AR) Slide Cards

Figure 3. VIRUSCAPE Augmented Reality (AR) Learning Component

The AR slide cards enabled students to interact directly with three-dimensional virus objects and replication animations. Through smartphone scanning, students could observe virus morphology and replication mechanisms dynamically, allowing abstract biological processes to become more concrete and understandable.

VIRUSCAPE Crossword Puzzle Activity

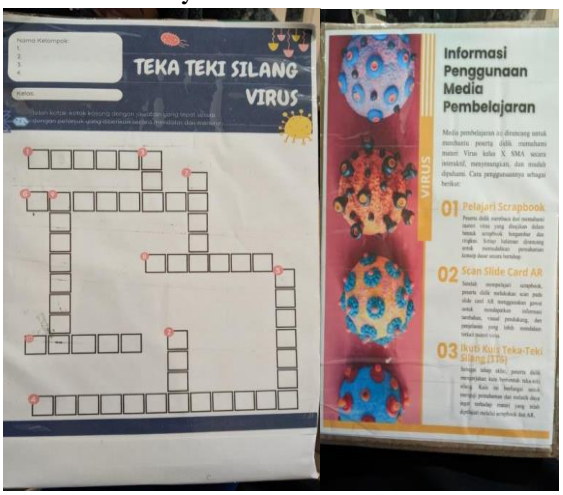

Figure 4. VIRUSCAPE Crossword Puzzle Educational Activity

The crossword puzzle component functioned as an educational game designed to reinforce students' understanding of biological terminology and virus-related concepts. The game-based activity encouraged active participation and provided a more enjoyable learning experience.

The developed media was subsequently validated by one material expert and one media expert. The material validation focused on content feasibility, scientific accuracy, curriculum relevance, conceptual clarity, and language readability. The material expert validation result is presented in Table 3.

Table 3. Material Expert Validation Results

Assessment Aspects	Maximum Score	Obtained Score
Content Feasibility	12	11
Depth and Breadth of Material	8	7
Scientific Accuracy and Up-to-Dateness	8	8
Integration of Material with Media	8	8
Language and Readability	8	8
Total	44	42

The results demonstrated that VIRUSCAPE obtained a total score of 42 out of a maximum score of 44, resulting in a feasibility percentage of 95.45%, which was categorized as "Very Feasible." The high validation score indicates that the developed learning media possessed strong scientific validity, appropriate curriculum alignment, and understandable language suitable for senior high school students.

Media expert validation was also conducted to evaluate visual appearance, technical quality, media usability, navigation consistency, and interactivity. The media expert validation result is presented in Table 4.

Table 4. Media Expert Validation Results

Assessment Aspects	Maximum Score	Obtained Score
Visual Design and Graphics	24	19
Technical Quality	24	21
Interactivity and Student Engagement	8	7
Suitability with Learning Objectives	16	14
Total	72	61

The results showed that VIRUSCAPE obtained a score of 61 out of a maximum score of 72, resulting in a feasibility percentage of 84.72%, categorized as "Very Feasible".

Based on validator suggestions, revisions were conducted to improve color consistency, font readability, image clarity, and navigation instructions for AR usage. These improvements enhanced the usability and visual quality of the developed media.

Discussion

The findings of this study demonstrate that VIRUSCAPE is highly feasible as a multimodal learning medium for biology learning on virus material. The high validation results from both material and media experts indicate that the integration of scrapbook media, Augmented Reality (AR) technology, and crossword puzzle educational games successfully fulfilled important instructional criteria, including scientific accuracy, visual attractiveness, interactivity, usability, and curriculum relevance [16].

The high material validation score reflects that the developed media effectively presented virus concepts in a scientifically accurate and understandable manner. Biology learning frequently involves abstract concepts that cannot be directly observed directly, particularly virus morphology, classification, and replication mechanisms [17]. Such abstract concepts often create misconceptions and cognitive difficulties among students when instruction relies mainly on lectures and textbooks [18]. AR visualization helps transform abstract concepts into more concrete and observable learning experiences, thereby improving students' cognitive understanding and reducing cognitive load [19].

The integration of scrapbook media and AR visualization within VIRUSCAPE supported meaningful learning processes by combining visual representation, concise conceptual explanations, and interactive digital experiences. Visual multimodal learning environments have been shown to improve students' cognitive processing because learners can simultaneously connect verbal explanations with visual representations and interactive activities [20]. AR technology also supports inquiry-based and student-centered learning by allowing learners to interact directly with three-dimensional visualizations of biological objects and processes [21]. This interactive experience is important in biology education because students often struggle to understand microscopic and dynamic scientific phenomena through static images alone [22].

The scrapbook component contributed significantly to improving visual engagement and information organization. The use of colorful illustrations, concise explanations, and interactive layouts enabled students to process information more effectively. These findings are consistent with research, which reported that scrapbook-based instructional media improve student motivation and facilitate conceptual understanding in biology learning [10]. Similarly, emphasized that visual multimodal learning environments support deeper cognitive processing and increase student participation during science learning activities [23].

The AR component represented one of the major innovations of VIRUSCAPE because it enabled students to visualize virus structures and replication cycles in three-dimensional forms through smartphone-assisted interaction. This feature reduced the level of abstraction commonly associated with virus learning and provided immersive educational experiences [16]. Recent systematic literature reviews revealed that AR implementation in biology education consistently improves learning motivation, conceptual understanding, scientific visualization skills, and collaborative learning experiences [19]. AR-based learning environments have also become an important trend in science education because they facilitate interactive learning experiences aligned with 21st-century educational demands [24].

The crossword puzzle activity also contributed significantly to improving students' understanding of virus-related concepts and scientific terminology. Game-based learning approaches are widely recognized for promoting active participation, enhancing problem-solving abilities, and fostering collaborative learning experiences [25]. Recent studies have shown that educational games can increase students' motivation and engagement by encouraging them to take an active role in the learning process and by creating more interactive and meaningful classroom experiences [26].

An important contribution of this study lies in the integration of three different instructional approaches into one multimodal learning system. Previous studies have primarily investigated augmented reality (AR) media, scrapbook-based learning media, and educational games as independent learning approaches in science education [27]. In contrast, VIRUSCAPE combines visual representation, digital interaction, and game-based reinforcement simultaneously within one instructional framework. This integration constitutes the novelty of the research and provides a more comprehensive learning experience compared to single-medium instructional approaches.

From a theoretical perspective, the findings strengthen constructivist learning theory, which emphasizes that students actively construct knowledge through interaction and meaningful experiences. The integration of visual, technological, and game-based learning components supported active cognitive engagement and independent conceptual construction. Furthermore, the study contributes to the development of multimodal science learning strategies capable of addressing abstract biological concepts more effectively.

Practically, VIRUSCAPE offers an innovative instructional alternative for biology teachers seeking to improve student engagement and conceptual understanding during virus learning. The media can be implemented both in classroom learning and independent study because it combines printed and digital learning resources. In addition, the multimodal integration model developed in this study has potential applicability to other biology topics involving abstract and microscopic concepts, such as genetics, microbiology, and cell division.

Overall, the findings indicate that VIRUSCAPE successfully addressed learning difficulties related to virus concepts through integrated scrapbook media, Augmented Reality visualization, and educational game activities. The very high feasibility scores obtained from expert validation demonstrate that the developed media possesses strong potential to improve conceptual understanding, learning motivation, and active participation in biology learning.

CONCLUSION

This study successfully developed VIRUSCAPE (Virus Scrapbook, Augmented Reality, and Crossword Puzzle) as an innovative multimodal learning medium for virus material in senior high school biology learning. The integration of scrapbook-based visual learning, Augmented Reality (AR) visualization, and crossword puzzle educational games effectively addressed students' difficulties in understanding abstract virus concepts, particularly virus morphology and replication mechanisms. The development process based on the 4D model produced a learning medium that combined visual representation, interactive digital technology, and game-based reinforcement into one comprehensive instructional system.

The validation results demonstrated that VIRUSCAPE possessed very high feasibility in terms of both material and media quality. The material expert validation obtained a feasibility percentage of 95.45%, while the media expert validation reached 84.72%, both categorized as "Very Feasible." These findings indicate that the developed media fulfilled important instructional criteria, including scientific accuracy, curriculum relevance, visual attractiveness, interactivity, and usability in biology learning.

Scientifically, this study contributes to the development of multimodal learning strategies in biology education by integrating visual media, AR technology, and educational games simultaneously within one learning framework. The novelty of this research lies in the comprehensive integration of these instructional approaches to support conceptual understanding, learning motivation, and active student participation during virus learning. The findings also strengthen the importance of interactive and technology-assisted learning environments in facilitating meaningful learning experiences for abstract scientific concepts.

Practically, VIRUSCAPE can serve as an innovative instructional alternative for biology teachers seeking to improve classroom engagement and conceptual understanding in science learning. The media also has potential applicability for other biology topics involving microscopic and abstract concepts,

such as genetics, microbiology, and cell division. Future research is recommended to investigate the effectiveness of VIRUSCAPE through large-scale classroom implementation and experimental studies focusing on students' learning outcomes, critical thinking skills, and long-term conceptual retention.

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AUTHOR CONTRIBUTIONS

Conceptualization, AW. Methodology, AW and FKM. Software, AMZAF. Validation, AW and LMN. Formal Analysis, AW and FKM. Investigation, SS, FKM, and AMZAF. Resources, AW and LMN. Data Curation, SS and FKM. Writing—Original Draft Preparation, SS and FKM. Writing—Review and Editing, AW and LMN. Visualization, AMZAF. Supervision, AW. Project Administration, AW. Funding Acquisition, AW. All authors reviewed and approved the final version of the manuscript prior to publication.

CONFLICTS OF INTEREST

The authors declare no conflict of interest regarding the publication of this research. The study was conducted independently without any commercial or financial relationships that could be interpreted as potential conflicts of interest. Furthermore, no funding sponsors were involved in the study design, data collection, data analysis, interpretation of findings, manuscript preparation, or the decision to publish the results.

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