RESEARCH ARTICLE

Development and evaluation of e-comic nervous system app to enhance self-directed student learning

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Abstract: Technological developments in various fields are the key to progress in the digital era. The utilization of technology-based learning media in education makes learning more interactive and supports independent learning. This study aims to develop and test the practicality and effectiveness of storyline-based nervous system e-comics media to support students' independent learning. This research uses the Research and Development (RnD) method with the Lee & Owen model, consisting of the analysis, design, development, implementation, and evaluation stages. The research was conducted with the subjects in this study, class XI MIPA SMA Negeri 2 Malang students, totalling 60 people. A pre-experimental design of one group pretest-posttest was used to test the effectiveness of the media. Data were collected through questionnaires and tests. The media validation results obtained 100%, material validation 100%, and student response results 98.7% in the class trial. The effectiveness test used a Pretest-Posttest Control Group Design. The results showed a significant difference between the posttest of both classes with Sig. (2-tailed) 0.00 <0.05, there is a significant difference between the control and experimental classes. Storyline-based nerve e-comic media can facilitate independent learning more interestingly and interactively.

Keywords: learning media; self-directed learning; storyline

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Introduction

The advancement in the digital era can no longer be separated from the development of technology in various fields. The development of technology has made significant progress in education (Kalolo, 2019; Visvizi & Daniela, 2019). Innovations such as game-based learning, using data analytics to understand student development, and using social media in educational contexts have opened the door for more interactive and adaptive learning methods (Al-Rahmi et al., 2022; Mukhametgaliyeva et al., 2022; Qian, 2016). Various technological devices and applications enable more interactive and engaging learning, increasing students' interest in learning (Hochberg et al., 2018; Lin et al., 2017). Technological developments also provide extensive opportunities for students to become self-directed learners (Beckers et al., 2016; K. Lee et al., 2014; Morris, 2019).

Self-directed learning empowerment represents an educational approach that gives students more control in managing and directing their learning (Boyer et al., 2014; Morris, 2019; Robinson & Persky, 2020). It encourages students to take the initiative in planning, organizing and evaluating learning, which helps develop skills such as problem solving, critical thinking and self-responsibility (Karatas & Zeybek, 2020). This approach encourages students to learn more independently, according to personal interests and needs. The development of self-directed learning should not be separated from the use of supportive learning media (Rashid & Asghar, 2016), such as illustrated stories or commonly called comic. Students who follow a self-directed learning approach can utilize this media to plan, organize and direct their learning.

E-comic is effective renewable media in learning. Using e-comic can enable more interactive and fun

teaching, thus motivating students to learn better (Mirosunnaily & Pramudiani, 2021). The development and evaluation of narrative-based e-comic applications for the nervous system to enhance student self-directed learning represent a new frontier in educational research. Many developments in the digital era have focused on the creation of interactive learning media to improve students' skills in studying nervous system materials. For instance, research on the development of learning media using Augmented Reality (AR) technology on nervous system concepts has shown that the developed media is considered suitable and effective for use in Biology learning with an effectiveness rate of 76% (Aripin & Suryaningsih, 2019). Another study on articulate storyline-based media on nervous system topics is guided by increasing students' interest in learning (Azzahra et al., 2023). The development of e-comics in biology education has begun to gain momentum, as evidenced by previous research on difficult digestive system topics that could be developed and assessed as effective learning tools (Udayani et al., 2021). Despite several studies, there is still no learning media that fully applies VAK-based e-comic storylines in nervous system materials, indicating significant potential for development. Applying the e-comic nervous system based on a storyline can be an innovative step in empowering self-directed learning for learners.

Developing e-comic media based on storylines offers a unique approach incorporating the nervous system and daily activities. This allows students to relate to the material and see its relevance to their lives. When comic media is designed with a constructivist approach to the coordination system content, it is effective for learning. Test results have demonstrated excellent qualifications, including content, media, and learning design. Therefore, the novelty of developing storyline-based e-comic media is its ability to present scientific information or messages in a captivating, compelling, and supportive manner. Learners can take control of their learning process by using a combination of e-comics that present material about the nervous system with the sophistication of an articulate storyline to create an interactive learning experience. This study aimed to develop and test the effectiveness and student responses to the application of the e-comic nervous system based on storyline to support students' self-directed learning.

Method

This research method used Research and Development (RnD) to develop the e-comic nervous system based on an articulate storyline. The research and development used the multimedia-based instructional design model (Lee & Owens, 2004). The selection of the development model was based on the fact that the research and development model is devoted to the use of technology, one of which is an interactive multimedia development model. The Lee and Owens (2004). development model has a procedural character as it has structured, coherent, and clear stages. The model has five stages: 1 analysis, which consists of need assessment and front-end analysis, 2 design, 3 development, 4 implementation, and 5 evaluations. The design method used in this research was a pretest-posttest control group design to test the product's effectiveness. The results can be seen after treatment by previously giving a pretest, and after being given an e-comic nervous system based on articulate storyline media, students are given a posttest. The research design can be seen in Table 1.

Table 1. Pretest-posttest control group design

Pretest	Treatment	Posttest
O1	X1	O2
O3	X2	O4

Source: Cohen et al. (2017)

Description

X1 : employing learning with a group investigation model assisted by interactive visual novels
X2 : using the group investigation model
O1, O3 : acquisition of pretest scores
O2, O4 : acquisition of posttest scores

The subjects in this study were 60 students of class XI MIPA State Senior High School 2 Malang. The research implementation time was in August-October 2023. The data collected in this study were qualitative and quantitative. Qualitative data was obtained by describing comments and suggestions from student questionnaires, educational practitioner expert validation sheets, material expert validation sheets, and media expert validation sheets. Quantitative data was obtained from calculations using numbers obtained from students' cognitive learning outcomes and the results of validity scores (material validators, media validators, and field practitioners).

The instruments used in this study were validation sheets (material, media, field practitioners), assignment assessment instruments to determine self-directed learning in students (along with rubrics), and pretest-posttest questions to determine student cognitive outcomes. This instrument can be seen in the following Table 2 and Table 3.

Experts analysed validation data by applying validation criteria for product development. Furthermore,

the data was evaluated using a formula that produces a number measured on a Likert scale based on Table 4.

Table 2. Media validation sheet 1

Aspect	Indicators
A. Visual novel design	The appearance of layout, rhythm, harmony and unity
	Harmonious colours that match the theme
	Easy-to-read fonts
	Illustrations in visual novels can illustrate the material
	Phenomena are contextual
	Flow is easy to understand
	Ease of installation
B. Animated video display	Animations have matching color arrangements and illustrations
	Animation representation is easy to understand
	Interesting animations
	Suitability of animation to the material displayed

Table 3. Media validation sheet 2

Aspect	Indicators
A. Components of visual novel material	Completeness of the material
	Depth of material
	The references used are reliable
B. suitability of visual novel material	Compatibility of visual novel material with the coordination system
	Illustrations and drawings according to the material
	Accuracy of the material

Table 4. Media and material expert validation Score

No.	Score	Level of Validity
1	5	Very good
2	4	Good
3	3	Poor
4	2	Very poor

The validation results comprised a scale of 1-5. Number 5 indicates very good criteria, number 4 indicates good criteria, number 3 indicates medium criteria, number 2 indicates poor criteria, and number 1 indicates very poor criteria. After the percentage was obtained using the available formula, the percentage was used to determine the level of validity of the media and material. Determination of the percentage size of media validation based on Table 5.

Table 5. Validation result criteria

No.	Percentage	Level of validity
1	76% - 100%	Very good
2	51% - 75%	Good
3	26% - 50%	Poor
4	1% - 25%	Very poor

Quantitative analysis has been conducted using the data from the initial and final examinations, intended to assess the significance of changes in students' cognitive achievement before and after applying the instructional media. The statistical method used in this analysis is the single ANCOVA test, which aimed to compare the means of two sample groups on one variable, namely cognitive learning outcomes.

Results and Discussion

This research and development used one of the models in the development of learning media, namely the Lee and Owens (2004) model. This model comprises five stages of product development: assessment/analysis, which includes need assessment and front-end analysis, design, development, implementation and evaluation.
The analysis stage conducted a series of analyses to understand student needs and learning objectives.

Surveys and interviews were conducted to identify students' understanding of the nervous system and assess the effectiveness of existing learning methods. It also conducted an analysis based on student response questionnaires, which helped see students' self-directed learning. The analysis showed that students need more interactive and exciting learning media to understand complex concepts in the nervous system material at school and independently. At this stage, Lee and Owens divided into two main stages: needs assessment and front-end analysis. The needs assessment was conducted at State Senior High School 2 Malang by giving pretest questions to see the extent of students' cognitive levels while describing the results of interviews with the relevant subject teachers. The analysis showed that students need more interactive and exciting learning media to understand complex concepts in nervous system material at school and independently.

Design consisted of material design and media design. The design stage aimed to design an e-comic media project that would be developed after completing the analysis stage, obtain basic information from the analysis and then design an interactive media product storyboard as shown in Figure 1.

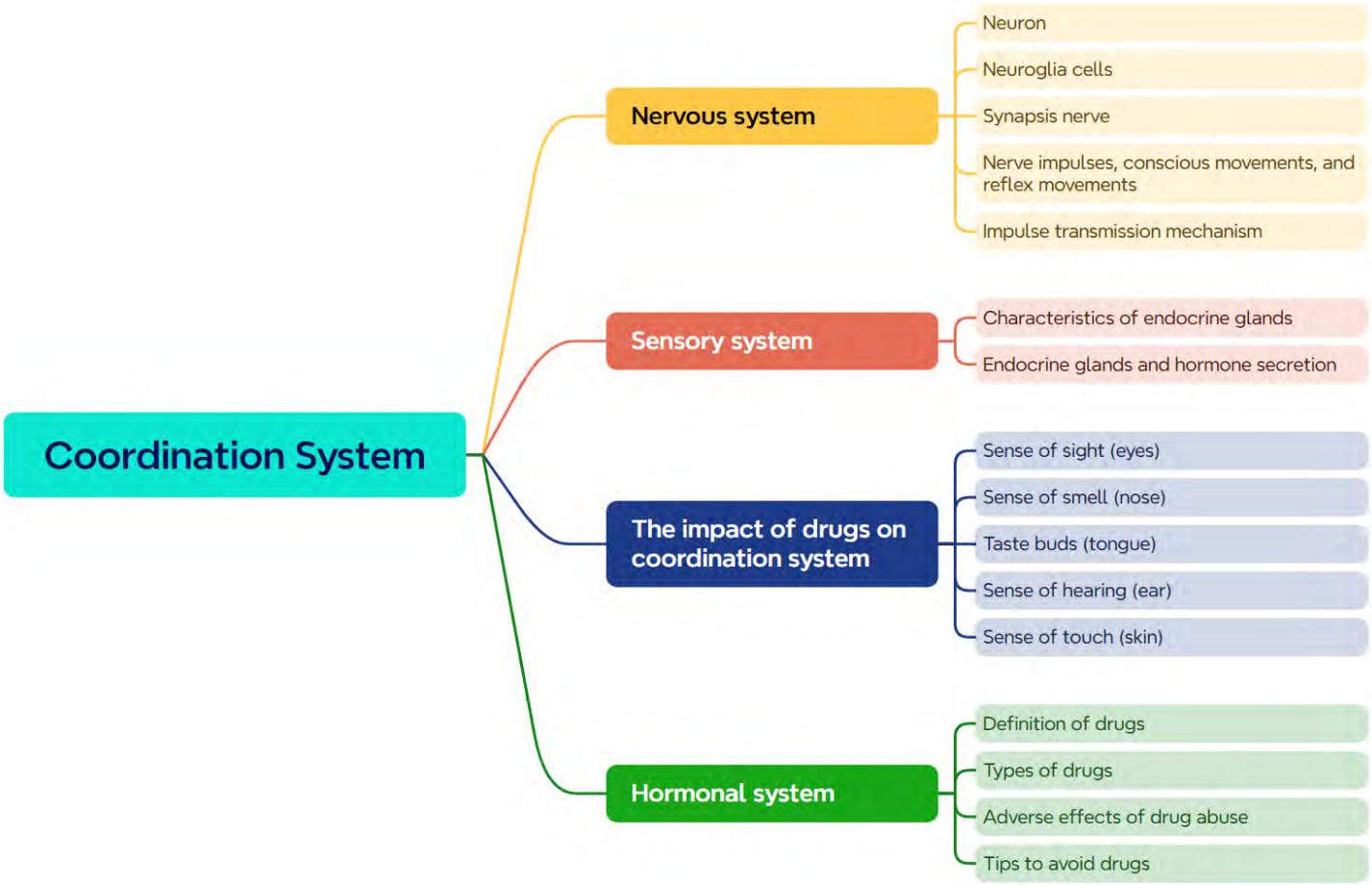

Figure 1. Story board e-comic nervous system

The development of the e-comic was started by drafting a script of conversations between characters in the comic and then designing a sketch of the image from the script. Then, the character visualization of the related characters determines the number of episodes and panels per page show in Figure 2. Application development using Unity, ui/ux media design using Adobe Illustrator, and illustrations in e-comic using procreate application experts, as well as evaluation materials, validated the results of media development before being implemented. The validation results were obtained from media experts, materials, and practitioners conducted by lecturers who are experts in their fields.

Figure 2. E-comic nervous system

Media validation obtained 100% results as listed in Table 6, but there are some suggestions for media such as adjusting the ratio on various smartphones and the ease of installation from the application model to the website so that it is easy to use on all devices.

Table 6. Media validation results

Aspect	Indicators	Skor
A. Visual novel design	The appearance of layout, rhythm, harmony and unity	5
	Harmonious colours that match the theme	5
	Easy-to-read fonts	5
	Illustrations in visual novels can illustrate the material	5
	Phenomena are contextual	5
	Flow is easy to understand	5
	Ease of installation	5
B. Animated video display	Animations have matching color arrangements and illustrations	5
	Animation representation is easy to understand	5
	Interesting animations	5
	Suitability of animation to the material displayed	5
	Total	**55**
	Precentage	**100% (Very Valid)**

Material validation obtained 100% results which are presented in Table 7. This ensures that the material presented in the media is accurate, relevant, and in accordance with learning needs. This validation process involves material experts and media experts who assess the quality of the material from various aspects, such as suitability to basic competencies, correctness of concepts, and ease of understanding the material. This validation is very important to ensure that the learning media developed effectively conveys learning materials to students.

Table 7. Material validation results

Aspect	Indicators	Skor
A. Components of visual novel material	Completeness of the material	5
	Depth of material	5
	The references used are reliable	5
B. suitability of visual novel material	Compatibility of visual novel material with the coordination system	5
	Illustrations and drawings according to the material	5
	Accuracy of the material	5
	Total	**30**
	Percentage	**100% (Very valid)**

The validated media was then tested for practicality with students at SMA Negeri 2 Malang. The trial stage was implemented with one-to-one, small group, and class trials in order to gather more detailed user practicality data (Branch, 2009). The results of the practicality test are described in Table 8.
Improvements were made to the UI/UX layout of the media to fit the screen ratios of all smartphone series. Another improvement was in the illustrations; the illustrations were given more text to make the story easier to understand. Then, a small group trial was conducted to test the results of the improvements. The data of the trial results are presented in Table 9.
At the implementation stage, product trials were carried out on 60 students of class XI IPA SMA Negeri 2 Malang, divided into control and experimental classes to test the effectiveness of the media in helping student's self-study the material of the coordination system assisted by e-comics. The implementation result data is presented in Table 10.
Evaluation, at this stage, a thorough evaluation of the research that has been carried out is carried out to determine whether the development product, namely e-comic, was influential in overcoming problems and could achieve the goals that had been determined through examination.

Table 8. Results of student responses one to one trial

Aspect	Skor	
	Maximum	Average
A. Layout appearance	5	4.3
B. Illustration	5	4.4
C. Contextual	5	4.8
D. Animation	5	4.4
E.Ease of understanding	5	4.5
F. Material suitability	5	4.6
G. Induces curiosity	5	4.4
H. Media Effectiveness	5	4.6
Total	40	**36**
Percentage	100%	**90% (Very Valid)**

Table 9. Results of small group trial student responses

Aspect	Skor	
	Maximum	Average
A. Layout appearance	5	4.7
B. Illustration	5	4.8
C. Contextual	5	4.8
D. Animation	5	4.6
E.Ease of understanding	5	4.6
F. Material suitability	5	4.7
G. Induces curiosity	5	4.8
H. Media Effectiveness	5	4.7
Total	40	**37.7**
Percentage	100%	**94.25 % (Very Valid)**

Table 10. Results of class trial student responses

Aspect	Skor	
	Maximum	Average
A. Layout appearance	5	5
B. Illustration	5	5
C. Contextual	5	4.7
D. Animation	5	5
E.Ease of understanding	5	4.8
F. Material suitability	5	5
G. Induces curiosity	5	5
H. Media Effectiveness	5	5
Total	40	**39.5**
Percentage	100%	**98.75 % Very Valid**

The effectiveness test used Pretest-Posttest Control Group Design. Conducted on 30 students in the control class and 30 students in the experimental class. Before conducting an unpaired T-test, a prerequisite test was carried out, namely normality and homogeneity tests on the pretest and posttest results of both classes. The data is normal and homogeneous, the results for pretest data are presented in Table 11.

Table 11. Homogeneity test

Levene Statistic	df1	df2	Sig.
2.620	1	58	0.111

The results of the pretest data homogeneity test get a significance value of 0.111> 0.05, so it can be concluded that the data is normally distributed. Followed independent T-test getting a Sig value. (2-tailed) 0.646> 0.05, there is no significant difference between the control and experimental classes. The independent T-test results on the pretest meant that the students' initial scores were equal. The results are presented in Table 12.

Table 12. Independent t-test pretest

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff	Std. Error Diff	Lower	Upper
Score	Equal variances assumed	2.620	0.111	0.461	58	0.646	1.20	2.60	-4.01	6.41
	Equal variances not assumed			0.461	56.179	0.647	1.00	2.60	-4.01	6.41

The media effectiveness test was analyzed using an independent t-test on the post-test score to see the difference in post-test averages. Previously, normality and homogeneity tests were conducted as prerequisites. The homogeneity test results are sig. 0.168 > 0.05, so it can be concluded that the data is homogeneous. The homogeneity test results are presented in Table 13. The t-test results are presented in Table 14.

Table 13. Homogeneity test

Levene Statistic	df1	df2	Sig.
1.945	1	58	0.168

Table 14. Independent samples test posttest

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff	Std. Error Diff	Lower	Upper
Learning outcome	Equal variances assumed	1.945	.168	-4.590	58	.000	-7.367	1.60	-10.58	-4.15
	Equal variances not assumed			-4.590	54.960	.000	-7.367	1.60	-10.58	-4.15

Research on the application of interactive e-comic for self-directed learning of nervous system material aimed to find and implement innovative educational solutions. The focus of this research was the use of interactive e-comic-based technology to help students learn on their own. The nervous system in the human body controls various vital functions, so it is considered an essential material to learn (Pratama et al., 2021). The material was considered difficult due to several factors, such as abstract concepts not being fully visualised, boring conventional teaching styles, too many concepts or knowledge that must be learned in detail, and the delivery of material is not contextualised (Lieu et al., 2018). School learning that tends to be conventional can reduce student interest (Ningrum & Widjana, 2019). Students must repeat material and learn independently outside class hours to maximise understanding (Rodriguez, 2013). Self-directed learning is often unvalidated by attractive learning media and teaching materials (Susanto et al., 2022). This research was essential to develop learning media that can increase the effectiveness of independent learning.

Nervous system material is contextual material based on actual phenomena. Understanding the nervous system material will be easier with examples of everyday events (Febriani et al., 2023). Looking at the characteristics of the material, suitable learning media to facilitate coordination system material is to use media with a storyline and can provide examples of actual events (Siregar & Harahap, 2022). E-comic is a learning tool that contains images and stories that can increase students' thinking power (Taufiq et al., 2020). So that e-comic can provide visualisation of events that can be used as examples of physiological processes in the nervous system. Interactivity, a key characteristic of interactive comics, is expected to increase learners' engagement and understanding of the nervous system material. E-comic can be linked to mobile, which is one of the solutions in the paradigm shift of education (Damopolii et al., 2022). This method can improve flexibility in teaching and learning activities in this modern era. Technology can be utilised to provide contextualised learning (Lan et al., 2018).

This material's design has been adjusted to the level of students who will be used as research subjects, namely senior high school students. Nervous system material for senior high school students includes hormones, nerves, and senses (Pratama et al., 2021). Sensory system material contains conceptual and abstract material (Nunaki et al., 2019). This material is complex and includes the nervous system, hormones, and senses. Students have difficulty understanding the basic concepts of the nervous system, hormones, and senses and how each works (Fauzi et al., 2021). Based on this, creative and innovative learning media are needed to overcome students' difficulties in learning material on the coordination system of nerves, hormones, and senses.

The analysis stage is used to analyse the learners' problems, the selected materials, the adjustment to the curriculum, the selection of the right story, the consistent story sequence, and the visual presentation that supports complex ideas (Hadiyanto et al., 2021). The design stage consists of material design and media design. Material design is done by selecting, compiling, and adjusting it to be included in a story. The media design is adjusted to the UI/UX tailored to the user. A good UI/UX design will create an experience that facilitates, enriches, and strengthens user interaction with the digital world (Nurpalah et al., 2021). In the development stage, the e-comic is developed using the articulate storyline platform to integrate visual content, narrative, and interactive elements easily. The e-comic will be designed to follow the story's development and attract students' interest in learning. Researchers will also ensure that the user experience with these e-comics becomes more engaging and useful for self-directed learning. It is essential to create exciting learning materials to facilitate the process of student understanding (Abykanova et al., 2016). The finished media will be materially and media validated for the implementation step.

Implementation with learners received a response that e-comic can bring students' experience to the actual event. Learners will be given examples of events related to the nervous system and asked to study the physiological flow. E-comic can make it easier for students to visualise physiological processes in the body (Mufaqih & Juanengsih, 2023). Some of the advantages of using e-comic in learning biology include making it easier to understand complex concepts. E-comic can present this information in a visual

form that is easier to digest, such as through illustrations or animations, making it easier for students to understand the material. Increasing student engagement, exciting and interactive comic formats tend to captivate students' attention more than plain text or presentations. E-comic provides interactive media, such as quizzes, animations, or hyperlinks to additional resources (Lazarinis et al., 2015).
Student can access e-comic through online learning platforms at their own time and pace. This allows them to learn independently while taking advantage of the interactivity and visualisation offered by e-comics. This study hopes to confirm that using interactive e-comics in self-directed learning can improve students' understanding of nervous system materials, learners' active engagement in self-directed learning with e-comics, and their response to the interactive elements.
Learning using the nervous system e-comic resulted in a significant increase in the post-test scores of the experimental class compared to the control class. However, data collection during the study faced challenges due to the self-directed nature of learning, which required more effort from the teacher to remind students. Therefore, teachers need to play a role in reminding students to do independent learning at home. Also, since the e-comic material is limited to the topic of the nervous system, animated videos on different subject matters would be very beneficial.

Conclusion

The e-comic nervous system based on the storyline effectively enhanced learners' self-directed learning, particularly of nervous system material. The e-comic contains information and incorporates interactive elements that encourage students to actively participate in learning and help them understand the material better. The e-comic received 100% validity from the material and media validation, so it can be practically and effectively used to improve students' independent learning. Case study results show that compared to conventional learning approaches, students who learn through interactive e-comics tend to understand the nervous system material better and are more engaged. So, self-directed learning can be enhanced by using a storyline-based e-comic of the nervous system. This research can encourage further research on the potential of technology to create more efficient learning methods. Suggestions for further research include implementing online teacher assistance to minimize external factors that can affect the results. In addition, the application of e-commerce needs to be studied on various topics at higher education levels so that the effectiveness results are more accurate.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

H. Susanto: introduction and background; **D. Setiawan:** review and data collection; **S. Mahanal:** review, **Z. Firdaus:** analysis; and **C. T. Kusmayadi:** data interpretation and editing.

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