



## Development of Articulate Storyline 3-Based Interactive Media to Enhance Conceptual Understanding of the Immune System among Madrasah Aliyah Students

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**Abstract:** This study aimed to develop and evaluate the validity, practicality, and effectiveness of interactive learning media based on Articulate Storyline 3 for teaching the Immune System topic to eleventh-grade students at Madrasah Aliyah. The developed media integrates learning materials, animations, videos, interactive quizzes, and learning navigation features. This study employed a Research and Development (R&D) approach using the 4D development model (Define, Design, Development, and Disseminate). The product was tested on 27 eleventh-grade students at MAN 1 Medan. The research instruments included material expert and media expert validation sheets, teacher and student response questionnaires, and conceptual understanding tests. The collected data were analyzed using descriptive quantitative analysis through validity, practicality, and N-Gain assessments. The results indicated that the developed media achieved a very high level of validity, with validation scores of 97% from material experts and 99% from media experts. The practicality assessment based on teacher and student responses showed scores of 96% and 96%, respectively, indicating that the media was categorized as highly practical. Students' average conceptual understanding scores increased from 48.22 in the pretest to 85.70 in the posttest, with an N-Gain score of 0.71, categorized as high. These findings suggest that interactive learning media based on Articulate Storyline 3 has the potential to support students' conceptual understanding of the Immune System topic. However, this study was limited to a single-class trial involving 27 students.

**Keywords:** Interactive media; Articulate Storyline 3; conceptual understanding; immune system

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## INTRODUCTION

In the current era of digital transformation, the integration of technology into education has become increasingly important to improve learning effectiveness and students' conceptual understanding. Educators are no longer expected to act merely as transmitters of knowledge but as facilitators who guide students in constructing meaningful understanding through appropriate technological support (Aditya et al., 2021). In biology education, this role is particularly important because many biological concepts involve complex, abstract, and dynamic processes that are difficult to understand through conventional instructional approaches. Therefore, the purposeful integration of technology is needed to facilitate concept-oriented learning and promote deeper understanding of biological phenomena (Pare & Murniarti, 2024).

Conceptual understanding is a fundamental component of biology learning because it enables students to comprehend biological structures, processes, and relationships among interconnected concepts. Effective biology learning requires students not only to recognize scientific facts and terminology but also to explain relationships among concepts and apply their knowledge to solve biological problems. Conceptual understanding refers to students' ability to describe learned concepts using their own words, connect related concepts, and apply knowledge in problem-solving

contexts (Adhani & Rupa, 2020). Students with strong conceptual understanding are better able to develop scientific reasoning, critical thinking skills, and problem-solving abilities (Setyaningrum et al., 2025). Therefore, conceptual understanding serves as an important indicator for evaluating the success of biology learning (Harahap, 2018).

However, achieving conceptual understanding in biology remains challenging, particularly for topics involving complex biological mechanisms. Students with insufficient understanding of biological principles often experience difficulties in interpreting abstract concepts and relating scientific knowledge to real-world phenomena. Such difficulties may result in superficial learning and limited academic achievement. One of the biology topics frequently considered challenging is the immune system, as it involves multiple components, complex interactions, and dynamic defense mechanisms within the human body (Alfiraida, 2018). The complexity of immune system concepts may hinder students' ability to interpret, classify, explain, compare, and apply biological concepts. Therefore, appropriate instructional strategies and learning resources are required to assist students in constructing a comprehensive understanding of immune system mechanisms (Safitri et al., 2021).

The limited availability of interactive learning resources may contribute to students' difficulties in understanding complex biological concepts. Agustina et al. (2021) reported that some teachers still rely primarily on conventional presentation media, such as PowerPoint, which may not fully support active student engagement. As a result, learning activities tend to remain teacher-centered and focus mainly on content delivery. This condition may reduce students' learning interest and concentration, particularly when students become distracted by unrelated activities, such as smartphone use during learning sessions (Syabri & Elfizon, 2020). Therefore, innovative learning media that integrate interactive features and multimedia elements are needed to provide more meaningful and engaging learning experiences.

Interactive multimedia learning has been reported to improve students' motivation, engagement, and understanding by presenting information through multiple representations, including text, images, animations, audio, and videos (Mauliana et al., 2025). Furthermore, Agustini et al. (2024) stated that interactive media can facilitate students' understanding of abstract and complex topics through more attractive and comprehensible presentations. One technology-based learning tool that supports the development of interactive multimedia materials is Articulate Storyline 3. This software enables educators to create digital learning media equipped with navigation systems, interactive responses, hyperlinks, quizzes with feedback, and multimedia components such as images, animations, videos, and audio (Rianto, 2020). These features allow learning materials to be presented in a more engaging and flexible manner (Agustin & Kurniawan, 2021). Nevertheless, the development of media using various multimedia features may produce relatively large file sizes, requiring devices with adequate technical specifications (Widyaningrum & Indrayati, 2025).

The need for interactive learning media for immune system concepts was also identified at MAN 1 Medan. Based on discussions with a biology teacher, the immune system topic remains difficult for students due to the abundance of biological terminology and the complexity of underlying mechanisms. Although existing resources, such as PowerPoint presentations and educational animations, have supported instruction, interactive learning media specifically designed to improve students' conceptual understanding have not yet been implemented. Student interviews also indicated that the immune system topic was perceived as difficult to understand and required more visual and interactive learning support. Therefore, the development of Articulate Storyline 3-based media is expected to provide clearer

visualization and facilitate students' understanding of immune system concepts. Previous studies have demonstrated the potential of Articulate Storyline-based media to improve learning outcomes and support students' understanding of learning materials (Octavia et al., 2021; Rohmah & Bukhori, 2020). In addition, Articulate Storyline-based learning media have been successfully implemented at secondary education levels (Rosiyanti & Farahdiba, 2022). These findings indicate that Articulate Storyline has potential as an instructional tool to support conceptual learning.

Previous studies have shown that Articulate Storyline-based learning media have been developed for various biology topics and educational levels. Rohmah (2024) developed Articulate Storyline-based learning media for the human skeletal system topic at the junior high school level. Sa'adah et al. (2023) developed interactive Articulate Storyline media for ecology learning at the senior high school level. Nasution and Adlini (2025) developed Articulate Storyline media integrated with a problem-based learning approach for the digestive system topic to improve students' creative thinking skills. Similarly, Amelia and Mintohari (2024) developed Articulate Storyline 3-based media for the digestive system topic at the elementary school level to improve students' learning outcomes.

Although previous studies have demonstrated the usefulness of Articulate Storyline-based media in education, several research gaps remain. First, previous studies have focused on different biology topics, while interactive media specifically designed for the immune system topic at the senior high school level remains limited. Second, many previous studies have emphasized general learning outcomes, whereas the evaluation of students' conceptual understanding based on Anderson and Krathwohl's cognitive dimensions has received less attention. Third, limited studies have simultaneously evaluated the validity, practicality, and effectiveness of Articulate Storyline 3-based media using a systematic development model. Therefore, this study introduces novelty by developing Articulate Storyline 3-based interactive learning media for the immune system topic using the 4D development model and evaluating its validity, practicality, and effectiveness in improving students' conceptual understanding.

Based on these considerations, this study aimed to develop and evaluate Articulate Storyline 3-based interactive learning media for the immune system topic among eleventh-grade Madrasah Aliyah students. The developed media is expected to contribute to the advancement of innovative biology learning resources by providing interactive, engaging, and concept-oriented instructional support that facilitates students' understanding and application of biological concepts.

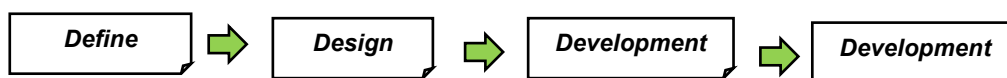
## METHOD

This study was conducted during the second semester of the 2025–2026 academic year at MAN 1 Medan, Deli Serdang Regency, North Sumatra, Indonesia. A Research and Development (R&D) approach was employed using the 4D development model combined with a One-Group Pretest–Posttest Design. The 4D model is one of the development models that can be applied to create various educational media products (Arkadiantika et al., 2020).

The research subjects were 27 students from class XI-Science B-5 at MAN 1 Medan during the 2025/2026 academic year. The class was selected as the trial subject based on considerations from the school and biology teacher, including the relevance of the learning material and the feasibility of the research implementation schedule. The inclusion criteria for participants were: (1) active students enrolled in class XI-Science B-5 at MAN 1 Medan during the 2025/2026 academic year; (2)

students who participated in the entire learning process using the developed media; and (3) students who completed both the pretest and posttest.

The stages of the 4D development model (Figure 1) consisted of Define, Design, Development, and Disseminate stages.



**Figure 1.** Stages of the 4D development model (Thiagarajan, 1974)

The 4D development model was designed to produce an interactive learning media product based on Articulate Storyline 3 aimed at supporting students' conceptual understanding. Each stage of the 4D model involved different but interconnected activities and instruments. The activities and instruments implemented in each stage are presented in Table 1.

**Table 1.** Activities in the 4D development model

| Stage              | Description of Activities                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Define</b>      | The define stage involved an initial analysis to identify learning problems related to the Immune System topic at MAN 1 Medan, particularly students' limited conceptual understanding and the restricted use of interactive learning media. A needs analysis was subsequently conducted through questionnaires distributed to teachers and students to determine learning requirements and the necessity of developing Articulate Storyline 3-based media. The results of this analysis served as the basis for designing learning media that corresponded to students' characteristics and needs to improve conceptual understanding of the Immune System topic.                                                                                                                                                    |
| <b>Design</b>      | During the design stage, the initial framework of the Articulate Storyline 3-based interactive learning media was developed according to the characteristics of the Immune System material and learning objectives. The navigation flow, visual interface, and interactive components of the media were designed. At this stage, research instruments were also prepared, including media and material expert validation sheets, teacher and student response questionnaires, and conceptual understanding tests. The design stage produced an initial draft of the media based on the developed storyboard.                                                                                                                                                                                                          |
| <b>Development</b> | This stage involved developing the learning media until it was ready for testing and revision based on evaluation results. The developed media was validated by three validators consisting of one material expert, one media expert, and one biology teacher. The material expert evaluated the suitability of the content with the learning objectives and presented material, while the media expert assessed the interface, design, and technical aspects of the media. The biology teacher evaluated the suitability of the media with classroom learning needs and implementation. The media was then revised based on suggestions and feedback from the validators. The revised media was subsequently tested to determine its practicality and effectiveness in improving students' conceptual understanding. |
| <b>Disseminate</b> | The final stage involved disseminating the developed learning media so that it could be utilized more broadly. This was conducted by preparing a scientific article, publishing the research findings in a journal, and distributing the developed learning media. The dissemination process was supported by documentation as evidence of implementation.                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

### Research Instruments and Data Collection Techniques

The instruments used in this study included a conceptual understanding test, teacher and student response questionnaires, media expert validation sheets, and material expert validation sheets. A five-point Likert scale was used for the validation instruments and response questionnaires.

The media expert validation instrument consisted of 33 items, while the material expert validation instrument consisted of 23 items covering content suitability, language, and presentation aspects. The teacher and student response questionnaires

consisted of 12 items assessing media practicality based on aspects including interest, ease of use, presentation quality, and visual appearance.

The conceptual understanding test consisted of seven essay questions administered as pretest and posttest. The obtained scores were analyzed using the N-Gain analysis. The evaluation questions were developed based on Anderson and Krathwohl's conceptual understanding indicators, including interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining.

### Data Analysis Techniques

The analyzed data included students' conceptual understanding test results, teacher and student responses, and validation results from media and material experts.

### Validity Test

The validity level of the developed learning media was determined through evaluation by media and material experts using validation questionnaires. The expert assessments were based on a Likert scale with several response options. The validity percentage was calculated using the following formula:

$$P = \frac{\text{Total Validation Score Obtained}}{\text{Maximum Score}} \times 100 \%$$

The obtained percentage was then categorized according to the validity criteria presented in Table 2 (Rohmah & Bukhori, 2020).

**Table 2.** Validity criteria

| Percentage (%) | Criteria         |
|----------------|------------------|
| 81–100         | Highly Valid     |
| 61–80          | Valid            |
| 41–60          | Moderately Valid |
| 21–40          | Less Valid       |
| 0–20           | Invalid          |

### Practicality Test

The practicality level of the Articulate Storyline 3-based learning media was evaluated based on the ease of use by teachers and students after the development process was completed. Practicality was measured using teacher and student response questionnaires. The obtained data were analyzed using the following formula:

$$P = \frac{\text{Total Score Obtained}}{\text{Maximum Score}} \times 100 \%$$

The resulting percentage was categorized based on the practicality criteria presented in Table 3 (Nasihah & Utami 2024).

**Table 3.** Practicality criteria

| Percentage (%) | Category             |
|----------------|----------------------|
| 0–20           | Not Practical        |
| 21–40          | Less Practical       |
| 41–60          | Moderately Practical |
| 61–80          | Practical            |
| 81–100         | Highly Practical     |

**Table 4.** Indicators of the conceptual understanding ability test

| No. | Cognitive Process Dimension | Indicators of Biology Conceptual Understanding                                                                                      |
|-----|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Interpreting                | Students are able to interpret biological concepts or phenomena from texts, images, graphs, or tables.                              |
| 2   | Exemplifying                | Students are able to provide examples of applying learned biological concepts in daily life contexts.                               |
| 3   | Classifying                 | Students are able to classify biological objects, structures, or processes based on specific characteristics.                       |
| 4   | Summarizing                 | Students are able to summarize biological information or concepts into an accurate and structured explanation.                      |
| 5   | Inferring                   | Students are able to draw logical conclusions from observed biological data or phenomena.                                           |
| 6   | Comparing                   | Students are able to compare two or more biological concepts, structures, or processes based on their similarities and differences. |
| 7   | Explaining                  | Students are able to describe cause-and-effect relationships between concepts and processes within biological systems accurately.   |

Source: Anderson & Krathwohl (2010)

### Effectiveness Test

The effectiveness of the Articulate Storyline 3-based learning media was determined based on improvements in students' conceptual understanding. The effectiveness analysis was conducted using the normalized gain (N-Gain) score calculated from the pretest and posttest results. The N-Gain formula was calculated as follows:

$$N - \text{Gain (\%)} = \frac{(\text{Posttest Score} - \text{Pretest Score})}{(\text{Maximum Score} - \text{Pretest Score})} \times 100$$

The normalized gain scores were classified into three categories, as presented in Table 5.

**Table 5.** Effectiveness criteria based on N-Gain

| N-Gain Value       | Category | Criteria             |
|--------------------|----------|----------------------|
| N-Gain < 0.3       | Low      | Less Effective       |
| 0.3 ≤ N-Gain < 0.7 | Moderate | Moderately Effective |
| N-Gain ≥ 0.7       | High     | Effective            |

Source: Yunipiyanto et al. (2020)

## RESULTS AND DISCUSSION

This study focused on improving students' conceptual understanding of the immune system topic. The development process resulted in an interactive learning media product designed using Articulate Storyline 3 software. Through interactive presentations, attractive graphical elements, and assessments designed to support students' comprehensive understanding, the developed learning media aimed to produce an authentic, useful, and effective educational product for enhancing students' conceptual understanding of the immune system. The 4D development model, consisting of Define, Design, Development, and Disseminate, was used as the framework for developing this educational resource. The results of the development of interactive learning media based on Articulate Storyline 3 to improve students' conceptual understanding of the immune system are presented as follows.

### Define (Needs Analysis)

At this stage, a needs analysis was conducted through questionnaires and interviews with teachers and students to collect information regarding the learning environment, instructional challenges, and the types of media currently used in classroom activities. The findings from the survey and interviews indicated that the school had implemented the Independent Curriculum (Kurikulum Merdeka) in biology instruction. However, the immune system topic remained challenging for teachers to deliver due to its abstract concepts and complex biological mechanisms.

Although teachers had utilized PowerPoint presentations, animations, and online assessments, additional interactive learning resources were still required to improve students' understanding. The analysis revealed that students continued to experience difficulties in comprehending scientific concepts and understanding the functions and mechanisms of the immune system. Therefore, the development of learning media based on Articulate Storyline 3 was considered necessary.

The developed media incorporated various interactive components, including animations, videos, quizzes, and assessments. These features were expected to present the immune system concepts in an engaging manner, facilitate students' conceptual understanding, and increase their motivation and enthusiasm for learning.

### Design (Media Design)

The design stage was the next step in the development process, focusing on the construction of the interactive learning media framework. The design included the development of the welcome page, user instructions, learning objectives and outcomes, learning resources, and evaluation components. The interface was designed using aesthetic graphical elements, appropriate color schemes, and user-friendly navigation controls to support students' learning experiences.

The storyboard of the interactive learning media developed using Articulate Storyline 3 is presented in Table 6.

**Table 6.** Storyboard of interactive learning media based on Articulate Storyline 3

| No. | Display                                                                             | Page       | Description                                                                                                                                                                                 |
|-----|-------------------------------------------------------------------------------------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   |  | Main Menu  | The opening page displays the title of the learning media, including the learning topic covered, and provides a button to start the program.                                                |
| 2   |  | Login Menu | In this section, students are required to enter their name and student identification number to access the interactive learning media.                                                      |
| 3   |  | Main Menu  | This page contains four main menus: information, learning outcomes and objectives, materials, and evaluation. Instructions for using the navigation buttons are also provided on this page. |

| No. | Display | Page                             | Description                                                                                                                                            |
|-----|---------|----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| 4   |         | User                             | This menu provides information regarding the use of the interactive learning media.                                                                    |
| 5   |         | Learning Outcomes and Objectives | This section presents the expected learning outcomes and objectives.                                                                                   |
| 6   |         | Learning Materials               | This page displays the learning materials accessed through the previous menu. The materials consist of five sections organized into two main chapters. |
| 7   |         | Material Content Display         | Each section presents a detailed explanation of the learning materials.                                                                                |
| 8   |         | Evaluation Menu                  | The evaluation component uses Google Forms, where multiple-choice questions are developed according to the indicators of conceptual understanding.     |

## Development

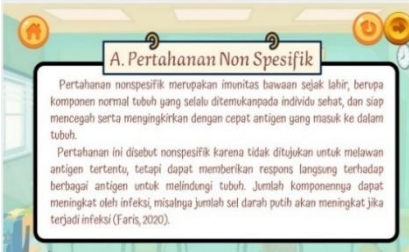
The development stage involved preparing the initial design of the Articulate Storyline 3-based learning media for the immune system topic and transforming the design into a complete educational product. The developed media was subsequently validated by experts to evaluate its content suitability, visual presentation, and functional aspects before being implemented in the learning process.

## 1. Media and material validation results

The validation process was conducted by two experts, consisting of one media expert and one subject matter expert. This validation aimed to determine the quality, feasibility, and appropriateness of the developed interactive learning media before its implementation in classroom activities. The improvements made based on the validators' suggestions are presented in Table 7.

**Table 7.** Product revision results based on validator suggestions

| Before Revision                                                                     | After Revision                                                                       | Description                                                                                                                                                         |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    |    | The name of the academic supervisor and the developer's identity were added to the opening page/main menu to provide clearer information about the media developer. |
|   |   | The institution logo was added to the login page to strengthen the identity of the developed learning media.                                                        |
|  |  | The Home icon was removed from the main menu to create a simpler and more organized interface.                                                                      |
|  |  | Additional information regarding the procedures for using the media was included in the user information section.                                                   |
|  |  | The presentation of the Learning Outcomes (CP) and Learning Objectives (TP) was revised by placing the CP section before the TP section.                            |
|  |  |                                                                                                                                                                     |

| Before Revision                                                                     | After Revision                                                                       | Description                                                                                                                                                       |
|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    |    | The subchapter titles in the material menu were formatted in bold to improve readability and make the content easier for users to identify.                       |
|    |    | References used in the learning materials were added to improve the academic quality of the content.                                                              |
|    |    | References were added, and image sources were included for each visual illustration presented in the learning materials.                                          |
|  |  | Information regarding the subject (Biology), grade level (Grade XI), and educational level (Senior High School/Madrasah Aliyah) was added to the evaluation menu. |

The validation results from the experts are presented in Table 8 as the basis for determining the feasibility of the developed media before it was applied in the learning process.

**Table 8.** Validation results by media expert validator

| Indicator                      | Number of Items | Obtained Score | Maximum Score | Percentage | Criteria   |
|--------------------------------|-----------------|----------------|---------------|------------|------------|
| Graphic or Visual Presentation | 5               | 20             | 20            | 99%        | Very Valid |
| Color Usage                    | 5               | 20             | 20            |            |            |
| Audio Clarity                  | 5               | 20             | 20            |            |            |
| Accuracy of Audio Volume Level | 5               | 20             | 20            |            |            |
| Animation Compatibility        | 5               | 19             | 20            |            |            |
| Animation Variation            | 3               | 12             | 12            |            |            |
| User Accessibility             | 3               | 12             | 12            |            |            |
| Design Consistency             | 2               | 8              | 8             |            |            |
| <b>Total Score</b>             |                 | <b>131</b>     | <b>132</b>    |            |            |

Based on the media expert validation results presented in Table 8, the developed interactive learning media obtained a validity score of 99%, which was categorized as Very Valid. This finding indicates that the media fulfilled the required criteria related to

color selection, animation, audio integration, visual suitability, usability, and design consistency.

This result is consistent with Pangestu et al. (2021), who stated that valid learning media should meet several essential aspects, including visual quality, audio elements, usability, and learning benefits. The animation compatibility aspect obtained a score of 19 out of 20, indicating that the animations effectively supported the delivery of learning content. Therefore, the media was considered appropriate for classroom implementation with only minor revisions based on validator recommendations.

**Table 9.** Validation results by subject matter expert validator

| Evaluation Aspect    | Number of Items | Obtained Score | Maximum Score | Percentage | Criteria   |
|----------------------|-----------------|----------------|---------------|------------|------------|
| Content Feasibility  | 7               | 28             | 28            | 97%        | Very Valid |
| Language Quality     | 8               | 31             | 32            |            |            |
| Presentation Quality | 8               | 30             | 32            |            |            |
| <b>Total Score</b>   |                 | <b>89</b>      | <b>92</b>     |            |            |

The interactive learning media for the immune system topic was categorized as very valid, with a validity percentage of 97%, based on the subject matter expert evaluation presented in Table 9. The content feasibility aspect received a perfect score of 28 out of 28, indicating that the materials were accurate, systematically organized, and aligned with the intended learning objectives.

This finding supports the statement by Maladona & Ilmiyati (2023) that content feasibility can be evaluated based on the alignment between learning materials, instructional indicators, and conceptual accuracy. Furthermore, the presentation aspect obtained a score of 30 out of 32, while the language aspect received a score of 31 out of 32. These results indicate that the learning materials were presented clearly, communicatively, and appropriately to support students' understanding of immune system concepts.

## 2. Practicality results of the learning media

To determine whether the developed learning media was easy to use and appropriate for users' needs, a practicality test was conducted through response questionnaires completed by teachers and students. The results of the practicality evaluation are presented in Table 10.

**Table 10.** Practicality test results based on teacher and student responses

| Respondents       | Number of Items | Obtained Score | Maximum Score | Percentage | Criteria       |
|-------------------|-----------------|----------------|---------------|------------|----------------|
| Teacher (n = 1)   | 12              | 46             | 48            | 96%        | Very Practical |
| Students (n = 27) | 12              | 46             | 48            | 96%        | Very Practical |

Based on the results presented in Table 10, the interactive learning media based on Articulate Storyline 3 was categorized as very practical according to both teacher and student evaluations. The teacher response obtained a score of 46 out of 48 (96%), indicating that the media met the criteria of ease of use, suitability for classroom implementation, and effectiveness in supporting the learning process.

Similarly, student responses obtained a score of 46 out of 48 (96%), indicating that students perceived the media as attractive, user-friendly, and beneficial for understanding the immune system topic. These findings demonstrate that the

developed media was not only feasible in terms of content and design but also practical for use by both teachers and students during learning activities.

### 3. Effectiveness results of the learning media

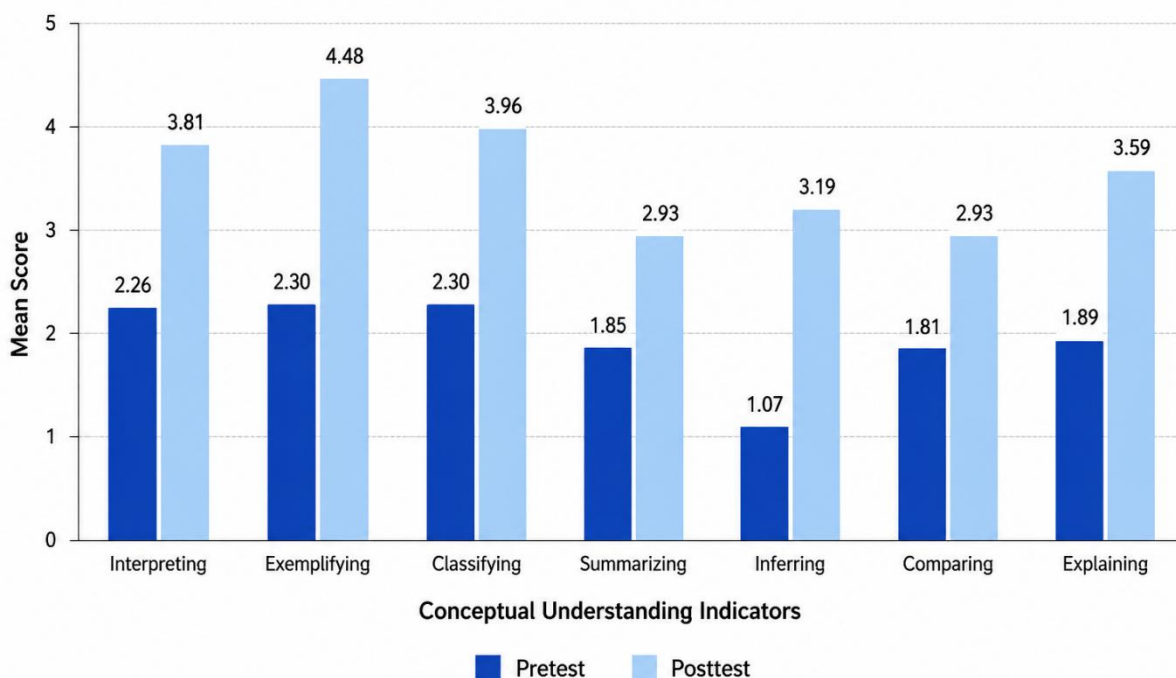
The effectiveness of the developed learning media was evaluated using the normalized gain (N-Gain) analysis to determine improvements in students' conceptual understanding before and after using the interactive learning media. The results of the analysis are presented in Table 11.

**Table 11.** Effectiveness test results based on N-Gain analysis

| Assessment | Mean Score | Maximum Score | N-Gain | Criteria         |
|------------|------------|---------------|--------|------------------|
| Pretest    | 48.22      | 100           | 0.71   | High / Effective |
| Posttest   | 85.70      | 100           |        |                  |

Based on Table 11, the effectiveness analysis indicated that the interactive learning media based on Articulate Storyline 3 improved students' conceptual understanding of the immune system topic. According to Hake (1998), the average pretest score increased from 48.22 to 85.70 in the posttest, resulting in an N-Gain value of 0.71, which was categorized as high.

These results indicate that the developed media showed potential in supporting the improvement of students' conceptual understanding. This finding is consistent with Setyaningsih et al. (2020), who reported that the presentation of information through attractive and interactive Articulate Storyline-based learning media can improve students' learning outcomes.



**Figure 2.** Conceptual understanding test results based on indicators

As shown in Figure 2, all indicators of conceptual understanding demonstrated considerable improvement after students used the interactive learning media. The figure presents the distribution of average pretest and posttest scores for each conceptual understanding indicator.

The interpretation (interpreting) indicator increased from 2.26 in the pretest to 3.81 in the posttest. The exemplifying indicator showed an increase from 2.30 to 4.48, representing the highest improvement among all indicators. The summarizing indicator increased from 1.85 to 2.93, while the classifying indicator improved from 2.30 to 3.96.

Furthermore, the inferring indicator increased from 1.07 to 3.19. The comparing indicator improved from 1.81 to 2.93, whereas the explaining indicator increased from 1.89 to 3.59. These findings indicate that the interactive features provided in Articulate Storyline 3 supported students in constructing a better understanding of immune system concepts, particularly through visualization and interactive representations of complex biological processes.

The normality test was conducted using SPSS to determine the distribution characteristics of the pretest and posttest scores obtained from 27 students. The results are presented in Table 12.

**Table 12.** Normality test results

| Data     | Kolmogorov–Smirnov Statistic | df | Sig.  | Shapiro–Wilk Statistic | df | Sig.  |
|----------|------------------------------|----|-------|------------------------|----|-------|
| Pretest  | 0.177                        | 27 | 0.029 | 0.855                  | 27 | 0.001 |
| Posttest | 0.147                        | 27 | 0.139 | 0.930                  | 27 | 0.070 |

The normality test results showed that the pretest data were not normally distributed, as indicated by the Shapiro–Wilk significance value of 0.001 ( $<0.05$ ). Meanwhile, the posttest data showed a significance value of 0.070 ( $>0.05$ ), indicating a normal distribution. Because one of the datasets did not meet the assumption of normality, a non-parametric Wilcoxon Signed-Rank Test was applied to examine whether there was a significant difference between students' pretest and posttest scores. The results of the Wilcoxon analysis are presented in Table 13.

**Table 13.** Wilcoxon signed-rank test results

| Test               | Z Value | Asymp. Sig. (2-tailed) |
|--------------------|---------|------------------------|
| Pretest – Posttest | -4.545  | 0.000                  |

The Wilcoxon Signed-Rank Test resulted in a significance value (Asymp. Sig. 2-tailed) of 0.000 and a Z value of -4.545. Since the significance value was lower than 0.05 ( $p < 0.05$ ), there was a statistically significant difference between students' pretest and posttest scores after using the Articulate Storyline 3-based interactive learning media.

The negative Z value indicates that the posttest scores were generally higher than the pretest scores. These findings suggest that the implementation of interactive learning media based on Articulate Storyline 3 contributed to improved conceptual understanding of the immune system among students.

Based on the achievement of each conceptual understanding indicator, the exemplifying indicator showed the highest improvement compared with other indicators. This improvement may be attributed to the interactive features available in Articulate Storyline 3, which facilitate students' understanding of biological concepts through concrete examples.

The animations provided in the media helped students visualize abstract biological processes, while audio elements strengthened information delivery. In addition, navigation features supported independent learning and enabled students to explore immune system concepts more effectively. This finding is consistent with Fajar et al. (2026), who reported that the exemplifying indicator tends to achieve higher

performance because students can more easily connect scientific concepts with concrete examples.

In contrast, the improvements in the summarizing and comparing indicators were relatively lower. These indicators require higher cognitive processes involving information organization and identification of relationships, similarities, and differences among concepts. Therefore, students may require more intensive practice and repeated learning experiences to further develop these abilities.

Although the findings demonstrated improvements in all conceptual understanding indicators, the implementation of this interactive learning media has several limitations. The use of digital media depends on the availability of electronic devices and stable internet access. This limitation is consistent with Ren & Zhu (2024), who stated that unstable internet connectivity may reduce student participation and negatively affect the quality of learning experiences when using digital learning media.

#### **d. Disseminate**

The dissemination stage represented the final phase of the 4D development model. At this stage, the validated Articulate Storyline 3-based interactive learning media was distributed to Grade XI students at MAN 1 Medan.

Students accessed the learning media through a link using their personal smartphones, allowing the developed product to serve as an alternative interactive learning resource for the immune system topic. The dissemination process was accompanied by documentation of students' implementation activities, as presented below.



**Figure 3.** Students using Articulate Storyline 3-based interactive media

## **CONCLUSION**

Based on the findings of this study, the following conclusions can be drawn: (1) The interactive learning media based on Articulate Storyline 3 developed for the Immune System topic was categorized as highly valid, as indicated by the validation results from the material expert (97%) and media expert (99%). (2) The results of teacher and student response questionnaires showed that the developed media was categorized as highly practical, with both groups providing the same practicality score of 96%. (3) Based on the N-Gain analysis, which yielded a score of 0.71 (high category), the interactive learning media based on Articulate Storyline 3 demonstrated potential effectiveness in improving students' conceptual understanding. (4) This study was limited by the implementation of the media trial involving only 27 eleventh-grade students from a single class at MAN 1 Medan. Therefore, further studies involving broader samples and different educational settings are required before the findings can be generalized to other student groups or schools.

## **RECOMMENDATION**

Future research is recommended to develop interactive learning media based on Articulate Storyline 3 that can be accessed offline, thereby reducing dependence on internet availability during the learning process. Further studies should also evaluate

the effectiveness of the developed media across diverse technological infrastructure conditions and school characteristics. Such investigations are expected to support broader, more effective, and equitable implementation of interactive learning media without being constrained by limited internet access.

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