



The effectiveness of a gamification-based student worksheet in improving students' learning outcomes on the human immune system

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Abstract. This study aimed to determine the effectiveness of a gamification-based student worksheet in improving students' learning outcomes on the human immune system. A quantitative approach with a one-group pretest–posttest design was employed, involving 36 students from Class XI-12 at SMA Negeri 1 Medan. The intervention was conducted over three learning sessions. Students' learning outcomes were measured using a 20-item multiple-choice test selected through expert validation and empirical item analysis. The data were analyzed using the normalized gain (N-Gain). The results showed that the mean test score increased from 56.52 on the pretest to 88.47 on the posttest, representing an increase of 31.95 points. The mean N-Gain was 0.7615 (76.15%), which was classified as high based on the criteria used in this study. These findings indicate that the gamification-based student worksheet was effective in improving students' learning outcomes on the human immune system within the context of this study. The worksheet integrated communicative explanations, supporting illustrations, step-by-step descriptions of immune mechanisms, and gamification elements, including levels, challenges, and rewards. The developed worksheet can serve as an alternative instructional resource for Biology teachers teaching the human immune system and as a reference for developing similar worksheets for other Biology topics, with appropriate adaptations to learning objectives and topic characteristics. Future research should involve larger and more diverse samples and appropriate comparison groups to strengthen the evidence of effectiveness. Further studies may also investigate students' learning motivation, engagement, and conceptual understanding, as well as assess learning retention through delayed posttests, to provide a more comprehensive understanding of the potential benefits of gamification-based student worksheets in Biology learning.

Keywords: *Biology learning, Gamification-Based student worksheet, Human immune system, Learning outcomes*

Received: 10 September 2026 Revised: 13 October 2026 Accepted: 18 October 2026 Published: 26 October 2026

INTRODUCTION

Biology is a science that studies life and its interactions with the environment. Therefore, Biology learning is designed to provide concrete and meaningful learning experiences so that students can develop a deeper understanding of the natural world. Biology encompasses various concepts, phenomena, and life processes related to humans, animals, plants, and microorganisms. However, Biology is often considered a difficult subject by students because of the use of scientific terminology, the complexity of concepts, and the abstract nature of the material (Syarah et al., 2021). These characteristics require students not only to memorize biological concepts but also to understand the relationships among concepts and the processes underlying various biological phenomena. One topic that reflects these characteristics is the human immune system. This topic is considered challenging because its cellular mechanisms cannot be directly observed and require students to connect multiple interrelated processes, such as antigen recognition, antibody formation, and the body's defense response to pathogens (Purnamasari, 2020). This difficulty is further reinforced by the fact that the body's defense mechanisms against foreign antigens cannot be directly observed, making it difficult for students to visualize and understand how these defense processes occur (Lewar et al., 2025).

Based on the findings from initial observations at SMA Negeri 1 Medan, students' learning outcomes on the human immune system were found to be suboptimal. An interview with a Biology teacher revealed that the learning process had implemented Problem-Based Learning (PBL) and Project-Based Learning (PJBL), although challenges remained in maintaining students' focus and active participation. The instructional media commonly used were PowerPoint presentations and printed modules, which provided limited support for visualizing the abstract mechanisms of the human immune system. The teacher also explained that students found this topic difficult to understand because they struggled to visualize how immune cells respond to and defend the body against pathogens. Based on student learning outcome data shown by the teacher, 26 of the 36 students in Class XI-12 (72.22%) had not achieved the mastery level established by the school. These findings indicate that students' mastery of the human immune system remains low.

The use of instructional media that is appropriate to the characteristics of the learning material is necessary to help students understand complex and abstract Biology concepts. Instructional media can support a more active learning process through students' interaction with the learning material (Munawir et al., 2024). Instructional media that are appropriately designed and implemented can also support the learning process, increase student engagement, and strengthen students' understanding and retention of the material being studied (Shabrina et al., 2025). One type of instructional media that can support this process is a student worksheet, which is a set of structured activities containing instructions, learning materials, and exercises to guide students in understanding concepts through learning activities and problem-solving rather than mere memorization (Nestiadi et al., 2024). A student worksheet can also function as a learning guide that helps students construct knowledge independently through scientific activities and understand the concepts being studied (Batubara et al., 2025). Therefore, a student worksheet designed according to the characteristics of the learning material can serve as an instructional medium that supports conceptual understanding and the achievement of student learning outcomes.

The development of student worksheets needs to consider not only the completeness of the material but also how learning content and activities are designed to actively engage students in understanding the concepts and mechanisms of the human immune system. The integration of contextual analogies, supporting illustrations, and reinforcing notes within student worksheets can serve as a cognitive bridge to simplify complex concepts, make abstract information more concrete, and help students visualize and understand how the immune system functions in the human body (Yuningsih & Susilo, 2018). In addition, student worksheets that primarily contain material explanations and routine exercises can be further developed through the integration of gamification elements.

Gamification is the application of game elements and mechanisms, such as points, levels, badges, challenges, and feedback, in non-game contexts to create more engaging and structured learning activities (Aini & Husna, 2025). Reviews of various studies on gamification in learning indicate that points, rewards, and challenges are among the most frequently applied elements and have been reported to positively influence student engagement and learning achievement (Rahman et al., 2018). In student worksheets, gamification can be implemented by organizing learning tasks progressively through levels and challenges, encouraging students to complete each stage of the activities. Rewards can also be provided to students who successfully complete tasks as a form of recognition for their achievements. The use of levels and challenges can guide students through learning activities progressively, while rewards can support their engagement in completing the assigned tasks (Jannah & Sudrajat, 2026). Thus, integrating communicatively presented learning materials, visual and contextual support, and gamification elements into student worksheets can create more engaging and structured

learning experiences while encouraging active student participation in understanding the mechanisms of the human immune system.

Gamification is particularly relevant to Biology learning because many Biology concepts, such as the human immune system, are complex, interrelated, and cannot be directly observed, making it difficult for students to connect concepts like antigens, antibodies, and immune cells to the underlying defense mechanisms of the body. Presenting such material through progressively structured levels and challenges can help students work through this complexity step by step, as challenges are a fundamental gamification element shown to support both engagement and learning achievement (Rahman et al., 2018). This is consistent with classroom action research showing that applying a gamification strategy on a Biology topic progressively raised students' mastery of the material across learning cycles, from 22.86% under conventional conditions to 77.14% after gamification-based instruction, alongside a marked increase in students' classroom engagement (Ramli & Nurhidayah, 2024). Within this structure, rewards for successfully completing each stage further reinforce students' sense of accomplishment, consistent with Selçuk and Keskin's (2024) systematic review reporting that gamification in Biology education supports cognitive development and the understanding of abstract concepts through more engaging learning activities. Gamification therefore holds strong potential for teaching the human immune system by breaking down complex, abstract biological processes into manageable, engaging stages of learning.

Despite this growing body of evidence, studies that specifically design student worksheets around gamification principles, rather than general gamified media or game-based worksheets, remain limited, and none has been directed at the human immune system material. This gap represents both a methodological opportunity and a practical need, since the topic's abstract nature makes it a suitable candidate for a worksheet that translates invisible cellular processes into concrete, structured, and rewarding learning tasks. The novelty of the present study therefore lies in combining the pedagogical structure of the student worksheet with gamification elements specifically to help students construct a concrete mental model of the immune system while working through a graded sequence of challenges and feedback.

Although gamification has been widely shown to support learning and student learning outcomes, prior studies have largely examined it as a general classroom teaching strategy rather than as an integrated component of printed instructional materials, such as a strategy applied through classroom action research to optimize learning outcomes on other Biology topics (Ramli & Nurhidayah, 2024) or as a broader digital game-based learning model (Aini & Husna, 2025), with gamification elements typically applied directly to learning activities rather than embedded within the structure of a worksheet itself (Rahman et al., 2018). Research that specifically integrates gamification into the structure of student worksheets remains relatively limited, particularly for the human immune system topic in Biology. This study addresses that gap by developing and testing the effectiveness of a gamification-based student worksheet on the human immune system topic. The novelty of this study lies in integrating levels, challenges, and rewards directly into the worksheet's structured activities to guide students through progressive stages of activity, encourage participation, and provide rewards for successfully completing the activities, with the worksheet's effectiveness subsequently evaluated based on its impact on students' learning outcomes.

Based on this background, the present study was conducted to determine the effectiveness of a gamification-based Student Worksheet on the human immune system material in improving the learning outcomes of Class XI students at SMA Negeri 1 Medan. It is expected that the worksheet used can serve as an alternative Biology learning medium that makes abstract immunological concepts more tangible and contributes to a measurable improvement in student learning outcomes.

METHOD

Research design

This study employed a quantitative approach with a one-group pretest-posttest design. This design was used to examine changes in students' learning outcomes before and after the learning process using a gamification-based student worksheet on the human immune system. Students took a pretest before using the worksheet and a posttest after participating in the learning activities using the gamification-based worksheet.

Participants

The participants were determined using a purposive sampling technique. The study involved 36 students of Class XI-12 at SMA Negeri 1 Medan. This class was selected because its students had homogeneous learning abilities categorized as lower-achieving, which made it suitable for examining the effectiveness of the gamification-based student worksheet. The learning activities focused on the human immune system material and were conducted over three learning sessions.

Research instrument and data collection technique

Learning outcome data were collected through a pretest and a posttest using the same 20 multiple-choice items. The pretest was administered before students used the gamification-based student worksheet, and the posttest was administered after students completed the three learning sessions.

Learning outcome instrument

Students' learning outcomes were measured using a multiple-choice test covering the cognitive domains C1–C6. The test indicators were derived from the learning objectives and are presented in the test blueprint in Table 1. A total of 40 items were initially prepared, and the quality of the items was examined through expert validation and empirical testing before the final 20 items were selected for use in the learning outcomes test in the research class.

Expert validation

The content validity of the learning outcomes instrument was evaluated by one expert lecturer using a validation sheet covering three assessment aspects: item content, item construction, and language. Each aspect was rated using a four-point scale. The percentage of instrument validity was calculated using the formula:

$$\text{Validity percentage} = \frac{\text{obtained score}}{\text{maximum score}} \times 100\%$$

The resulting percentage was then interpreted based on the instrument validity criteria presented in Table 2.

Empirical testing

After the expert declared the test feasible, it was administered to 36 students of Class XII-9 at SMA Negeri 1 Medan who had previously studied the human immune system. The responses were analyzed using SPSS to determine empirical validity, reliability, difficulty level, and discrimination, as described below.

Table 1. Blueprint of the learning outcome test

Learning objectives	Indicator	Cognitive domain					
		C1	C2	C3	C4	C5	C6
Describe the components of cells, tissues, and organs that make up the body's defense system accurately, and identify non-specific defense mechanisms in responding to pathogenic infections.	Describing the definition of the immune system and its main functions.	1	6				
		2					
		3					
		4					
		5					
	Explaining the mechanisms of first-line non-specific immune defenses, including physical, mechanical, chemical, and biological defenses. Identifying the role of inflammation, phagocytosis, or antimicrobial proteins in a given infection scenario.	7	8	11			
			9	12			
			10	13			
			14	16			
			15	17			
		18					
Identify specific defense mechanisms (humoral and cellular), analyze the structural relationships (antigen-antibody, B-cell-T-cell) and the functions between these components.	Using the concepts of humoral and cellular immune responses to explain the mechanisms of antibody action, B cells, and T cells in a given infection scenario.			19	21		
				20	22		
	Analyzing the relationship between antigen-antibody structure and the roles of B cells and T cells in the mechanisms of the specific immune system.			23	25	28	
				24	26		
					27		
Comparing the roles of humoral and cellular immune responses in dealing with various types of pathogens.				29	31		
				30			
Investigate public health conditions related to the immune system (e.g., autoimmune disorders, allergies, HIV) through case studies	Analyzing the causes and mechanisms of immune system disorders (autoimmune diseases, allergies, and HIV/AIDS) based on the given case studies.				32	35	
					33		
					34		
	Assessing the impact of immune system disorders on individual and public health based on information provided in the case studies.					36	37
							38
Proposing prevention and management strategies for immune system disorders based on the analysis of the case studies.						39	
						40	
Number of Questions		6	6	10	10	4	4
Total Number of Questions		40					

Table 2. Criteria for the validity of the learning outcomes instrument

Percentage (%)	Category
0 - 20	Not Feasible
21 - 40	Less Feasible
41 - 60	Moderately Feasible
61 - 80	Feasible
81 - 100	Very Feasible

(Syafitriyani *et al.*, 2023)

Validity test

The validity test was conducted to determine the extent to which each item measured what it was intended to measure. Validity was assessed using the Pearson Product-Moment correlation between each item score and the total score, calculated with SPSS using the following formula (Widodo et al., 2023).

$$r_{xy} = \frac{N \sum xy - (\sum x)(\sum y)}{\sqrt{(N \sum x^2 - (\sum x^2))(N \sum y^2 - (\sum y^2))}}$$

Description:

- r_{xy} = Correlation coefficient
N = Number of respondents
x = The score of each item on the instrument
y = Total score

An item was considered valid when its calculated correlation coefficient exceeded the critical r-value at the 5% significance level. The criteria used to classify item validity are presented in Table 3.

Table 3. Test instrument validity criteria

The value of r	Classification
0.81–1.00	Very High
0.61–0.80	High
0.41–0.60	Moderate
0.21–0.40	Low
0.00–0.20	Very Low

(Widodo et al., 2023)

Reliability test

The reliability of the learning outcomes instrument was assessed to determine the internal consistency of the test items. Since the items were scored dichotomously, reliability can theoretically be estimated using the Kuder–Richardson Formula 20 (KR-20):

$$r_{11} = \left(\frac{k}{k-1} \right) \left(1 - \frac{\sum pq}{\sigma^2 t} \right)$$

(Karima et al., 2026)

Where r_{11} is the reliability coefficient, k is the number of test items, p is the proportion of students who answered an item correctly, q is the proportion of students who answered the item incorrectly ($q = 1 - p$), and $\sigma^2 t$ is the variance of the total test scores. In SPSS, this coefficient is obtained as Cronbach's Alpha, which is equivalent to KR-20 for dichotomous items. Reliability was calculated for the items that met the validity criterion. A coefficient of $\alpha \geq 0.70$ was considered acceptable (Taber, 2018).

Difficulty level test

The difficulty index indicates the level of difficulty or ease of a test item. An item is considered difficult when most test takers answer incorrectly and easy when most answer correctly (Inanna et al., 2021). The test items were classified into three difficulty levels: easy, moderate, and difficult, with a composition ratio of 3:5:2, corresponding to 30%, 50%, and

20%, respectively (Magdalena et al., 2021).

The difficulty index was calculated using the following formula:

$$I = \frac{B}{N}$$

Description :

- I = Difficulty index for each question item
- B = The number of students who answered each question correctly
- N = The number of students who gave answers to the intended question.

The difficulty index is used to determine the level of difficulty of each test item, where a lower index value indicates a more difficult item, while a higher index value indicates an easier item to solve. Based on the difficulty index criteria proposed by Yadnyawati (2019), the classification of item difficulty levels is presented in Table 4.

Table 4. Difficulty index range	
Index range	Difficulty category
0.00 - 0.30	Difficult
0.31 - 0.70	Medium
0.71 - 1.00	Easy

(Yadnyawati, 2019)

Based on the results of the difficulty analysis, items with an appropriate difficulty level were retained, whereas items that were too easy or too difficult were either revised or discarded.

Discrimination power test

Discrimination analysis was conducted to assess the ability of each test item to distinguish between students with higher and lower levels of overall performance. An item is considered to have good discrimination when students with high overall scores tend to answer it correctly, whereas items that fail to make this distinction are less effective in representing students' actual abilities (Yadnyawati, 2019). In this study, item discrimination was determined using the Corrected Item-Total Correlation generated by SPSS, which is the correlation between the score of each item and the total score of the remaining items. The coefficients were interpreted using the criteria in Table 5.

Table 5. Criteria for question differentiating power	
Criteria for question differentiating power	Interpretation
0.00 – 0.19	Poor
0.20 – 0.39	Satisfactory
0.40 – 0.70	Good
0.71 – 1.00	Very good

(Kaune et al., 2025)

Final item selection

From the items that met the validity criterion, 20 items were selected for the pretest and posttest based on difficulty level and discrimination power. The selection maintained the 3:5:2 composition (6 easy, 10 moderate, and 4 difficult items) and included only items with discrimination of at least satisfactory.

Data analysis

The improvement in students' learning outcomes between the pretest and posttest was analyzed using the Normalized Gain (N-Gain) formula (Sugiyono, 2023).

$$N - gain = \frac{Posttest\ score - Pretest\ score}{Maximum\ score - Pretest\ score}$$

The resulting N-Gain score was first classified using the criteria in Table 6.

Table 6. N-gain classification of learning outcomes

Interval	Classification
$g > 0.7$	High
$0.3 \leq g \leq 0.7$	Medium
$g < 0.3$	Low

(Sugiyono, 2023)

The N-Gain percentage was then interpreted for effectiveness using the criteria in Table 7.

Table 7. Category of N-gain effectiveness interpretation on student learning outcomes

Percentage (%)	Interpretation
< 40	Ineffective
40 - 55	Less effective
56 - 75	Quite effective
> 76	Effective

(Listiani et al., 2024)

RESULTS AND DISCUSSION

Results

Validation of the learning outcomes test questions

Before being used to measure the effectiveness of the gamification-based worksheet, the learning outcomes test was subjected to expert and empirical analysis. The test covered the Human Immune System material and was validated by an expert lecturer to determine the accuracy of measurement and the feasibility of the items in terms of content, construction, and language. The results of the validation assessment are presented in Table 8.

Table 8. Results of the validation assessment of the learning outcomes test instrument

No	Aspect	Total score	Maximum score	Percentage	Category
1	Item Content Feasibility	14	16	93.75%	Very Feasible
2	Construct Feasibility	11	12	91.66%	Very Feasible
3	Language Feasibility	12	12	100%	Very Feasible
Total Score		37	40	92.5%	Very Feasible

Based on Table 8, the validation assessment conducted by the expert lecturer obtained a total score of 92.5%, categorized as Very Feasible. After being declared feasible, the test items were subsequently administered to Class XII-9 students at SMA Negeri 1 Medan, who had previously studied the human immune system material, to obtain empirical data for determining the validity, reliability, difficulty level, and discrimination of each item.

Test validity analysis

The validity of the test instrument was examined using the Pearson Product-Moment correlation technique processed through SPSS. Each item was considered valid if its calculated r-value exceeded the critical r-value of 0.329 at the 5% significance level. A summary of the validity test results is presented in Table 9.

Table 9. Results of test validity item

Criteria	Question item number	Amount
Valid	1, 3, 4, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 22, 24, 25, 26, 27, 28, 29, 31, 32, 34, 35, 36, 37, 38, 39, 40	33
Invalid	2, 5, 6, 15, 23, 30, 33	7
Total		40

Reliability test

The reliability of the learning outcomes instrument was assessed using Cronbach's Alpha through SPSS. A Cronbach's Alpha coefficient of ≥ 0.70 was considered to indicate acceptable internal consistency. The results of the reliability analysis are presented in Table 10.

Table 10. Reliability statistics

Cronbach's alpha	N of items
0.949	33

The analysis yielded a Cronbach's Alpha coefficient of 0.949 for the 33 valid items, which exceeded the 0.70 threshold. Therefore, the learning outcomes instrument was considered reliable and suitable for use as a data collection instrument in the study.

Difficulty level test

The difficulty level analysis was conducted to determine the level of difficulty of each test item based on the proportion of students who answered the item correctly. The test items were designed according to a difficulty-level composition ratio of 3:5:2 for the easy, moderate, and difficult categories, respectively. Of the 40 items tested, 12 items were categorized as easy, 20 items as moderate, and 8 items as difficult. The summary of the difficulty level test results is listed in Table 11.

Table 11. The results of the difficulty level test

Category of difficulty level	Question item number	Number of items
Easy 0.71-1.00	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12	6
Medium 0.31-0.70	13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 29, 30, 31, 32, 33	8
Difficult 0.00-0.30	28, 34, 35, 36, 37, 38, 39, 40	6
Total		40

Discrimination power test

Item discrimination analysis was conducted using the Corrected Item-Total Correlation values generated by SPSS. A higher correlation coefficient indicates greater discriminatory power, meaning that the item is better able to distinguish between students with higher and lower levels of overall test performance.

The selection of test items was based on both item difficulty and item discrimination, following a 3:5:2 proportion for the easy, moderate, and difficult categories, respectively. The selected items demonstrated discrimination levels ranging from satisfactory to very good. Of the 20 items selected for the final test, 15 demonstrated good discrimination, four demonstrated very good discrimination, and one demonstrated satisfactory discrimination.

The quality of the test instrument is essential for ensuring the accurate interpretation of the effectiveness of an instructional intervention. In this study, the instrument underwent expert validation and empirical item analysis before being administered to assess students' learning outcomes. Therefore, the changes observed in students' test scores provide a more reliable basis for evaluating the effectiveness of the gamification-based worksheet. The summary of the discrimination power test is listed in Table 12.

Improvement in students' learning outcomes

The implementation of the gamification-based worksheet resulted in a substantial increase in students' learning outcomes on the human immune system material. The average pretest score was 56.52, while the average posttest score increased to 88.47. Thus, the average learning

outcome increased by 31.95 points after students participated in learning activities using the gamification-based worksheet (Figure 1).

Table 12. The result of the discrimination power test

Discrimination power category	Question item number	Number of item
Very Good $0.71 \leq DT \leq 1.00$	18, 19, 20, 34	4
Good $0.40 \leq DT < 0.70$	1, 3, 8, 9, 10, 11, 17, 21, 22, 27, 32, 35, 36, 38, 39	15
Satisfactory $0.20 \leq DT < 0.39$	4	1
Not Good $0.00 \leq DT < 0.19$	-	-
Total		20

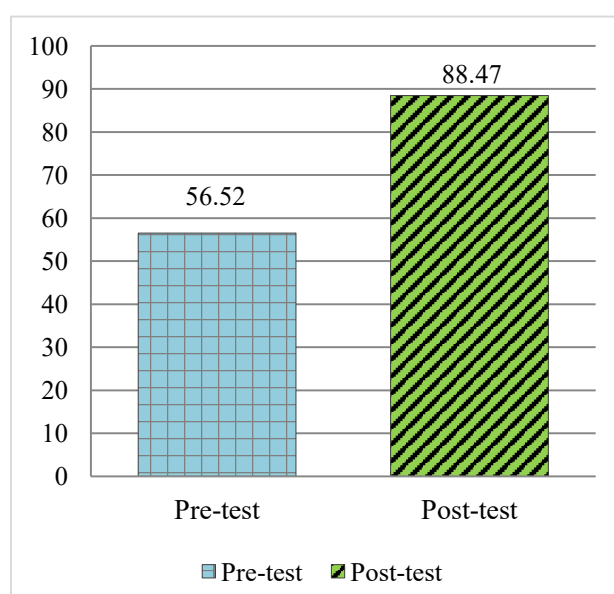


Figure 1. Results of students' learning outcomes

The increase in learning outcomes indicates that students demonstrated better mastery of the human immune system after the learning intervention. The worksheet provided structured activities through which students were required to engage with biological concepts rather than merely receive information. Gamification elements such as missions, challenges, points, and progressive activities were incorporated into the learning process. These elements provided a structured sequence of tasks that encouraged students to process concepts, complete activities, and apply their understanding to different learning situations.

The pretest and posttest data were subsequently analyzed using the N-Gain test to determine the extent of improvement in students' learning outcomes. The results are presented in Table 13.

Table 13. N-Gain analysis results of students' learning outcomes

	N	Minimum	Maximum	Mean	Std. Deviation
Ngain_Score	36	.56	1.00	0.761	0.125
Ngain_Persen	36	55.56	100.00	76.151	12.508
Valid N (listwise)	36				

Based on Table 13, the N-Gain analysis of students' learning outcomes shows an average N-Gain score of 0.7615 (76.15%), with the highest score reaching 1.00 and the lowest

score being 0.56, and a standard deviation of 0.12. Based on the N-Gain score criteria, the average score falls into the high category with an effective interpretation, and the improvement occurred relatively consistently across students. These results demonstrate that the gamification-based worksheet is effective as a learning medium for improving students' learning outcomes on the human immune system material.

Discussion

Before the effectiveness of the gamification-based student worksheet was analyzed, the quality of the learning outcome test instrument was first established through expert validation and empirical item analysis. The validation results showed that the instrument obtained a feasibility score of 92.5%, which was classified as Very Feasible (Syafitriyani et al., 2023). Based on the empirical analysis, 33 out of 40 test items were declared valid, with a Cronbach's Alpha value of 0.949. This value exceeded the threshold of 0.70, indicating high internal consistency of the instrument (Taber, 2018). Subsequently, 20 test items were selected for use in the pretest and posttest based on validity, difficulty level, and discriminating power, with a ratio of easy, moderate, and difficult items of 3:5:2. This procedure was carried out to ensure that the instrument used had adequate quality for measuring students' learning outcomes before and after the implementation of the gamification-based student worksheet. Thus, the comparison of pretest and posttest scores could provide a more measurable picture of changes in students' learning outcomes.

The results showed an improvement in students' learning outcomes after using the gamification-based student worksheet on the human immune system material. The mean score increased from 56.52 on the pretest to 88.47 on the posttest, with a difference of 31.95 points. In addition, the mean N-Gain value of 0.7615, or 76.15%, was classified as high and effective (Listiani et al., 2024). These findings indicate that students achieved higher learning outcomes after participating in learning activities using the gamification-based student worksheet.

The human immune system material covers concepts related to antigens, antibodies, various types of immune cells, and the mechanisms of the body's responses to pathogens. Understanding this material requires not only the ability to recall terms but also the ability to understand the relationships among components and the sequence of biological processes occurring in the body. Some of these mechanisms occur at the cellular and molecular levels, making them difficult to observe directly (Purnamasari, 2020). To help students understand this material, the gamification-based student worksheet was developed with communicative presentation and supplemented with illustrations, images, and supporting notes (Yuningsih & Susilo, 2018). Complex biological mechanisms were also explained step by step, using images that helped students follow the sequence of processes and understand the relationships among the stages. This presentation provided visual support and more structured explanations for learning concepts that are difficult to imagine. Thus, the worksheet functioned not only as an activity sheet but also as learning material that helped students develop an understanding of the mechanisms of the human immune system.

In addition to the presentation of the material, this worksheet integrated gamification elements in the form of levels, challenges, and rewards to make learning more engaging and less monotonous (Arafah & Sudrajat, 2026). Each activity was designed to give students targets to achieve by completing challenges. Successful completion of challenges was followed by rewards as a form of recognition for students' achievements. This structure provided clear direction for completing learning activities while also potentially increasing students' enthusiasm for participating in each stage. When gamification elements are combined with questions and tasks related to the learning material, students are directed not only to achieve game targets but also to learn the concepts that are the objectives of the learning process. Thus, the use of levels, challenges, and rewards in this worksheet supported the implementation of

more structured and engaging learning activities, while communicative explanations and supporting images helped students understand the material being studied (Sari & Ferry, 2024).

These findings are consistent with Sailer and Homner (2020), whose meta-analysis showed that gamification has the potential to positively influence learning outcomes, including cognitive, motivational, and behavioral outcomes. These findings support the use of game elements as part of instructional design to help students engage in learning activities. In this study, levels, challenges, and rewards provided clear targets for completing tasks, while the communicative and step-by-step presentation of the material supported students' understanding of human immune system concepts. The integration of these two aspects was the main characteristic of the developed worksheet. The increase in the mean score from 56.52 to 88.47 and the N-Gain value of 0.7615 indicate that students achieved higher learning outcomes after participating in learning activities using the gamification-based student worksheet. Thus, the findings of this study support the potential application of gamification combined with material presentation suited to the characteristics of biological concepts to help improve students' learning outcomes.

Support for the application of gamification in biology learning has also been found in the review by Selçuk and Keskin (2024) and the study by Ramli and Nurhidayah (2024). Selçuk and Keskin (2024) reviewed 39 empirical articles and found that gamification was associated with positive effects on students' cognitive, social, and psychological skills, as well as increased motivation and participation in biology learning. Ramli and Nurhidayah (2024), through classroom action research on the excretory system, found that a gamification strategy increased students' learning mastery from 22.86% to 77.14% in the second cycle. In this study, gamification was implemented through a student worksheet specifically designed for the human immune system material, with learning activities organized into levels and challenges, and the material presented through communicative explanations, illustrations, and step-by-step descriptions of mechanisms. The combination of these elements enabled gamification to be used to organize activities that remained focused on understanding the material, rather than merely adding game elements. The improvement in learning outcomes in this study strengthens the support for the use of gamification in developing biology learning materials, particularly for topics that require an understanding of processes and relationships among concepts.

The success of implementing the gamification-based student worksheet in this study can also be considered in relation to students' responses during the learning process and the potential role of gamification elements in supporting learning. Levels and challenges provide goals for students to achieve, while rewards recognize their successful completion of learning activities. These elements may encourage students to participate actively throughout the learning process. Ratinho and Martins (2023), through a systematic review of gamification and motivation in secondary and higher education, discussed the use of game elements such as points, badges, and leaderboards to support learning motivation. Chon et al. (2024) also examined the potential of gamification to enhance learning motivation, while Chans and Castro (2021) discussed its implementation in higher education chemistry learning in relation to motivation, engagement, and academic outcomes. Similarly, Christopoulos and Mystakidis (2023) discussed the role of gamification elements in supporting student engagement and learning achievement. In the present study, students appeared enthusiastic as they progressed through the worksheet activities and completed the challenges. This observation, together with the increase in the mean test score from 56.52 on the pretest to 88.47 on the posttest, provides a positive indication of the implementation of the gamification-based student worksheet for human immune system learning.

The improvement in learning outcomes should also be understood in relation to students' learning needs. The preliminary study showed that 72.22% of students had not achieved the minimum mastery criteria established by the school, even though previous

instruction had used the Problem-Based Learning and Project-Based Learning models supported by PowerPoint and printed modules. This condition indicated the need for learning materials that could help students understand the human immune system material in a more structured manner. The developed gamification-based student worksheet provided support through communicative explanations, supporting images, step-by-step mechanisms, and learning activities organized into levels and challenges. This combination offered an alternative learning approach that integrated support for conceptual understanding with engaging activities. The increase in pretest and posttest scores showed that the use of this worksheet was accompanied by an improvement in students' learning outcomes. These findings emphasize the relevance of developing learning materials that not only convey information but also organize learning activities according to the characteristics of the material and students' needs (Shabrina et al., 2025).

Overall, the results of this study show that the gamification-based student worksheet is effective in improving students' learning outcomes on the human immune system material. This is demonstrated by the increase in the mean score from 56.52 on the pretest to 88.47 on the posttest, with a difference of 31.95 points, as well as an N-Gain value of 0.7615, or 76.15%, which was classified as high based on the criteria used in this study. The effectiveness of this worksheet was supported by the combination of communicative material presentation, supporting illustrations and images, step-by-step explanations of biological mechanisms, and gamification activities involving levels, challenges, and rewards. The presentation of the material helped students understand the complex concepts and mechanisms of the human immune system, while the gamification elements provided goals and challenges that made learning activities more engaging and structured. Thus, the gamification-based student worksheet can be used as an effective alternative learning material to support the improvement of students' learning outcomes on the human immune system material.

CONCLUSION

The findings indicate that the gamification-based student worksheet was effective in improving students' learning outcomes on the human immune system within the context of this study. The mean score increased from 56.52 on the pretest to 88.47 on the posttest, representing an improvement of 31.95 points. The mean N-Gain score was 0.7615 (76.15%), which was classified as high and interpreted as effective based on the criteria applied in this study. The worksheet integrated communicative explanations, supporting illustrations, step-by-step descriptions of immune mechanisms, and gamification elements consisting of levels, challenges, and rewards. This combination provided a structured learning resource to help students understand complex biological concepts through progressive learning activities. In addition, the use of gamification elements has the potential to make the learning process more engaging and enjoyable, thereby encouraging students' interest in learning about the human immune system.

These findings suggest that gamification-based student worksheets can serve as an alternative instructional resource for Biology learning, particularly for topics involving abstract processes that are difficult to observe directly. Biology teachers can use the developed worksheet as a learning resource for the human immune system and adapt its instructional design as a reference for developing similar worksheets for other Biology topics, taking into account the learning objectives and characteristics of each topic. Future research is recommended to involve larger and more diverse samples and appropriate comparison groups to obtain stronger empirical evidence regarding the effectiveness of gamification-based student worksheets in improving students' learning outcomes. Further studies may also investigate students' learning motivation, engagement, and conceptual understanding, as well as evaluate learning retention through delayed posttests. These efforts are expected to provide a more

comprehensive understanding of the educational benefits and applicability of gamification-based student worksheets in Biology learning.

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