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Development of a problem-based learning biology learning website on the body defense system material

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ABSTRACT

The development of digital technology encourages the use of learning media that increase student engagement and problem-solving abilities. However, biology learning about the body's defense system material is still dominated by conventional methods, making it less than optimal in training these abilities. This study aims to develop and test the feasibility of a WordPress-based Problem-Based Learning (PBL) biology learning website. The study employed the ADDIE model, which includes analysis, design, development, implementation, and evaluation stages. Research subjects involved media experts, material experts, biology teachers, grade XI students, and teachers from MAN in Bekasi City. Data were collected through validation questionnaires and response questionnaires. The research results show that the learning website has very high validity with percentages of 88.8% (media expert) and 92% (material expert), very high practicality with percentages of 90% (teachers) and 94.7% (students), and 89% effectiveness in the effective category. The PBL-based biology learning website is declared suitable for use as a learning medium on body defense system material.

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INTRODUCTION

The development of information and communication technology has brought significant changes to education, particularly in the use of digital learning media (Resti, Wati, Ma'Arif, & Syarifuddin, 2024). Technology-based learning media are considered capable of improving the quality of learning by providing more interactive, flexible, and easily accessible materials for students (Wibowo, 2023). The utilization of digital media is also in line with the demands of 21st-century learning, which emphasizes mastery of critical thinking, collaborative, and problem-solving skills (Ghazy, Ghozali, & Wibowo, 2025).

Digital media can be defined as all forms of media that are produced, stored, and disseminated through digital technologies, enabling information to be accessed, processed, and shared efficiently via electronic devices and internet networks (Yatimah, Puspitaningrum, Solihin, & Adman, 2018). The use of digital media in learning enhances accessibility, interactivity, and student-centered learning, which are essential in modern education (Rosamsi et al., 2023). The success of technology in education lies not only in its availability but also in how effectively it is integrated into pedagogical practices (Zulfiani, Suwarna, I. P., El Islami, R. A. Z., & Sari , 2025)

Learning media refers to all tools, resources, or instruments used to convey learning messages from educators to students to achieve instructional objectives effectively. The development of learning media, particularly interactive and digital-based media, has been shown to improve students' understanding of biological concepts. Studies have shown that the development of interactive learning media can enhance student engagement and conceptual understanding, especially in complex biological materials. (Darmawan & Nawawi, 2020).

Biology learning requires appropriate learning media because many concepts are abstract and complex. Media play a strategic role, especially for complex and abstract material such as the body's defense system, which involves dynamic processes and intricate interactions among various cells and mediators (Susanti, Amar, & Iradat, 2025). These concepts require visualization and clear context to be meaningfully understood by students. Traditional media, such as static diagrams or two-dimensional videos, have limitations in providing dynamic learning experiences that visualize biological processes at the cellular level (Susanti, Amar, & Iradat, 2025). Well-designed learning media can help students build conceptual understanding and relate biology material to everyday life phenomena (Indah & Fadilah, 2024).

These learning problems are reinforced by instructional practices that are still dominated by lecture methods and teacher-centered approaches. Conventional learning models tend to position students as passive recipients of information, thus providing insufficient opportunities to develop higher-order thinking skills and problem-solving abilities. This condition impacts low student engagement in the learning process (Husna, Ilmi, & Gusmaneli, 2025).

Interviews conducted with several biology teachers at a Madrasah Aliyah in Bekasi City revealed that classroom instruction is still dominated by conventional methods. Students are rarely exposed to contextual problems related to everyday phenomena, resulting in learning that focuses primarily on theoretical content delivery. In addition, learning resources are limited to printed textbooks without support from varied learning media. The findings also indicate that teachers have not optimally utilized technological developments in designing interactive and innovative learning media. This condition highlights the need to develop learning media that align with technological advancements to support the achievement of learning objectives effectively (Ali, Maniboey, Megawati, Djarwo, & Listiani, 2024).

These problems can be addressed by implementing student-oriented learning models. One relevant learning model is Problem-Based Learning (Astuti, Nurhayati, Ristanto, & Rusdi, 2019). The PBL model emphasizes learning that begins with real-world problems, thereby encouraging students to actively seek information, engage in discussions, and construct knowledge independently (Setyo, Fathurahman, & Anwar, 2020).

Problem-Based Learning is highly relevant to biology learning because it connects scientific concepts to real-life contexts (Maulana et al., 2021). Through PBL, students not only understand concepts but are also trained to analyze problems, develop solutions, and communicate their ideas effectively (Anggela et al., 2021). A meta-analysis study confirms that PBL significantly improves students' cognitive learning outcomes in biology (Astuti, Nurhayati, Ristanto, & Rusdi, 2019).

The implementation of PBL requires support from appropriate learning media to ensure optimal learning processes. Website-based digital media has great potential to support PBL stages

because it enables the presentation of problems, materials, discussions, and evaluations in a structured manner within a single platform (Irawan et al., 2024). Learning websites offer advantages such as high accessibility, flexibility in time and place, and the ability to integrate various media formats, including text, images, videos, and animations. In addition, such platforms can support both independent and classroom learning (Hendra et al., 2023).

However, most existing learning websites still focus primarily on content delivery without systematically integrating PBL stages. Technology-based learning media developed through rigorous validation demonstrate high validity scores and receive positive responses from both teachers and students (Susanti, Amar, & Iradat, 2025). These findings highlight the importance of developing learning media that not only utilize technology but are also aligned with problem-based learning principles.

Therefore, it is necessary to develop a learning website that integrates PBL stages to facilitate active, independent, and problem-oriented learning. The novelty of this research lies in the integration of Problem-Based Learning stages into a website-based learning platform developed using WordPress, which is systematically designed to support each phase of PBL. Unlike previous studies that primarily focus on digital media development or PBL implementation separately, this study combines both aspects into a structured and interactive learning system. Furthermore, this research specifically addresses the body defense system material, which is known for its complexity and abstract nature, by providing visualized, interactive, and problem-oriented learning experiences. The developed website is also comprehensively evaluated in terms of validity, practicality, and effectiveness, making it not only a technological product but also a pedagogically grounded learning solution.

This research contributes to the development of digital learning media oriented toward problem-based learning and addresses the need for more interactive and student-centered biology instruction. It also provides alternative solutions for teachers in overcoming limitations in learning media, particularly in supporting the implementation of the Merdeka Curriculum and the development of 21st-century skills (Ghazy, Ghozali, & Wibowo, 2025).

Based on the above description, this study aims to develop and test the feasibility of a PBL-based biology learning website on the body defense system material for grade XI SMA/MA students. Product feasibility is measured based on: (1) validity assessed by media and material experts, (2) practicality assessed by teachers and students, and (3) effectiveness based on KKM achievement. The results of this research are expected to provide both theoretical and practical contributions to improving the quality of biology learning in the digital era.

RESEARCH METHODS

Research Design

This study uses the Research and Development method. According to Sugiyono, Research and Development is a process for producing products, especially in the field of education, and for testing and validating their effectiveness. In line with this opinion, Sugiyono explains that the research and development method is a research approach aimed at producing a product and assessing the effectiveness level of the developed product. This study aims to develop and validate a product, namely a Problem-Based Learning website on the body defense system (Sugiyono, 2023). The Research and Development steps used in this study adapt the ADDIE development model (Analysis, Design, Development, Implementation, and Evaluation) proposed by Branch (2009). The ADDIE model was chosen because it is systematic and flexible and allows for continuous product revision based on expert validation results and field trials. The product developed in this study is a Problem-Based Learning (PBL) website built on WordPress that uses Body Defense System materials for high school students. The feasibility and effectiveness of the developed learning website are evaluated with respect to validity and practicality.

Population and Samples

The population in this study comprised all grade XI students at Madrasah Aliyah Negeri (MAN) in Bekasi City. The sample was selected using purposive sampling based on criteria aligned with the research objectives, namely: (1) students who had learned the basic concepts of the immune system, (2) students who actively participated in biology learning activities, and (3) students who had access to digital devices to support website-based learning. Based on these criteria, 36 students from grade XI in the odd semester of the 2025/2026 academic year were selected as the research sample. This study also involved validators and a practitioner to evaluate the validity and practicality of the developed product. The validation was conducted by one media expert, one material expert, and one practitioner. The media expert was a lecturer in Informatics Engineering who assessed the design, usability, and functionality of the website. The material expert was a lecturer in Biology Education who evaluated the accuracy, relevance, and depth of the content. The practitioner, a biology teacher, assessed the practicality and suitability of the media for classroom implementation. All validators were selected based on their expertise relevant to the study.

Instruments

The instruments in this study are used to collect data on the validity, practicality, and effectiveness of the Problem-Based Learning website built on the WordPress platform for Body Defense System material. The instruments used in this study are as follows:

Expert Validation Sheet

The expert validation sheet is used to assess the validity of the developed learning website and to inform product revisions. Validation assessment is conducted by material experts and media experts. Assessment by material experts includes several aspects: the appropriateness of the material content, alignment with the curriculum, concept accuracy, integration with the Problem-Based Learning (PBL) approach, material presentation, and language. Meanwhile, assessment by media experts includes aspects of website design display, graphics, display consistency, ease of use (user-friendly), navigation, and the usefulness of the website as a learning medium.

Practitioner Validation Sheet and Student Response Questionnaire

The practitioner validation sheet is used to obtain assessments from biology teachers as learning practitioners on the developed learning website. Practitioner assessments include material content appropriateness, learning presentation, integration with the PBL model, website display, language, ease of use, and the website's usefulness in supporting biology learning. In addition, student response questionnaires are used to determine the practicality level of the developed learning website. Student response questionnaires are given during both small-group and large-group trials. Aspects assessed in student response questionnaires include website display, material clarity, learning presentation, language, ease of use, feature attractiveness, and the website's usefulness in understanding body defense system material.

Learning Achievement Test Sheet

The learning achievement test instrument was used to determine the effectiveness of the developed learning website. The instrument consisted of 13 items, comprising 10 multiple-choice questions and 3 essay questions with sub-items, developed based on competency achievement indicators related to the body defense system material.

The multiple-choice questions were designed to measure students' cognitive abilities at the levels of applying and analyzing, while the essay questions aimed to assess higher-order thinking

skills, including evaluating and creating. Before implementation, the test items were validated by a material expert to ensure the validity and appropriateness of the content.

The learning achievement test was administered as a post-test after the implementation of the learning website. The effectiveness of the learning media was analyzed based on students' learning achievement, referring to the Minimum Completeness Criteria (KKM). The learning website is considered effective if ≥ 80% of students achieve the set KKM.

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Procedures

The development of this learning website followed the ADDIE model, which includes analysis, design, development, implementation, and evaluation stages. The analysis stage involved identifying learning needs, curriculum alignment, student characteristics, material on the body defense system, and the application of the Problem-Based Learning (PBL) model. The design stage focused on preparing the website structure, learning materials, PBL-based activities, interface design (UI/UX), and research instruments. The development stage included the creation of a WordPress-based learning website, followed by validation by media experts, material experts, and practitioners, as well as revisions based on their feedback. The implementation stage consisted of small-group and large-group trials involving students. Finally, the evaluation stage assessed the feasibility of the product based on validation results, student responses, and learning outcomes referring to the Minimum Completeness Criteria (KKM).

Data Analysis

The research data were obtained from the distribution of validation instruments to one media expert, one subject matter expert, and one field practitioner. Meanwhile, data on effectiveness and respondents' feedback regarding the media were collected from students. The learning achievement test results were used to determine students' attainment of the Minimum Completeness Criteria (KKM).

The data analysis technique used to determine the validity and practicality level of learning media uses a Likert scale of 1-5. The data analysis technique in this study uses the following formula:

$$P = \frac{total\ score\ of\ data\ collection\ results}{total\ criteria\ score} \text{ x } 100\%$$

Description:

P : Validity Percentage

After calculating the validity percentage, we conclude the calculation results using the criteria as in Table 1 (Lawshe, 1975).

Table 1. Range of Learning Media Validity Percentage

Validity Value	Validity Criteria
81% - 100%	Very Valid/Very Practical
61% - 80%	Valid/Practical
41% - 60%	Fairly Valid/Fairly Practical
21% - 40%	Less Valid/Less Practical
<21%	Invalid/Impractical

The following is the flow of the ADDIE model stages in the development of the learning website, as shown in the following Figure 1.

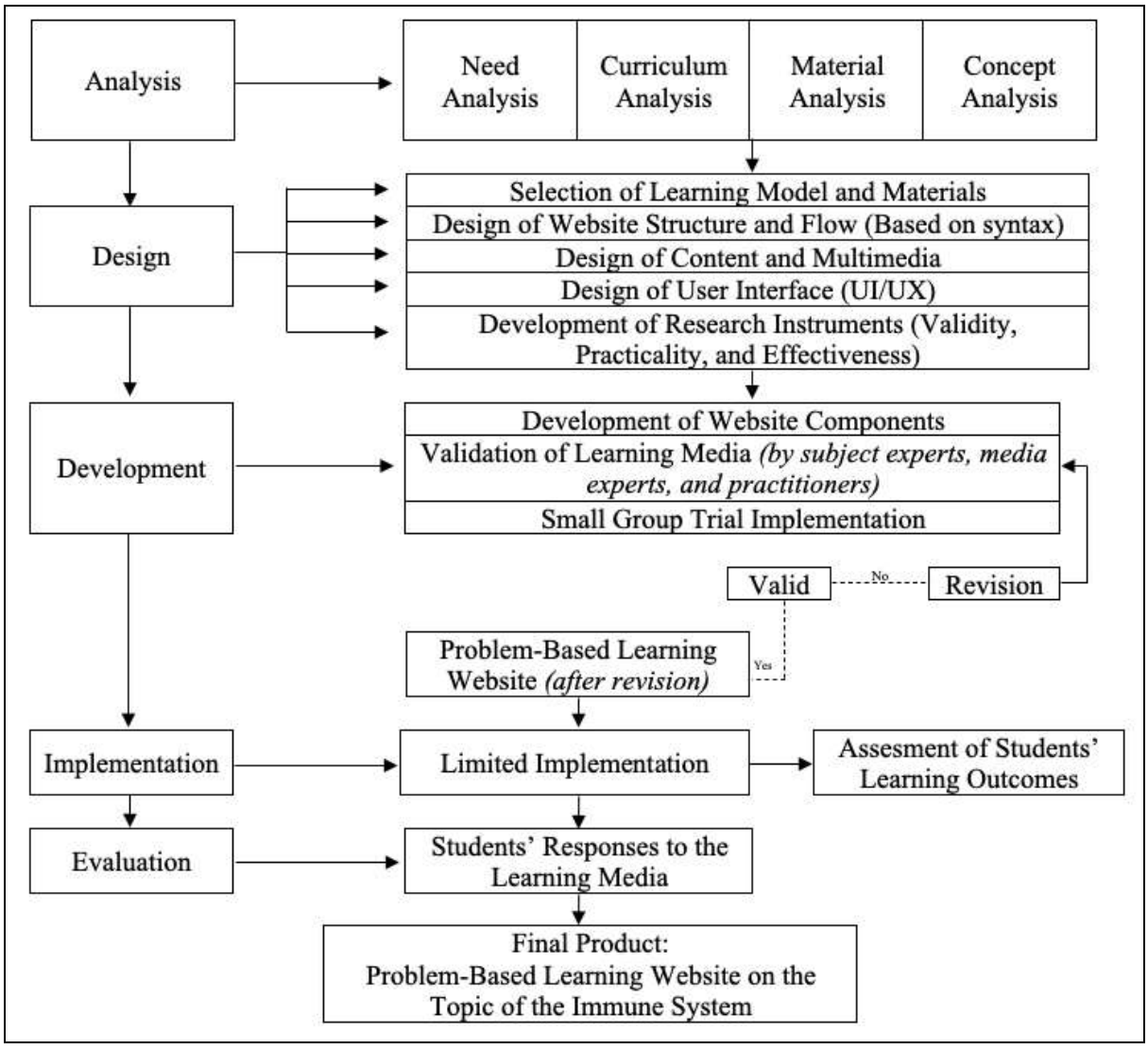


Figure 1. ADDIE Development Flow in Learning Website

RESULTS

Description of Learning Website Development Results

Learning website development was carried out based on the ADDIE stages. The results of learning website development are described as follows.

Analysis Stage

1. Need Analysis

A needs analysis was conducted through interviews with biology teachers and 10th-grade XI students at MAN in Bekasi City to identify learning problems and the efforts to overcome them. Interview results showed that 7 out of 10 students found the body defense system material difficult due to the many scientific terms, abstract concepts, and limited visualization in textbooks. Teachers struggle to deliver material due to limited learning media, so learning is still centered on verbal explanations, textbooks, and simple presentations. The use of digital media remains minimal despite available facilities, due to a lack of curriculum-aligned media and skills to integrate technology.

Based on these findings, it is necessary to develop online, interactive, and visual learning media (animations, videos, and illustrations) and to implement the Problem-Based Learning (PBL)

model to train critical thinking and problem-solving abilities. The media must include complete content aligned with the Merdeka Curriculum, equipped with learning resources, practice questions, and evaluation, and feature an attractive display and intuitive navigation. The results of this analysis become the foundation for developing the ImmunoQuest learning website based on PBL on body defense system material for grade XI SMA/MA.

2. Curriculum Analysis

A curriculum analysis was conducted to align learning media with the applicable Merdeka Curriculum. According to the Merdeka Curriculum documents, material on the body defense system is included in the Living Things Interaction with Environment element. Learning Achievement (CP) emphasizes students' ability to understand the body's defense mechanisms against pathogens and analyze disorders and diseases related to the immune system.

Learning objectives in the ImmunoQuest media are designed based on CP and aligned with Problem-Based Learning (PBL) principles, including: (1) analyzing components and mechanisms of the body defense system, (2) evaluating the relationship between body defense system disorders and health conditions, and (3) communicating analysis results about the importance of maintaining the body defense system. Learning media provide contextual problems that stimulate higher-order thinking, collaboration, and communication, in line with the Merdeka Curriculum's demands.

3. Material Analysis

Material analysis was conducted to identify and map learning materials for the learning website. Body defense system material is divided into three sub-materials: (1) Introduction to the body defense system, (2) mechanisms of the body defense system, (3) Factors that influence and disorders of the body defense system. Materials are presented interactively through text, images, animations, videos, and illustrations to enhance understanding of microscopic and abstract concepts. Materials are integrated into the Problem-Based Learning (PBL) model, which encourages students to think critically and analyze contextual problems across five learning phases, following PBL syntax. The following are the Problem-Based Learning model stages applied in the research presented in Table 2.

Table 2. Problem-Based Learning Stage

PBL Stage	Description
Orientation to the problem	Students are given contextual problems related to the body defense system to stimulate curiosity and learning motivation.
Organizing students to learn	Students identify necessary information, formulate questions, and plan problem-solving strategies.
Guiding individual/group investigation	Students conduct investigations through available learning resources (text, videos, articles) to actively construct knowledge.
Developing and presenting the work	Students develop and present solutions in the form of reports, presentations, or discussions to train scientific communication skills.
Analyzing and evaluating the problem-solving process	Students reflect on the learning process, analyze the strengths and weaknesses of solutions, and receive feedback to strengthen understanding.

4. Concept Analysis

Concept analysis was conducted to identify and map key concepts in body defense system material hierarchically, so that the material can be presented systematically and make it easier for

students to understand the material comprehensively. Reference sources used include: (1) Book "Biology for SMA/MA Grade XI" Merdeka Curriculum by the Ministry of Education, Culture, Research, and Technology in 2021, (2) Book "Biology for SMA/SMK Grade XI" Revised Edition by the Ministry of Education and Culture in 2017, and (3) digital sources such as scientific journals, learning videos, and trusted scientific articles. The analysis results produce a concept map that becomes the basis for designing the flow of material presentation in website-based learning media.

Design Stage

The design stage is the initial phase of the learning website before development and implementation. At this stage, design is carried out systematically based on the results of the previous needs analysis, to produce a Problem-Based Learning (PBL)-based website design that aligns with the characteristics of body defense system material and the needs of grade XI SMA students. Activities at this stage include selecting models and materials, designing the website structure, designing content and multimedia, designing the user interface (UI/UX), and preparing research instruments.

1. Selection of Learning Model and Material

The learning model used to develop this website is Problem-Based Learning (PBL), which encourages active student engagement through contextual problem-solving and develops critical thinking and problem-solving skills. The material chosen is the Human Body Defense System in grade XI SMA Biology because it is complex, abstract, and difficult to understand when delivered only through lecture methods and two-dimensional media. Therefore, integrating the PBL model with website media is expected to help students understand concepts more deeply and in context.

2. Website Structure and Flow Design (According to PBL Syntax)

The structure and flow of the learning website are designed based on Problem-Based Learning syntax, namely: (1) orienting students to the problem, (2) organizing students to learn, (3) independent and group investigation, (4) developing and presenting work, and (5) analyzing and evaluating the problem-solving process. Each PBL stage is realized through website menus and activities, such as presenting contextual problems, holding discussions, exploring materials, and conducting learning evaluations, so that students can follow the learning flow systematically.

3. Content and Multimedia Design

Website content is presented as text, illustrated images, learning videos, and stimulus articles relevant to the body's defense system. Content presentation is adjusted to students' characteristics and problem-based learning principles, with each material accompanied by contextual problems that serve as critical-thinking triggers. The multimedia used aims to visualize microscopic and abstract biological processes, making them easier for students to understand.

4. User Interface Design (UI/UX)

The website's user interface is designed with ease of use (user-friendly), readability, display consistency, and navigation in mind. The website design is simple yet attractive, with a clear menu layout, comfortable color selection, and a responsive layout that works well on various devices, such as laptops and smartphones. This UI/UX design aims to ensure that students can focus on learning without encountering technical difficulties when using the website.

5. Research Instrument Design

At the design stage, research instruments are also designed to assess the validity, practicality, and effectiveness of the developed learning website. The instruments prepared include Material

expert validation sheets, media expert validation sheets, practitioner validation sheets (biology teachers), student response questionnaires for small- and large-group trials, and learning evaluation instruments. These instruments are designed to ensure that the developed learning website meets content and media quality standards and to have a positive impact on the learning process and student learning outcomes.

Development Stage

The development stage is carried out to realize the website-based learning media product according to the initial design. The product is developed using WordPress as a Content Management System (CMS) with considerations of ease of content management, user-friendly interface, varied plugin and theme systems, and does not require in-depth coding skills. The development process includes hosting infrastructure and domain preparation, WordPress installation and configuration, the use of page builders for visual design, to the development of comprehensive learning content.

The product that has been developed is then validated by media experts and material experts to obtain improvement suggestions and input. Learning media is also tested in small groups to obtain student responses to the developed product. Based on validation results and student responses, the product is then revised to improve quality so as to produce a final product that is suitable for use and ready to be tested extensively.

I. Website Development Preparation

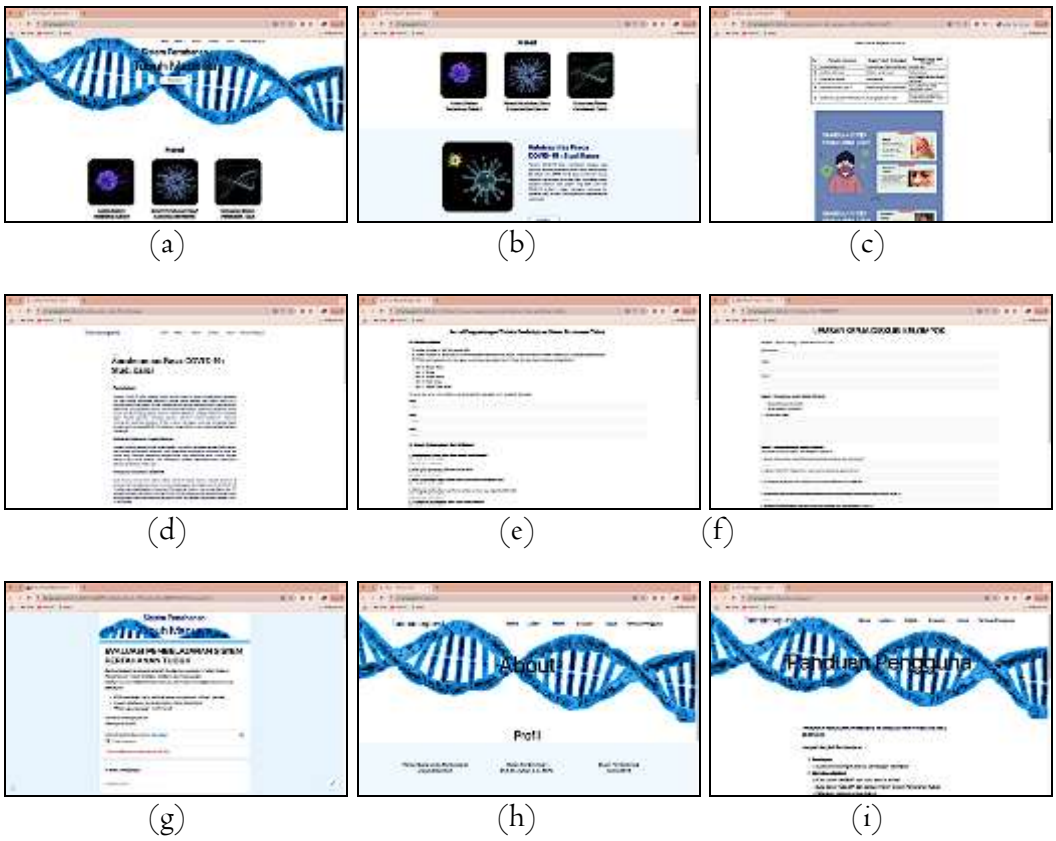
Learning website development begins with technical infrastructure preparation in the form of hosting and a domain using Niagahoster services, with considerations of reliability, Indonesian-language customer support, server location in Indonesia, and affordable costs. The immunoquest.my.id domain was chosen because it is relevant to the material, easy to remember, and uses the official Indonesian extension. WordPress installation is performed with an optimized hosting package that includes SSL, caching, and automatic backups. The website's page structure is organized into Home, Material, Articles, Evaluation, and supporting pages such as About, Contact, and FAQ.

To build an attractive, interactive website display, the Elementor plugin is used as a page builder, offering an intuitive drag-and-drop interface and responsive editing for various devices. Elementor provides various widgets (text, images, videos, buttons) and section and column features for flexible page structure arrangement. The MetForm plugin is installed to add interactive features to forms, surveys, and quizzes, integrating various input fields with Elementor.

Content development is carried out on each page by integrating text, visual elements, interactive components, and multimedia. The main page features a hero section with a title, a background image, and a "Read Now" call-to-action button, along with a section on website usage instructions. The material page presents learning content in card format, grouped by topic, with search and filtering features. The article page contains supporting content in blog format, while the evaluation page provides a website development survey using MetForm, a learning evaluation through Google Forms, discussion forums for collaborative learning, a Developer Profile, and a User Guide.

After content is developed, display customization is done to maintain visual consistency through color scheme settings, typography, layout, and responsive design optimization using Elementor features. The final stage is functionality testing which includes aspects of functionality (links, forms, navigation), usability by involving users, compatibility across various browsers and

devices, performance (access speed), and security (SSL certificate). Testing results are used as a basis for improvement until the website is declared ready to be used as a stable, safe, and effective learning medium.



(a) (b) (c) (d) (e) (f) (g) (h) (i)

Figure 2. ImmunoQuest website pages display: (a) and (b) Home page display, (c) Material page display, (d) Article page display, (e) Website development survey page display, (f) Discussion forum page display, (g) Evaluation page display on Google Form, (h) Developer profile display, (i) User guide display

2. Learning Website Validation

To assess the quality and feasibility of the learning website, validation instruments are prepared for use by media experts, material experts, and practitioners. Validation instruments aim to obtain assessments, criticisms, and suggestions to inform the determination of product feasibility and the material for consideration in revising and improving learning media. In addition, student response instruments are prepared as direct users to assess ease of use, material clarity, website display, and interest during learning.

Material expert validation was conducted by a Biology Education lecturer at UIN Syarif Hidayatullah Jakarta and a biology teacher at MAN in Bekasi City, while media expert validation was conducted by an Informatics Engineering lecturer at UIN Syarif Hidayatullah Jakarta. Based on validation results, the material expert's validation value was 92%, and the media experts was 88.8%, both in the very valid category. Meanwhile, the practitioner validation value was 90% in the very practical category. After the validation process, the learning website was revised based on

the validators' comments and suggestions before being implemented for students. Further details can be seen in Table 3.

Tabel 3. The Result of the Validation of Media

No	Assessment Aspect	Validator	Result (%)	Category	Description
1.	Material Validation	Material Experts	92%	Very Valid	The material is appropriate, accurate, and feasible for use
2.	Media Validation	Media Expert	88.8%	Very Valid	The website design and functionality are excellent
3.	Practitioner Validation	Practitioner	90%	Very Practical	Easy to use in the learning process

3. Small Group Trial

After the learning website was validated by experts and practitioners and improved based on suggestions, trials were conducted with students in small groups. This trial was conducted limited to 10 grade XI students at MAN in Bekasi City. The trial results for small-group students received a very positive response, with 94.7% approval, and met the practical criteria. Further details can be seen in Table 4.

Table 4. The Results of Student Response Assesment

No.	Assessment Aspect	Percentage (%)
1.	Display	94,5%
2.	Material	94%
3.	Presentation	92,7%
4.	Language	95%
5.	User Ease	96%
	Average	94,7%

Implementation Stage

After the learning website was declared feasible and received positive responses in the small-group trial, the media was implemented for 36 grade XI students at MAN in Bekasi City to assess student responses and measure the media's effectiveness on learning outcomes. Implementation was carried out in two meetings. The first meeting included an introduction to the immunoquest.my.id website and its use. In the second meeting, students were divided into six groups to study material on the body defense system, complete assignments, and complete available learning activities. After learning was completed, students filled out response questionnaires to assess ease of use, material clarity, and website attractiveness, and took learning achievement tests (post-test) to measure media effectiveness based on achievement of Minimum Completeness Criteria (KKM). The distribution of students' final evaluation scores and their frequencies is presented in Table 5.

Table 5. Student Evaluation Score Statistical Data

Mean	85,14
Median	84,5
Modus	83,00
Minimum	63,00
Maximum	94,00

Evaluation Stage

The evaluation stage assesses and improves each stage of learning website development through continuous formative and summative evaluation. Formative evaluation is conducted during the analysis, design, and development stages, based on input from supervising lecturers and on validation results from media and materials experts. Formative evaluation results show that the learning website meets very valid criteria, so in terms of material, display, and functionality, it is considered suitable for use.

Summative evaluation is conducted during the implementation stage through trials with students. Evaluation results show that the learning website received very practical responses from students, with an average learning achievement test score of 83.68 and a learning completion rate of 89%, which met the effectiveness criteria. Based on formative and summative evaluation results, the Problem-Based Learning website developed has met the criteria for validity, practicality, and effectiveness, making it suitable for use as biology learning media on the body defense system.

DISCUSSION

The development of a Problem-Based Learning (PBL) website on the body defense system was undertaken to present learning media that align with the characteristics of biology materials and the needs of students in the digital era. Based on research results, the developed website demonstrates high quality in terms of validity, practicality, and effectiveness, making it a suitable alternative biology learning medium for high school. These findings are supported by previous studies, which state that digital and interactive learning media can enhance student engagement and conceptual understanding, particularly in complex biology material (Darmawan & Nawawi, 2020; Rosamsi et al., 2023).

Final Product Review

1. Validity Analysis

The developed website-based learning media was categorized as very valid based on assessments from media and material experts. Media expert validation reached 88.8%, covering aspects of interface design, navigation, multimedia integration, interactivity, accessibility, and responsiveness. Meanwhile, material expert validation reached 92%, covering content suitability, language, alignment with learning objectives, application of the Problem-Based Learning model, and evaluation components. These results indicate that the material on the body defense system is presented systematically, contextually, and in accordance with the Merdeka Curriculum.

The high validity of the developed media is consistent with the principle that effective learning media must meet aspects of content accuracy, instructional design, and usability to support meaningful learning (Darmawan & Nawawi, 2020). In addition, these results are in line with research by Delvita, Yulianti, and Arrahim (2024), which developed website-based biology learning media and obtained validation results above 90% with very valid criteria. Both studies utilize the ADDIE development model and website-based platforms; however, the difference lies in the focus, where previous research emphasizes critical thinking skills, while this study integrates the Problem-Based Learning model to promote active student engagement. Based on these findings, the developed learning media meet the validity criteria and is appropriate for implementation.

2. Practicality Analysis

The practicality of the developed learning media was evaluated through practitioner assessments and student responses. The practitioner assessment resulted in a score of 90% with very practical criteria, covering aspects such as curriculum alignment, implementation of the PBL model, support for skill development, flexibility in learning, and evaluation processes. Meanwhile,

student responses from small-group trials showed a practicality percentage of 94.7%, indicating that the website is easy to use, has an attractive interface, clear navigation, and understandable language.

High practicality indicates that the developed media is user-friendly and supports independent learning, which are essential characteristics of effective digital learning media in the 21st century (Hendra et al., 2023). These findings are consistent with research by Cantika and Suryanti (2025), which reported that website-based biology learning media achieved practicality scores of 94.7% from teachers and 88.5% from students, both categorized as very practical. This similarity shows that website-based media are effective in supporting flexible and accessible learning. Therefore, the developed learning website fulfills practicality criteria and is suitable for use in the learning process.

3. Effectiveness Analysis

The effectiveness of the learning media was measured based on students' achievement of the Minimum Completeness Criteria (KKM) after the implementation of the learning website. The analysis was conducted using post-test results from 36 students. The learning media was considered effective if at least 80% of students achieved the KKM. The results showed that 32 out of 36 students (89%) met the KKM, indicating that the effectiveness criteria had been achieved.

These results indicate that the PBL-based learning website is effective in supporting the learning process and helping students achieve the expected learning outcomes. The effectiveness of this media is closely related to its ability to facilitate active learning and problem-solving processes, as emphasized in the Problem-Based Learning model, where students construct knowledge through real-world problem contexts (Setyo et al., 2020). These findings are also in line with research by Saidah (2023), which reported that website-based learning media improved student learning outcomes, with 82.5% of students achieving KKM after implementation. The similarity lies in the use of website-based media and KKM as an effectiveness indicator, while this study specifically integrates PBL into the learning design. Therefore, the developed learning website can be considered effective and suitable for use as a biology learning medium.

Research Limitation

Although this study shows positive results, several limitations should be acknowledged. The implementation of the learning website was conducted on a limited scale in terms of the number of participants and duration of use, which may affect the generalizability of the findings. In addition, the evaluation of effectiveness was limited to the achievement of KKM and did not fully measure improvements in higher-order thinking skills. Therefore, future research is recommended to involve larger samples, longer implementation periods, and more comprehensive evaluation indicators.

CONCLUSION

The findings of this study demonstrate that the Problem-Based Learning (PBL)-based biology learning website on the body defense system was successfully developed using the ADDIE model. The product achieved a very valid category based on material expert (92%) and media expert (88.8%) evaluations, and was considered very practical by practitioners (90%) and students (94.7%). Furthermore, the effectiveness test showed that 89% of students met the Minimum Completeness Criteria (KKM), indicating that the developed learning website is valid, practical, effective, and suitable for use in biology learning. The novelty of this research lies in the integration of Problem-Based Learning stages into a website-based learning platform developed using WordPress, which provides a structured and interactive learning environment. This integration enables students to engage in problem-solving activities while accessing learning materials in a

flexible and accessible manner. The implications of this study emphasize the need for schools to support the implementation of digital learning media by providing adequate technological infrastructure. Teachers are encouraged to adopt innovative, PBL-oriented digital media to improve student engagement and higher-order thinking skills. For future research, it is recommended to examine the effectiveness of similar media with larger and more diverse samples, as well as to expand the development to other biology topics or learning models.

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