



Development of a Problem-Based E-Module on the Immune System Material to Enhance Systemic Thinking Skills

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Abstract

One of the major challenges in biology education is students' limited understanding of abstract and interconnected concepts, particularly in the topic of the immune system, which requires higher order thinking skills. Teacher centered learning and the limited availability of engaging instructional materials often make it difficult for students to recognize the relationships among concepts within a system as a whole. Therefore, innovative learning media are needed to develop students' systemic thinking skills. This study aims to develop a problem based e-module to enhance students' systemic thinking abilities on the immune system material. The research employed an R&D approach using the ADDIE model. In the analysis stage, needs assessment was conducted to examine learners' needs, curriculum requirements, and learning characteristics. The design stage produced an e-module prototype equipped with interactive components such as videos and QR codes. The development stage involved creating the e-module and carrying out validation by content experts, media experts, and language experts. In this study, the development process was limited to the development stage because the primary focus was to produce a learning medium that was judged to be feasible by experts. The validation results indicated that the content experts assessed the e-module as highly feasible for use. The media expert also concluded that the graphical design, content presentation, and language use were categorized as highly feasible. Although media validation was conducted only once, several suggestions for improvement were provided, including adding game based quizzes, embedding hyperlinks to support QR code features, and providing clearer instructions for accessing the embedded learning videos. It can be concluded that the developed e-module is highly feasible for classroom use and is recommended for broader implementation in biology learning.

Keywords: ADDIE; e-module; immune system; problem based learning; systemic thinking

INTRODUCTION

Education plays a central role in national development, particularly in creating high quality human resources that are adaptive to the changing times. Education is not merely a means of transferring knowledge but also serves as a crucial foundation for supporting the achievement of the Sustainable Development Goals (SDGs), especially Goal 4, which targets inclusive and quality education for all (Rad *et al.*, 2022; Yonanda *et al.*, 2023; Santa *et al.*, 2024). In the era of globalization and Society 5.0, quality education becomes the key to producing individuals capable of facing challenges and utilizing technology as an integral part of everyday life. Society 5.0 is an era in which the integration between the physical and virtual worlds generates solutions to social problems through advanced technologies (Mytra *et al.*, 2020; Amalia, 2022; Meisuri *et al.*, 2025). Therefore, education must be directed toward developing 21st century skills such as critical thinking, collaboration, creativity, and problem solving abilities. To address these challenges, the implementation of systemic thinking based learning can serve as an effective solution.

This approach encourages students to understand problems holistically, identify interrelationships among components, seek innovative solutions, and collaborate with others, thereby better preparing them to face real world challenges. Consequently, students can develop critical thinking, problem solving, and creativity skills that are highly essential in the digital era (Nuraeni *et al.*, 2020; Rosmiati, 2025).

In the face of increasingly complex challenges characterizing the era of the Fourth Industrial Revolution and Society 5.0, education must move beyond traditional knowledge transmission toward cultivating learners who can understand systems as dynamic and interconnected structures. This capability includes recognizing relationships among components, interpreting patterns of change, and integrating digital technologies as essential elements of the learning process (Al-Menshawi & Abu, 2020; Ekselsa *et al.*, 2023; Novianti *et al.*, 2025). A systemic thinking approach supports learners in developing a holistic cognitive framework, enabling them to analyze global issues ranging from climate problems to digital disruption through more coherent and comprehensive perspectives. In this context, innovative learning media, particularly problem based e-modules, serve as effective tools to activate 21st competencies while strengthening learners' abilities to identify causal relationships and dynamic flows within systems (Pitorini *et al.*, 2024; Ardiyanto *et al.*, 2025; Novianti *et al.*, 2025). Such efforts contribute to shaping adaptive, critical, and future oriented individuals who are capable of participating actively in sustainable national development.

Systemic thinking skills are increasingly recognized as essential in biology education, as many biological concepts involve complex interactions and multi layered relationships. These skills help learners connect ideas, identify causal mechanisms, and reason about dynamic changes within biological systems. Recent studies have emphasized that systemic thinking enables students to construct deeper conceptual linkages and make sense of biological complexity more effectively (Tripto *et al.*, 2016; Evagorou & Puig, Mauriza, 2017; Haniyah & Hamdu, 2022). Despite its importance, students' systemic thinking performance in biology classrooms remains relatively low. Preliminary findings from a public senior high school revealed that the average systemic thinking score was only 48, likely because students had never encountered assessment instruments specifically designed to measure systemic reasoning. Survey responses also indicated that 88.4% of students perceived their tests as focusing primarily on memorization and isolated factual recall rather than examining relationships among biological concepts or system level interactions. Assessments addressing the interdependence of biological structures and processes core aspects of biological systems had never been implemented. Interviews with biology teachers further confirmed the absence of tools targeting systemic thinking. Another factor contributing to low performance is the minimal use of digital learning media. Supporting this, questionnaire data showed that approximately 74.1% of students reported never using electronic media during biology instruction (Yuniarti *et al.*, 2020; Ekselsa *et al.*, 2023).

One of the biology topics that students frequently struggle to understand is the immune system. Questionnaire results indicated that 65.2% of students identified this topic as the most challenging area in biology. The immune system is perceived as difficult because the content is abstract, rich in scientific terminology, and involves mechanisms that cannot be directly observed. Approximately 84.8% of students reported confusion regarding the terminology used in this topic. Recent studies support this finding, noting that the complex and abstract nature of immune responses makes the material difficult for learners to conceptualize (Fakhriah *et al.*, 2022; Lewar *et al.*, 2025; Safitri *et al.*, 2025). Another factor contributing to students' low systemic thinking skills is the heavy reliance on textbooks, which typically present information in a linear, condensed format. Such presentation limits students' opportunities to explore deeper conceptual connections across biological systems (Yuniarti *et al.*, 2020; Afifah & Sumiaty, 2025; Safitri *et al.*, 2025). Meanwhile, students today show a clear preference for learning that incorporates interactive digital and visual media. Preliminary findings also revealed that 75% of students had never used electronic media in biology learning, and 83% expressed a need for more engaging formats, such as videos, animations, and interactive graphics media shown to improve comprehension of complex biological processes (Arsal *et al.*, 2019; Pratiwi *et al.*, 2020; Yuniarti *et al.*, 2020).

To address these challenges, the researcher developed a problem based e-module as an effective and viable instructional alternative. Compared to traditional printed materials, e-modules offer several

pedagogical advantages they are interactive, easily accessible, and capable of integrating multimedia components such as animations, videos, and audio, while also providing immediate feedback to support learner understanding (Hardiyantari, 2017; Arsal et al., 2019; Mellisa *et al.*, 2023). Previous studies have demonstrated that problem based e-modules can significantly improve learners' critical thinking and problem solving abilities (Fuad, 2023), while other research highlights their positive impact on enhancing scientific literacy (Pratiwi *et al.*, 2020; Fuadiyah & Wijayanti, 2024). In line with these findings, this study aims to develop a problem based e-module to strengthen students' systemic thinking skills in the immune system topic at a public senior high school.

METHOD

This study employed a Research and Development (R&D) approach using the ADDIE development model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation (Siregar *et al.*, 2022; Szabo, 2022; Mellisa *et al.*, 2023). However, the present research was limited to the development stage, as the primary objective was to produce and evaluate the feasibility of a valid and ready to use problem based e-module. The R&D method was selected because it aligns with the objective of producing an instructional product that meets validity and feasibility criteria. The ADDIE model was chosen due to its systematic, flexible structure and its broad application in instructional media development. The object of this research was high school students, with a focus on the immune system topic. The study was conducted from September 2024 to May 2025. The research design adopted was developmental research, emphasizing product creation, validation, and evaluation rather than experimental testing. This design centered on the development process, expert validation of content, media, and language, and user response testing involving teachers and students to determine the e-module's feasibility and practicality.

The instruments used in this study were adapted to the ADDIE stages involved Analysis, Design, and Development. During the analysis stage, interview guidelines and needs analysis questionnaires were employed to identify learning challenges, student needs, and teacher expectations related to the media being developed. In the design stage, validation instruments were prepared, including media validation questionnaires, material validation questionnaires, and systemic thinking instrument validation forms, all used to assess the e-module's design prior to further development. In the development stage, the instruments consisted of expert validation sheets and response questionnaires for teachers and students. The media feasibility assessment was conducted by a multimedia expert, while material validation was carried out by biology lecturers and biology teachers. Validation of the systemic thinking instrument involved a biology education evaluation expert. Validation data from media, material, and systemic thinking experts covering various feasibility indicators combined with teacher and student responses, were used to determine the practicality of the e-module, including ease of use, visual quality, and clarity of learning instructions. The results were presented in percentage form to determine the final feasibility and practicality scores. The level of product feasibility achieved through this development research was determined based on the percentage score obtained from data analysis. A higher percentage reflected a higher level of feasibility of the developed product. The data analysis technique applied in this study involved calculating percentage values derived from expert validation results and user responses.

$$Percentage = \frac{Total\ score\ obtained}{Maximum\ score} \times 100\%$$

The criteria for the feasibility level based on the percentage analysis of the developed product can be seen in Table 1.

Table 1. Criteria for learning media validation test

Percentage score (%)	Criteria
0 - 20	Very Poorly Feasible
21 - 40	Poorly Feasible
41 - 60	Fairly Feasible
61 - 80	Feasible
81 - 100	High Feasible

RESULT AND DISCUSSION

The development of the problem based e-module aims to facilitate students' understanding of immune system concepts and to enhance their systemic thinking skills. This e-module was developed using the ADDIE development model. The ADDIE model was selected because it positions students at the center of the learning process and emphasizes active interaction between students and teachers (Hidayat *et al.*, 2021; Mellisa *et al.*, 2023). In this study, the development process was limited to the development stage, as the primary objective was to produce a valid and feasible learning medium based on expert evaluation. In the analysis stage, several examinations were conducted, including a review of the curriculum implemented at the school, classroom learning activities, available learning tools and media, and the characteristics of students' learning needs. A needs analysis was also carried out to determine the expectations of teachers and students regarding appropriate learning media to support biology instruction. The results of interviews with teachers and students indicated that the Merdeka Curriculum had been implemented at all grade levels, with biology learning outcomes in phase F emphasizing understanding the structure and function of human organ systems, including the immune system and its role in maintaining health. However, several challenges were identified in actual classroom practice. Biology teachers reported difficulties in developing interactive learning media due to limited resources and time, resulting in learning activities that still rely heavily on textbooks and PowerPoint presentations. Although learning models such as inquiry learning and discovery learning have been used, problem based models such as Problem Based Learning (PBL) and Project Based Learning (PjBL) are seldom implemented because of time constraints. This is notable, as such models are highly relevant for improving students' conceptual mastery and systemic thinking abilities.

Based on the results of the analysis stage, it was found that the learning resources used in the classroom were limited primarily to school issued textbooks. The insufficient availability of textbooks in many schools remains one of the major barriers to improving educational accessibility, as it restricts students' ability to follow lessons effectively and develop a comprehensive understanding of the material (Sari *et al.*, 2024; Afifah & Sumiaty, 2025). In addition, the learning media used by teachers were not sufficiently varied and relied mostly on conventional PowerPoint presentation slides. To overcome these limitations, teachers are required to demonstrate greater creativity by integrating more innovative learning media. The use of engaging and innovative media can enrich the learning experience and foster higher levels of student participation (Octasyavira & Nurlizawati, 2022; Safitri *et al.*, 2025). Furthermore, the immune system topic is considered challenging for students to understand. The immune system contains numerous abstract concepts, scientific terminology, complex mechanisms, and a wide range of interconnected components, making the material difficult for students to grasp. Revealed that students struggled to distinguish the various components of the immune system based solely on teacher provided illustrations (Sonia & Yuliani, 2023; Lewar *et al.*, 2025). They also found it difficult to differentiate between natural and artificial immune responses, particularly when required to recall and explain these mechanisms over an extended period.

The analysis stage, it was also identified that students' systemic thinking skills tended to be low. One of the primary factors contributing to this issue is the lack of structured training and the absence of assessment instruments specifically designed to develop systemic thinking. Systemic thinking is crucial in biology learning because it enables students to recognize the interconnections among concepts and processes within living systems. However, its integration into instructional practices remains limited,

resulting in students becoming unaccustomed to linking biological concepts in a holistic and meaningful way. This challenge emerges largely because biology requires students to comprehend concepts that are abstract, complex, and interrelated (Nuraeni *et al.*, 2020; Sarip *et al.*, 2022). Research by Utami & Fadilah (2023) further emphasizes that various factors influence students' systemic thinking skills, including the limited use of effective learning models, strategies, and media that intentionally cultivate this ability. That systemic thinking in learning involves a cognitive process in which students address learning problems as an integrated whole while simultaneously understanding the components in depth. Central to this process is the presence of interaction interaction between students and their learning environment, including teachers, peers, tools, media, and other learning resources. Preliminary test findings also indicated that 83% of students expressed a need for electronic learning media equipped with engaging visuals and videos to support their understanding of biology concepts. These findings highlight the necessity of developing problem based electronic learning media, such as e-modules, to enhance students' systemic thinking skills specifically within the immune system topic (Mukti *et al.*, 2021; Nadira *et al.*, 2022; Octasyavira & Nurlizawati, 2022).

In the design stage, the initial planning and development process of the learning media were undertaken. The e-module was designed using canva for structuring the material layout, while wordwall and quizizz were utilized to create interactive quiz based activities in the form of educational games. The first step involved formulating the overall concept and content framework of the e-module, followed by determining the layout structure and selecting appropriate and appealing color schemes that aligned with the immune system material. A varied and aesthetically appealing design can help make the learning process more engaging and reduce monotony (Monoarfa & Haling, 2021; Samaniego *et al.*, 2024). The e-module is organized into three main components: the introduction, the content, and the closing section. The introduction includes the cover, e-module identity, preface, table of contents, user guide, instructions for implementing the PBL model, an explanation of the e-module features, and a concept map. This section also outlines the learning phases, learning outcomes, learning strategies, and learning objectives that guide students through the content to be studied.

The content section consists of three learning activity menus. The first learning activity presents subtopics related to the definition, components, and organs of the immune system. The second learning activity discusses the mechanisms of the immune system, while the third learning activity addresses disorders that may occur in the immune system. Each activity includes clearly stated learning objectives to ensure that students understand the competencies they are expected to achieve. The material is presented using engaging explanations and supported by relevant media elements to facilitate comprehension. Additionally, several supporting features such as ImmunoInsight, ImmuneBits, ImmuneFlicks, ImmunoQuiz, and ImmunoRecap are incorporated to enhance students' learning experience. The closing section comprises self-evaluation exercises, a glossary, references, an author profile, and the back cover.

The development stage, the designed e-module was submitted for validation by media experts and material experts. This validation process aimed to determine the feasibility of the e-module as a learning medium for the immune system topic, particularly in supporting the enhancement of students' systemic thinking skills. A learning medium is considered feasible when it meets validity criteria based on expert assessments that evaluate essential aspects relevant to the analyzed variables (Octiana *et al.*, 2020; Irianti & Mahrudin, 2021; Nadira *et al.*, 2022). Media expert validation focused on evaluating the graphical and language feasibility of the e-module, including layout consistency, readability, and overall visual design. Meanwhile, material expert validation assessed the alignment of the content with the curriculum, the accuracy and completeness of the material, and the appropriateness of the presentation structure. Input from both media and material experts whether in the form of suggestions, corrections, or recommendations played a crucial role in refining the e-module so that it met the required feasibility standards as an instructional medium. The validation process involved three types of expert evaluation: material validation, media validation, and language validation. Each component contributed to ensuring that the developed e-module was accurate, visually appropriate, and linguistically clear, thereby

supporting its use as a high-quality learning resource. The average score of the e-module expert validation can be seen in Table 2.

Table 2. Average score of e-module expert validation

Aspect	Validator 1 (%)	Validator 2 (%)	Average (%)	Category
Material	91.5	100	96	Very feasible
Media and language	91	-	91	Very feasible

The validation of the material presented in the e-module was conducted to ensure its alignment with the intended learning outcomes and objectives within the immune system topic. Material validation is essential because learning media must meet standards of content accuracy, curriculum relevance, conceptual clarity, and presentation coherence to effectively support students' learning processes (Fitriyyah *et al.*, 2024; Lewar *et al.*, 2025). Based on the validation results from the first material expert (lecturer), the e-module obtained a score of 91.5%, categorized as *very feasible*. The second material expert (biology teacher) provided a score of 100%, further confirming the strong accuracy and suitability of the content. These findings indicate that the structure and depth of the immune system material in the problem-based e-module align well with the competency targets and are highly appropriate for field implementation.

In addition to material validation, media validation was conducted to assess both the graphical and linguistic quality of the e-module. Media validation is crucial because high quality learning media must be visually appealing, readable, consistently formatted, and accessible to support cognitive processing and reduce unnecessary learning load (Astuti *et al.*, 2024; Lewar *et al.*, 2025). The media expert's evaluation showed that the graphical aspect received a score of 93%, while the language aspect obtained 89.5%. The combined final score of 91% placed the e-module in the very feasible category. These results demonstrate that the e-module meets the criteria of media feasibility, including clarity, readability, and design consistency, which are essential for supporting student engagement and comprehension. Although the media validation was conducted once, the expert provided several constructive revision notes, including the addition of game based quizzes, the creation of hyperlinks for QR coded features, and the inclusion of instructional prompts for accessing embedded learning videos. These revisions are consistent with the principles of interactive digital learning media, which emphasize accessibility, user guidance, and multimodal elements to enhance learning effectiveness (Alqurashi, 2019). After incorporating the suggested improvements, the e-module was categorized as highly feasible for field testing. The implementation of these improvements has significant implications for the learning process. The addition of interactive quizzes and multimedia elements can increase students' motivation and active participation, while clear navigation and instructional guidance reduce confusion and enhance independent learning. Furthermore, multimodal features such as videos and QR-linked resources support diverse learning styles, strengthen conceptual understanding, and improve overall learning effectiveness in digital environments.

CONCLUSION

Based on the findings of this study, the problem based e-module on the immune system was declared highly feasible for use in learning. Validation by the first material expert (lecturer) and the second material expert (teacher) indicate well material presented aligned with the intended learning outcomes and objectives. In addition, the media validation also showed a highly feasible category. Although the media validation was conducted only once, the validator provided several revision notes, including adding game-based quizzes, providing hyperlinks for features using QR Codes, and adding instructional sentences for the embedded learning videos. After revisions were made based on these suggestions, the e-module was declared highly feasible to be used as a learning medium to enhance students' understanding of the immune system content. Moreover, the results of this study offer global benefits. The development of a validated and high quality e-module can serve as a reference for educators in various

countries to design interactive and contextual digital learning materials aligned with the demands of 21st century learning. The problem-based learning model implemented in this e-module also supports the enhancement of scientific literacy internationally, in line with *Sustainable Development Goal* (SDG) 4 on quality education.

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