Developing a Differentiated Learning-Based E-Module to Support Immune System Learning in Undergraduate Biology

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Abstract: The diversity of students' interests, readiness, and learning profiles presents challenges in teaching complex biological concepts such as the immune system. Differentiated learning offers a strategy to address these differences by adapting content, processes, and learning products. This study aimed to develop and evaluate a differentiated learning-based electronic module (e-module) for undergraduate biology students. This study employed Educational Design Research based on the Plomp and Nieveen model, consisting of three phases: preliminary research, prototyping, and assessment. Data were collected through needs analysis questionnaires, expert validation sheets, student response questionnaires, and learning outcome assessments. The preliminary phase indicated that 82.6% of students strongly needed e-module-based learning materials. In the prototyping phase, the module achieved high validity scores from material experts (91.2%, very valid), media experts (79.16%, fairly valid), and practitioners (89%, very valid). Small-group testing showed very positive student responses (87%, very good). In the assessment phase involving undergraduate students, the average learning outcome was moderate, with variation across performance levels. The results indicate that the developed e-module is feasible and has the potential to support student engagement and may contribute to conceptual understanding. However, improvements in usability, assessment design, and the duration of implementation are required to enhance its effectiveness.

Keywords: Differentiated Instruction, E-Learning Module, Immune System, Educational Design Research

INTRODUCTION

The diversity of student interests, readiness, and learning profiles presents a challenge in teaching. The Independent Curriculum offers differentiated learning as a solution by adapting the content, process, and learning products (Suwarni, 2024; Wardani & Darmawan, 2024). Differentiation in content can take the form of variations in teaching materials and coverage, while differentiation in process adapts delivery methods to student needs (Azmy & Fanny, 2023; Pozas et al., 2021; Smale-Jacobse *et al*., 2019). Furthermore, product differentiation allows students to demonstrate their understanding in different ways. Flexibility in learning is one of the characteristics of the latest Indonesian curriculum, the Independent Curriculum (Alfaeni et al., 2023).

In Animal and Human Physiology courses, biology students often rely on the internet for information because it is convenient. However, the information obtained is often inaccurate. This is especially true for students with poor literacy skills. Interviews at Universitas Nusantara PGRI Kediri revealed that many students struggle to understand current teaching materials. These materials generally consist of PowerPoint slides with minimal explanations. Therefore, more comprehensive teaching materials are necessary.

The immune system is a complex topic, but it is crucial to understand, especially when addressing health challenges (Adedokun et al., 2024). Health problems are more easily addressed by those who understand the immune system (Jamali, 2024). This complexity presents a challenge for educators because it involves many organs, tissues, cells, and new scientific terms (Siani et al., 2024). Innovation in learning is needed to simplify the material without losing its essence.

Given these challenges, educators need to develop tools, such as differentiated learning modules. Modules were chosen because they present comprehensive information and assessments, allowing students to learn independently. Digital learning modules have been widely reported to support self-paced learning and improve student autonomy in higher education contexts (Englmeier, 2024; Friyatmi et al., 2025). To enhance student understanding of the immune system, applying Discovery Learning principles in this module is expected to help (Nurcahyono et al., 2023). The differentiated module developed by the researchers emphasizes differences in content, such as reading, video, and simulation, and varies in material complexity. This allows students to choose materials that match their interests and understanding, ensuring all students can use the module.

RESEARCH METHODS

This study used Educational Design Research, following (Plomp & Nieveen, 2013), which consists of three main stages: Preliminary Research, Prototyping, and Assessment. This research involved three phases: preliminary research using questionnaires to analyze needs and feasibility; prototyping, including e-module development, expert validation, and small-group trials; and assessment, including large-group implementation, learning outcome evaluation, and student response analysis.

After the module was developed, it underwent validity testing by experts in the field. The product was then tested in a small group consisting of five Biology Education students from the 2022 cohort of Universitas Nusantara PGRI Kediri, following the prototyping phase procedures. Subsequently, the product was implemented in a larger group involving students from the 2023 cohort, as part of the assessment phase.

Researchers used several instruments, including: (1) Needs analysis sheet for the preliminary research phase; (2) Expert validation sheet, which includes material and expert validation sheets, design and media validation sheets, and practitioner lecturer validation sheets; (3) Student response sheets given to students who tried the module; (4) Learning outcome summary sheets, which are files collected by students to record their learning progress.

The learning outcomes were assessed using a structured rubric that included several criteria, such as content accuracy, conceptual understanding, creativity, and presentation quality. Each criterion was scored using a predefined scale, and the total scores were categorized into five levels: very good, good, moderate, low, and very low, as presented

in Table 2. The assessment was conducted by the course lecturer. To ensure consistency, scoring guidelines were provided. However, formal inter-rater reliability testing was not conducted, which is acknowledged as a limitation of this study.

The results of the data analysis from the needs analysis sheet will be presented in main points, analyzed descriptively, and supported by a literature review. In addition, data obtained from the validation sheet instrument will be averaged and presented in percentages, so that the scores can be categorized with a Likert scale of validity in Table 1. The Likert scale of validity is adapted from (Sudjana, 1995). The results from other instruments, namely the analysis of student responses, will also be averaged and presented as percentages, and the scores will then be categorized according to the Likert scale from Sofnidar & Yuliana (2018) in Table 2. Finally, student learning outcomes obtained from the learning outcome summary sheet will be discussed and supported by a literature review. Learning outcome data will also be reviewed and categorized based on the Likert scale in Table 2.

Table 1. Validity Criteria

Skor	Criteria
80 – 100%	Very Valid
70 – 79%	Valid
60 – 69%	Fairly Valid
40 – 59%	Less Valid
0 – 39%	Not Valid

Source: Sudjana (1995)

Table 2. Student Response Criteria

Interval	Criteria
81%-100%	Very Good
61%-80%	Good
41%-60%	Average
21%-40%	Bad
0-20%	Very Bad

Source: (Sofnidar & Yuliana, 2018)

RESULTS AND DISCUSSION

Preliminary Phase

The development research began with a Google Forms needs analysis questionnaire. It was distributed to small-group participants. The scope of the questionnaire included: (1) Discussion of biology material considered difficult to understand; (2) Student interest in learning using electronic media; and (3) Student enthusiasm for research on developing E-modules based on differentiated learning.

The results of the first discussion indicate that almost half of the total students have difficulty learning the immune system (Figure 1). This may be due to the many scientific terms used in learning about the immune system. The complexity of the material and the numerous scientific terms used can hinder students' understanding, according to (Henderson & Wellington, 1998), who stated that language complexity is one of the biggest obstacles in science learning. Furthermore, the results of the second discussion from the questionnaire are shown in Figure 2, which indicates that almost all students (91.3%) agree with the use of electronic teaching materials, suggesting that electronic

media has strong potential to increase student engagement (Hadinuddin et al., 2025; Yuliantoro et al., 2025). Although the e-module supports flexible learning in terms of content access, its practical implementation is currently limited by technical constraints, particularly the requirement for local server setup and limited mobile compatibility (Hasby et al., 2025; Kalita & Potencki, 2003). These findings support the need for innovative teaching tools. Therefore, while the module demonstrates strong potential as a learning tool, further development is required to improve its usability and accessibility across platforms.

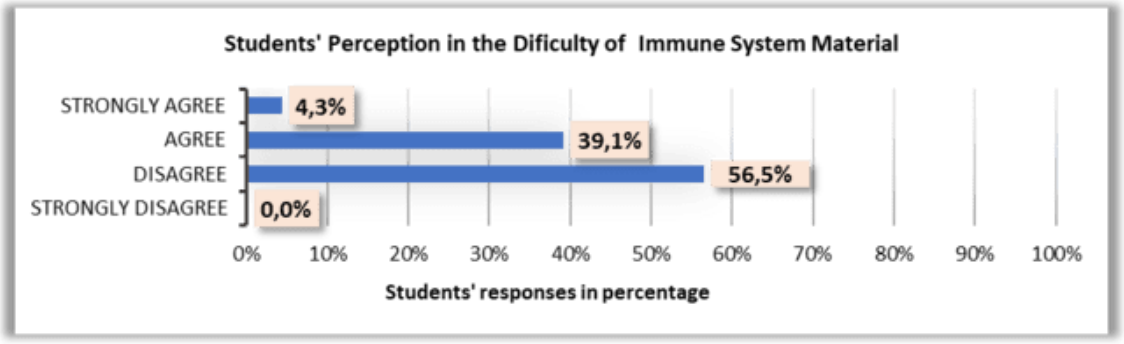


Figure 1. Survey of Difficulties of Immune System Material

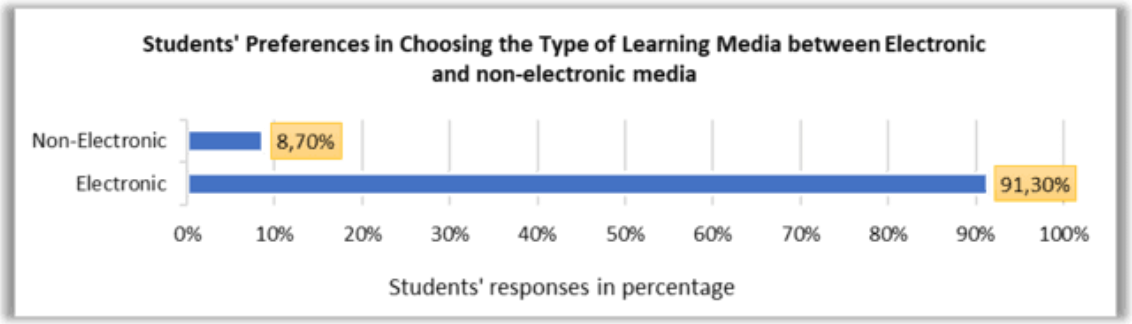


Figure 2. Survey of Interest in Learning with Electronic Media

Finally, the results of the third needs analysis questionnaire showed very high enthusiasm, as evidenced by the scores presented in Figure 3: 82.6% of respondents stated they really needed it, and 17.4% stated they needed it. Based on these results, the development research was deemed worthy of proceeding to the next phase.

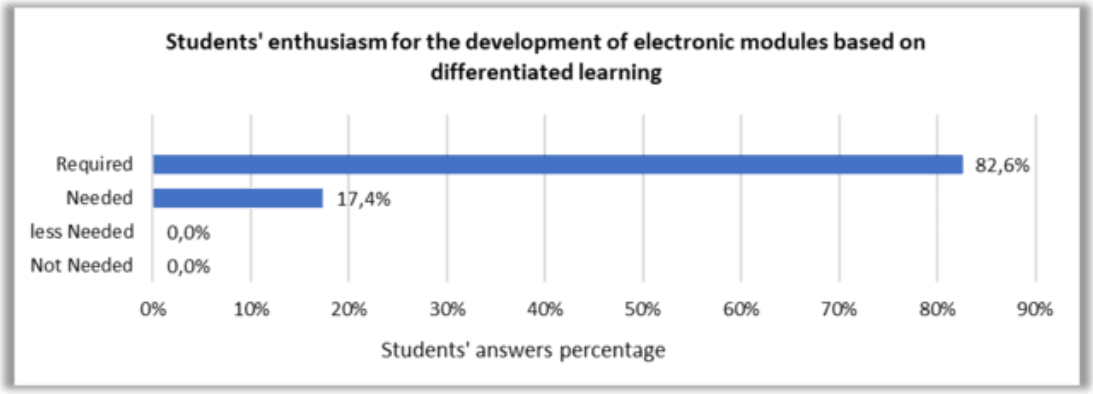
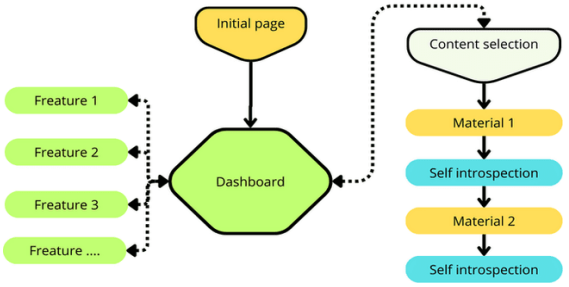
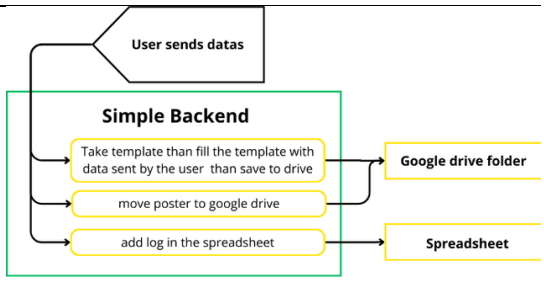


Figure 3. Survey of Student Enthusiasm for the Development of Electronic Modules

Prototyping phase

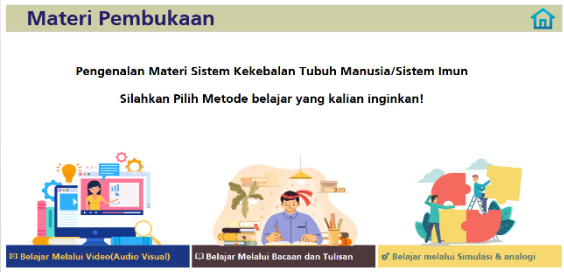
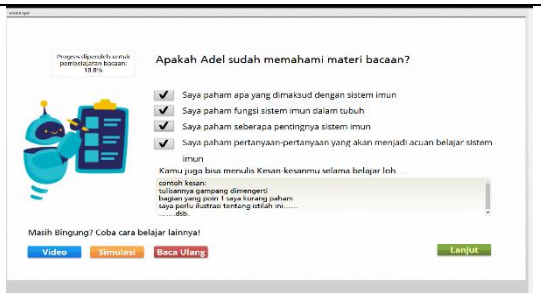
It begins with application design. The application consists of two main parts: the Immune System Electronic Module and the Rest-API backend. The learning module contains all general module components, including CP, TP, ATP, and assessment. Differentiated learning is implemented by providing three distinct content types: reading, video, and virtual simulation. Student learning outcomes must be collected by teachers. Therefore, researchers must also design a backend API to collect them. This integration of module design and technological infrastructure supports the aims highlighted in earlier research phases.

Table 3. Application flow diagram and Rest-API Backend flow

Application Flowchart	Backend API Flowchart
	

After the design guided by the supervisor is completed, the next stage is application development. The immune system learning application is built using Articulate Storyline on Windows 11. The application components include: (1) Registration Page; (2) Dashboard; (3) Information About the Application; (4) Learning Materials; (5) Self-introspection Sheet; (6) Complementary features (Glossary, Concept Maps, etc.); (7) assessment; and (8) recap of learning outcomes. Several application screenshots are presented in Table 4. In addition, researchers developed a Rest-API using Google App Script services as a backend to collect student learning outcomes. The application architecture design is presented in Table 3. The application will eventually be exported into a zip package containing HTML5 files that can be opened in a browser.

Table 4. Application Screenshots

Home Page	Dashboard
	
Differentiated Learning Options	**Self-Reflection**
	

After the Electronic Immune System Module was created during the prototyping phase, the next stage was expert validation. These experts included material, media, and practitioner experts. The material validation score results in Table 5 show very similar scores for all aspects. Furthermore, all assessment aspects, including introduction, learning, content, language, and assessment, were rated very good, with scores above 80% (very valid). The overall average material validity score was 91.2% (very valid).

Table 5. Validity by Material Experts

Aspect	Percentage Scores and Results		Average Results
	Expert 1	Expert 2	
Introduction	96%	96%	96% (Very Valid)
Learning	92%	92%	92% (Very Valid)
Content	94%	94%	94% (Very Valid)
Language	80%	80%	80% (Very Valid)
Assessment	94%	94%	94% (Very Valid)
Average			**91.2% (Very Valid)**

In addition to scoring, the material validator also provided input on the validation instrument. The first comment suggested presenting contextual data, while the second suggested readjusting the learning objectives and learning outcomes. Contextual learning is a learning concept that links the material taught to students' real-world situations. Contextual learning encourages students to connect their existing knowledge with its application in everyday life (Afriani, 2018). The second comment recommended reviewing the formulations of the CP, TP, and ATP, as they needed adjustment. The revised results are shown in Table 9.

The next validation was by media experts (Table 6). The module's validity score from media experts was 79.16 (fairly valid), with 84% (very valid), 75% (fairly valid), and 78% (fairly valid) for homepage design, content design, and ease of operation, respectively. The criteria obtained for content design and ease of operation were sufficiently valid, but they indicated several shortcomings in the E-module application. In comments, the Validator stated that the module application was complex, specifically in the module access method. Although it is a web application, opening the E-module for the immune system is not like opening a website; it requires more than just typing a URL in a browser. This is because the application has not been published. Quite severe complexity can be found on the device platform, where module users must first set up a local server by installing many applications. The complexity that exists on the device platform causes the electronic immune system module to not meet one of the module requirements, namely, user-friendly, referring to Pebriantika (2019) statement about the 5 requirements for learning modules. Therefore, the complexity of accessing modules on mobile platforms is a major drawback of the researchers' electronic modules. Therefore, the researchers strongly recommend using a desktop for module access.

Table 6. Module Validation Results by Media Experts

Aspect	Validator Score Percentage		
	Expert 1	Expert 2	Average
Homepage Design	81%	88%	84.5% (Very Valid)
Content Design	75%	75%	75% (Fairly Valid)
Usability	75%	81%	78% (Fairly Valid)
Total			79.16 (Fairly Valid)

The second media validator comment concerned adding clarity to the instructions for opening the module. Module improvements based on this comment are presented in Table 9, along with screenshots comparing the before and after states.

Table 7. Score Results Obtained from Practitioners

Aspect	Percentage
Content Suitability	98% (Very Valid)
Language Suitability	94% (Very Valid)
Presentation Suitability	75% (Fairly Valid)
Total	89% (Very Valid)

The final validation process was practitioner validation (Table 7). There were three aspects that practitioners assessed: content suitability, language suitability, and presentation suitability, with scores of 98% (very valid), 94% (very valid), 75% (fairly valid), and 89% (very valid), respectively. In addition to the scores, the practitioner validator also stated two suggestions that needed attention. The first suggestion was to improve the audio volume, which was unstable. Audio instability in video learning is caused by the microphone position changing constantly during recording. The second suggestion was to provide a settings button. In addition to writing input on the validation sheet, the practitioner validator also provided comments directly. The practitioner validator found navigation access difficult. In addition, the practitioner validator suggested adding a "back navigation" button so users can return to previous material

without having to return to the dashboard. The results of these suggestions have been implemented and are presented in Table 9.

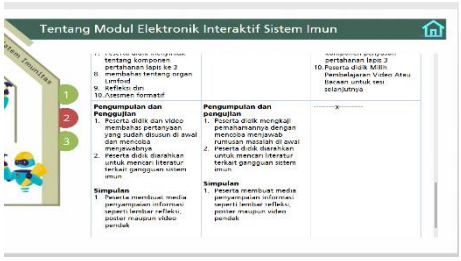
After the electronic immune system module was validated by experts and improvements were made based on the feedback (Table 9), it was tested with a small group. This small group consisted of five students who had previously studied animal physiology and covered various cognitive levels. The responses were recorded in a student response questionnaire completed after the small-group participants used the module. The analysis of the student responses is shown in Table 8.

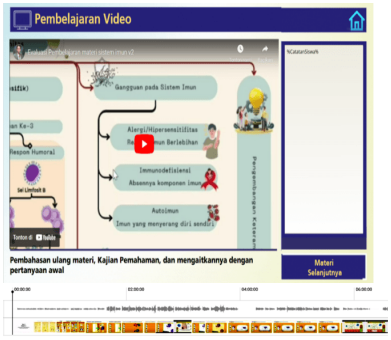
In Table 8, only the physical aspect received the lowest score (78%) and was thus categorized as good. Furthermore, all remaining aspects received an average score above 80%, indicating very good performance. Table 2 shows that the average score for all module aspects was 87%, which is categorized as very good. The lower average score for the physical aspect is due to the module's format: it is not a ready-to-use application but requires preparation to access. This is identical to the scores and input from the media expert validator. However, due to the researcher's limited capabilities, the E-module immune system application cannot yet be packaged into a webview application for a specific platform.

Table 8. Small Group Responses

Module aspects	Student					Average
	1	2	3	4	5	
Physical	80%	95%	75%	70%	70%	78%(Good)
Introduction	96%	96%	75%	71%	100%	88% (Very Good)
Content	93%	93%	79%	82%	100%	89% (Very Good)
Assessment	100%	100%	83%	83%	100%	93% (Very Good)
Practical	94%	100%	81%	69%	100%	89% (Very Good)
Total Average	93%	97%	79%	75%	94%	87% (Very Good)

Table 9. Module Revisions

Before revisions to the ATP section	After revisions to the ATP section	Description
		Re-adjustment of CP, TP, and ATP based on input from subject matter expert validators
1. Gunakan **berkas-modul-win.exe(khusus windows)** a. Download berkas-modul.exe lalu buka, maka akan muncul dialihkan ke browser. b. *jika ada notifikasi keamanan, Klik* ***jalankan/run*** *saja,* c. *jika ada popup firewall blokir internet, klik* ***allow acces inte*** d. Biarkan jendela terminal terbuka. 2. Menggunakan **Source-code.zip**, bisa untuk semua jenis PC a. Download dan EXTRAK file Source-code.rar b. lalu buka file story.html atau index.html. buka dengan brows c. Maka modul akan terbuka di browser ara membuka modul Elektronik **di ANDROID (sangat ribet)** 1. Download file **Source-code.zip** (contoh di gambar ini adalah di folder download/source-code.zip) di gambar screenshot, nama file Source-code.zip saya ganti menja imun.zip(opsional).	*ka ada notifikasi keamanan, Klik* ***jalankan/run*** *saja,* *ka ada popup firewall blokir internet, klik* ***allow acces internet*** iarkan jendela terminal terbuka. 	Improved module opening tutorial instructions based on input from design and media expert validators

		Added Back button and stabilized audio volume (normalized) based on input from practitioner validators

The immune system E-Module application has undergone expert validation and trial processes and has been improved based on existing input, making it suitable to proceed to the next research stage, namely the assessment phase.

Assessment Phase

A total of 22 students participated in the assessment phase. Student performance was evaluated based on two tasks: a literature review and a poster project. The results are presented as categorical distributions due to the nature of the assessment; therefore, no inferential statistical analysis was conducted. Since this study did not employ a pretest–posttest design or a control group, the findings should be interpreted as preliminary evidence of the module's potential rather than definitive proof of its effectiveness.

The results of the literature review task (Figure 4) showed that 30% of students achieved very good performance, 50% were in the good category, and 20% were in the poor category. Similarly, in the poster task, 40% of students were categorized as very good, 30% as good, 10% as moderate, and 20% as very poor. These findings indicate that student performance varied across different levels.

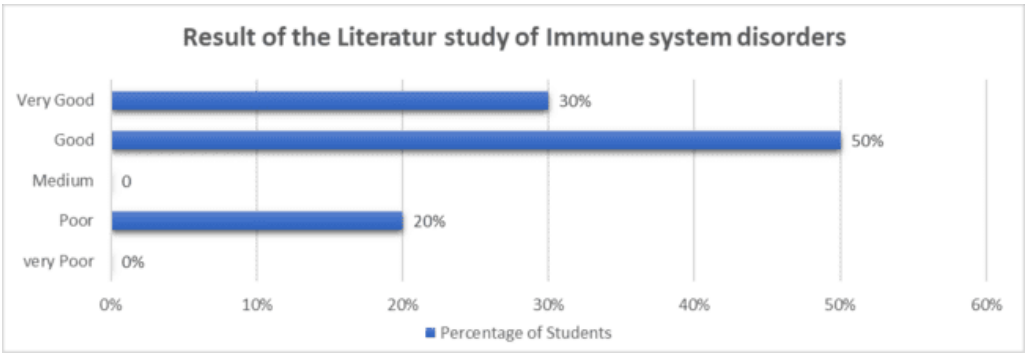


Figure 4. Results of the Literature Review Assignment

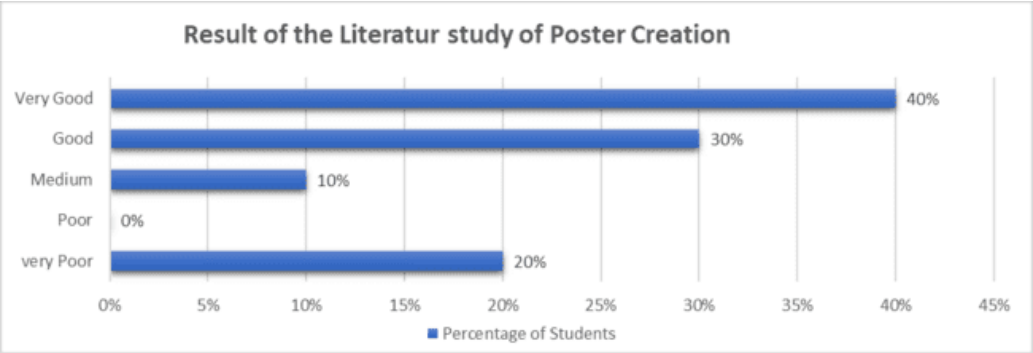


Figure 5. Poster Creation Assignment Results

Figure 5 shows that student learning outcomes fall into several categories, ranging from excellent to very low. Presenting data as categorical distributions provides a comprehensive picture of variation in student performance. This variation may reflect differences in student readiness, prior knowledge, and learning preferences, which are consistent with the principles of differentiated learning. However, it should be interpreted cautiously, as multiple factors such as task complexity, duration of implementation, and assessment conditions may also influence student performance.

Furthermore, the predominance of moderate-level performance suggests that a single implementation of the e-module may not be sufficient to produce optimal cognitive outcomes. This finding aligns with previous studies indicating that differentiated learning often has a more immediate impact on student engagement and motivation, while improvements in academic achievement require longer and more consistent implementation (Safawi & Akay, 2022).

The discrepancy between highly positive student responses (average 85%) and moderate learning outcomes indicates that the e-module appears to enhance student engagement and learning experience, but its impact on measurable learning outcomes remains limited. Therefore, the results of this study should be interpreted as initial evidence of the module's potential rather than conclusive proof of its effectiveness.

In addition, several limitations identified during implementation, including limited platform compatibility, non-responsive layout, and the requirement for local server setup, indicate that the current version of the e-module is not yet fully practical for widespread use. These technical constraints may also have influenced student performance during the assessment phase.

Overall, the findings suggest that the developed e-module is feasible and well-received by students; however, further refinement and more rigorous evaluation designs are required to strengthen its effectiveness in supporting student learning outcomes.

Based on these results, it can be concluded that the electronic immune system module based on differentiated learning has the potential to support meaningful learning, particularly in increasing student motivation and engagement. However, to achieve more optimal learning outcomes, strengthening cognitive assessment, increasing the duration of module use, and developing more reliable assessment instruments are needed. Therefore, the assessment results in this study can be seen as initial evidence of the potential of the electronic immune system module to support learning and as a basis for further development in higher-level cognitive assessment.

Table 10. Large Group Responses

Aspect	Score
Physical	82% (Very Good)
Introduction	85% (Very Good)
Content	88% (Very Good)
Assessment	86% (Very Good)
Practical	84% (Very Good)
Average	85% (Very Good)

Student response questionnaires were distributed after the learning process using the immune system e-module application. The average results for large-group student responses are presented in Table 10. From the data presented, it can be seen that all scores across all aspects of the module are in the very good range (above 80%) or meet the "very good" criteria.

The results of the assessment phase indicate that the developed e-module has reached an acceptable level of feasibility and user satisfaction for initial implementation. However, several limitations identified from student feedback, including layout responsiveness, progress indicators, and cross-platform compatibility, indicate that further development is still required. Therefore, the current version of the e-module can be considered suitable for limited use, but not yet fully optimized for broader implementation.

Large-group participants provided input to the researcher via a response questionnaire. The input included: (1) A more responsive layout; (2) Addition of learning progress percentage criteria; (3) Improved compatibility on device platforms. The first input explained that a fixed layout can make the application difficult to use across different screen sizes. This is because the application development uses a fixed size for the desktop platform. The second input showed that students were confused about whether their scores were good. The solution was to provide progress percentage criteria, as in Table 2 of the E-Module application. The third input indicated that device compatibility issues need to be fixed. For this input, future improvements should focus on enhancing cross-platform compatibility through collaboration with application developers.

This study provides initial evidence for the feasibility and potential of a differentiated learning-based e-module in undergraduate biology education. However, further studies employing more rigorous experimental designs are needed to evaluate its effectiveness in improving student learning outcomes.

CONCLUSION

The differentiated learning-based e-module developed in this study was found to be valid and feasible for use in undergraduate biology learning. The module achieved high validity scores from material experts (91.2%) and practitioners (89%), while media validation indicated a fairly valid category (79.16%). Student responses were very positive in both small-group (87%) and large-group (85%) trials. Although learning outcomes varied across performance levels and were generally in the moderate category, the findings suggest that the e-module has the potential to support student engagement and facilitate understanding of immune system concepts. However, improvements in

platform compatibility, usability, and assessment quality are still required to optimize its effectiveness and broader implementation.

SUGGESTIONS

Future research should employ more rigorous experimental designs, improve the usability and accessibility of the e-module, and develop more reliable assessment instruments. In addition, longitudinal studies are needed to examine the long-term impact of differentiated learning-based digital modules on student learning outcomes.

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