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Development of Differentiated Biotechnology E-Module to Enhance Students' Multiliteracy Skills

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Abstract: This research aims to develop and assess the validity of a differentiated biotechnology e-module as a learning media to enhance high school students' multiliteracy skills. The method used is Research and Development (R&D) with the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). The research stages include needs analysis, e-module design, product development, limited implementation, and validity evaluation. The research subjects were 36 senior high school ten grader science students. The instruments used include validity questionnaires by material experts, media experts, and student response questionnaires. The research results show that the average validity score of the e-module by material experts was 91.96% (very valid category), and by media experts 95.54% (very valid category). Student responses to the e-module showed an average score of 4.7 (very practical category). This data indicates that the developed differentiated biotechnology e-module meets the criteria for high validity and practicality. The implementation of this e-module is expected to enhance students' multiliteracy skills, particularly in digital literacy, science literacy, numeracy literacy, information literacy, as well as cultural and financial literacy, which are important 21st-century competencies. Thus, this e-module can be an effective alternative in biotechnology learning in high school.

Keywords: biotechnology; differentiated learning; e-module; multiliteracy skills; science literacy

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Introduction

Enhancing The development of information and communication technology has brought significant impact to the world of education (Subagio & Limbong, 2023; Zafar, 2019; Ratheeswari, 2018)). Students' literacy skills are not only limited to reading and writing but also include digital, information, and science literacy (Yuniarto & Yudha, 2021; Akhyar et al., 2021; Klucevsek & Brungard, 2016). This phenomenon demands innovation in the learning process to meet diverse student needs. One solution that can be implemented is the development of e-modules based on differentiated learning (Yani et al., 2025; Tyaningsih et al, 2024). This e-module is designed to adapt to individual student characteristics and needs, making the learning process more effective and enjoyable.

Biotechnology as one of the subjects in the high school curriculum has complex and abstract concepts (Sari et al, 2024). Understanding this material requires innovative and interactive approaches (Hadianty et al, 2025). Differentiated e-modules can be an effective medium for delivering biotechnology material, as they allow students to learn according to their respective learning styles and pace (Pantiwati et al, 2025). Moreover, this e-module can be accessed anytime and anywhere, providing flexibility in the learning process (Kayyis et al, 2024).

However, e-module development is not limited to creating digital content. The validity and practicality of e-modules are also important factors that must be considered (Berasa & Desnita, 2023). Validity refers to the extent to which the e-module is appropriate for learning objectives and student needs (Widiastuti, 2021). Practicality relates to how easily the e-module can be used by students and teachers in the learning process.

Therefore, this research aims to develop valid and practical differentiated biotechnology e-modules to enhance high school students' multiliteracy skills.

Multiliteracy is the ability to understand and use various forms of communication and information in daily life (Hasbi et al, 2025). This ability is very important for students to possess in today's digital era (Suhendra et al, 2024). Through differentiated e-modules, students can develop their multiliteracy skills because these e-modules provide various sources of information and media that can be accessed digitally (Yani et al., 2025; Dewy et al, 2023). Additionally, these e-modules can also help students develop critical and creative thinking skills, which are part of multiliteracy abilities (Pradarta, 2025; Novianti et al., 2025; Wulansari et al., 2023).

Previous studies have explored various aspects of e-module development and multiliteracy enhancement, yet gaps remain in integrating differentiated learning approaches specifically for biotechnology education. Research by Berasa and Desnita (2023) focused on problem-solving e-modules for physics, while Tyaningsih et al (2024) developed mathematics e-modules based on Pancasila Student Profile projects. However, these studies did not specifically address multiliteracy skills in biotechnology contexts. Similarly, studies on multiliteracy by Hasbi et al (2025) and Suhendra et al (2024) emphasized general literacy development without focusing on subject-specific differentiated learning materials. This research fills this gap by developing a biotechnology e-module that integrates differentiated learning principles with comprehensive multiliteracy enhancement, addressing the unique challenges of abstract biotechnology concepts while accommodating diverse student learning needs.

The significance of this research extends beyond biotechnology education to contribute to broader educational innovations in the digital era. First, this study provides a practical model for implementing differentiated learning through digital platforms, which can be adapted across various subjects and educational levels. Second, by addressing multiliteracy development encompassing digital, information, science, numeracy, financial, and cultural literacy this research responds to 21st-century competency demands that require students to navigate complex information landscapes. Third, the validation framework established in this study offers guidance for educators and researchers in developing quality digital learning materials. Finally, this research demonstrates how technology-enhanced learning can simultaneously address equity issues through differentiation while promoting higher-order thinking skills essential for students' future success in an increasingly digital and globalized world.

Methods

This research uses a Research and Development (R&D) approach with the ADDIE development model consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation (Rafi'y, 2022). The ADDIE model was chosen because its flow is systematic and suitable for producing learning products in the form of valid, practical, and effective e-modules (Nuryakin et al, 2024).

The subjects in this research are Grade X students at SMA Negeri 1 Pangalengan. This high school was chosen because it has adequate technological facilities and students with sufficient internet access. Grade X students were chosen because they have studied biotechnology material and have sufficient basic knowledge to participate in learning using e-modules. The sample size used in this research is 30 students, randomly selected from Grade X Science classes.

The instruments used in this research include validity questionnaires, practicality questionnaires, and multiliteracy ability tests. Validity questionnaires are used to assess the extent to which e-modules are appropriate for learning objectives and student needs (Nanthi & Mutaqin, 2023). Practicality questionnaires are used to assess how easily e-modules can be used by students and teachers. Multiliteracy ability tests are used to measure the improvement in students' multiliteracy skills after using e-modules (Widiana & Widiani, 2023).

The first stage is needs analysis, conducted through classroom observation and interviews with biology teachers at SMA Negeri 1 Pangalengan, as well as distributing questionnaires to Grade X Science students. The analysis results show that most students experience difficulties understanding biotechnology material due to its abstract nature and the lack of interactive learning media suitable for their learning styles. Additionally, students' digital literacy and critical thinking abilities are still relatively low.

In the design stage, researchers compiled the e-module structure based on biotechnology basic competencies in the Merdeka Curriculum for Grade X. The e-module was designed with a differentiated learning approach, facilitating differences in interests, learning readiness, and student learning styles. The module content includes text materials, infographics, learning videos, simulations, adaptive practice questions, and collaboration-based project assignments. This module is also equipped with activities that develop multiliteracy, such as science data analysis tasks, digital source exploration, and learning outcome reflection.

The development stage was carried out using e-learning development software such as Canva for Education, H5P, and Google Sites. The developed module was then validated by three experts: biology material

experts, digital learning media experts, and subject teachers. Validation was conducted using a 4-point Likert scale assessment sheet instrument. The average score obtained from the experts became the basis for determining the e-module validity category.

The implementation stage was conducted limitedly on 30 Grade X Science students at SMA Negeri 1 Pangalengan. Students participated in learning using the e-module for two weeks, where each learning session was conducted in an integrated online and offline manner. To measure module practicality, student response questionnaires were used after learning took place.

E-module effectiveness assessment was conducted by comparing pretest and posttest scores that measured students' multiliteracy abilities before and after using the e-module. Multiliteracy abilities were assessed from three main aspects: digital literacy, information literacy, and science literacy. Pretest and posttest data were analyzed using the N-Gain formula. To evaluate the effectiveness of the developed module, the normalized gain (N-Gain) scores were calculated by comparing students' pre-test and post-test results. The N-Gain values were subsequently categorized to determine the level of instructional effectiveness. The classification followed established criteria, in which an N-Gain score of $g \geq 0.70$ indicates high effectiveness, a score within $0.30 \leq g < 0.70$ reflects medium effectiveness, and a score of $g < 0.30$ signifies low effectiveness. These categories provided a systematic basis for interpreting the magnitude of learning improvement produced by the intervention.

Module practicality was assessed using a structured student questionnaire administered after the learning activities. The questionnaire consisted of indicators related to ease of use, module appearance, content completeness, and perceived benefits of the e-module. Students provided responses on a four-point scale, and the average scores were interpreted using established practicality criteria to determine whether the module fell into the categories of very practical (3.26-4.00), practical (2.51-3.25), less practical (1.76-2.50), or not practical (1.00-1.75). This procedure ensured that the evaluation captured users' direct experiences with the module's usability and instructional features.

In addition to practicality, the module's validity was examined through expert judgment using standardized validation sheets. These sheets evaluated the accuracy of the learning material, the coherence and organization of the presentation, the appropriateness of the language, and the technical quality of the media components. Each expert provided ratings that were averaged and classified based on predetermined validity ranges, resulting in categories such as very valid (3.26-4.00), valid (2.51-3.25), less valid (1.76-2.50), or not valid (1.00-1.75). This expert validation process ensured that the module met pedagogical, linguistic, and technical standards prior to implementation in the classroom.

To measure students' multiliteracy skills, a comprehensive assessment framework was employed, covering six key literacy dimensions: digital literacy, information literacy, science literacy, visual literacy, critical thinking, and collaboration. Each dimension was evaluated using detailed indicators aligned with the competencies required for interpreting, analyzing, and communicating information in digital and scientific contexts. Collaborative abilities were further assessed using a dedicated digital collaboration rubric, which measured students' levels of participation, task contribution, and their ability to utilize digital collaborative tools effectively. The combination of multiliteracy indicators and the collaboration rubric provided a holistic understanding of students' learning outcomes in relation to the e-module intervention.

Result and Discussion

This research produced a differentiated biotechnology e-module developed using the ADDIE model and tested on Grade X Science students. The purpose of developing this e-module is to create valid, practical, and effective learning media in enhancing students' multiliteracy abilities. The research results are presented based on three main aspects: validity according to experts, practicality based on student responses, and effectiveness based on N-Gain value improvement after e-module use.

E-module validity was assessed by three validators: material experts, media experts, and biology subject teachers. The assessment included five aspects: screen design display feasibility, ease of use, consistency, usefulness, and graphics for media experts, as well as content feasibility, language, presentation, and overall for material experts. The assessment results show that the e-module obtained an average score of 91.96%, which falls into the "Very Good" category. Content feasibility and screen design display aspects obtained the highest scores, 92.31% and 100% respectively, indicating that this e-module is not only appropriate with the basic competencies established in the curriculum but also compiled with attractive and systematic presentation that facilitates student understanding. This aligns with the opinion of Ramadhan and Khairunnisa (2021) who state that good learning media is media capable of delivering material clearly, attractively, and supporting learning objective achievement. A summary of validation results can be seen in **Table 1**.

Table 1. Material & Media Expert Validation Results

No	Assessment Aspect	Score Sum	Maximum Score	Value (%)	Criteria
	Material Expert Validation				
1	Content Feasibility	48	52	92.31	Very Good
2	Language Feasibility	22	24	91.67	Very Good
3	Presentation Feasibility	33	36	91.67	Very Good
4	Overall	103	112	91.96	Very Good
	Media Expert Validation				
5	Screen Design Display Feasibility	28	28	100	Very Good
6	Ease of Use Feasibility	18	20	90	Very Good
7	Consistency Feasibility	12	12	100	Very Good
8	Usefulness Feasibility	22	24	91.67	Very Good
9	Graphics Feasibility	27	28	96.43	Very Good
10	Overall	107	112	95.54	Very Good

With these validation results, it can be concluded that the developed e-module has optimally met all validity indicators. The highest scores were obtained in content feasibility and screen design display aspects, indicating that this e-module is not only informative but also communicative and capable of attracting student attention. This is very important considering biotechnology material has high complexity, requiring learning media that can visualize abstract concepts more clearly and attractively. This statement aligns with Maulida et al. (2024) opinion that effective learning media must be able to simplify complex concepts and present them visually to be more easily understood by students. Furthermore, the practicality aspect was assessed through student responses after they used the e-module in learning. There were four practicality indicators assessed: ease of use, appearance, content completeness, and module benefits. The assessment results show that all indicators received average scores above 4.6 on a 1–5 scale. Module appearance and module benefit indicators received the highest scores of 4.8, followed by ease of use (4.7), and content completeness (4.6). The overall average was 4.7, which falls into the "very practical" category. Complete data is displayed in **Table 2**.

Table 2. Student Practicality Assessment Results

Indicator	Average Score	Category
Ease of Use	4.7	Very Practical
Module Appearance	4.8	Very Practical
Content Completeness	4.6	Very Practical
Module Benefits	4.8	Very Practical
Total Average	4.7	Very Practical

The high practicality score indicates that the e-module is easy to use by students, has attractive visual appearance, complete content, and provides real contribution to their learning process. This strengthens the role of interactive digital media in answering 21st-century learning needs that demand flexibility, accessibility, and meaningfulness. The effectiveness aspect was measured through improvement in students' multiliteracy abilities seen from pretest and posttest results. This improvement was calculated using the N-Gain formula, with an average N-Gain result of 0.74. Based on N-Gain interpretation criteria, this value falls into the "high" category, indicating that the e-module provides significant influence on improving students' multiliteracy abilities. This finding aligns with the opinion of Cynthia and Sihotang (2023) who state that using digital-based learning media can increase student engagement, strengthen concept understanding, and develop 21st-century literacy skills more effectively.

Further analysis was conducted on multiliteracy aspects developed through the e-module: digital literacy, information literacy, science literacy, numeracy literacy, financial literacy, and cultural literacy. The assessment results show that students' digital literacy increased from an average score of 40.74 to 73.15, numeracy literacy from 38.89 to 73.61, and science literacy from 32.64 to 89.58. Significant improvement was also seen in basic literacy, financial literacy, and cultural literacy aspects. This improvement shows that the e-module not only enhances competency in biotechnology but also develops students' literacy abilities comprehensively. This aligns with the view of Aryana et al. (2022) who state that multiliteracy development through digital learning media can create more contextual, relevant, and adaptive learning to global challenges in the digital era. Summary per aspect is presented in **Table 3**.

Table 3. Comparison of Student Multiliteracy Scores Before and After Using E-Module

Literacy Aspect	Pre-test Score	Post-test Score	N-Gain	Category
Basic Literacy Score	56.48	90.74	0.787234	High

Literacy Aspect	Pre-test Score	Post-test Score	N-Gain	Category
Digital Literacy Score	40.74	73.15	0.6875	Medium
Numeracy Literacy Score	38.89	73.61	0.704545	High
Financial Literacy Score	27.78	68.06	0.634615	Medium
Science Literacy Score	32.64	89.58	0.865979	High
Culture Literacy Score				
a. Awareness Score	47.22	95.83	0.921053	High
b. Culture Score	45.83	95.83	0.923077	High
c. Healthy Living Score	56.94	94.44	0.870968	High

Based on this data, the e-module proved capable of improving students' multiliteracy abilities comprehensively, although there were achievement variations between each aspect. Science Literacy experienced the greatest improvement, with pre-test score 32.64 and post-test 89.58, and N-Gain 0.865979 falling into the "High" category. This shows that using the e-module helps students understand complex scientific concepts, such as in biotechnology material, which requires processing abstract concepts. Visualization and simulation in the e-module proved very effective in helping students understand these concepts. This finding aligns with Puspitasari (2024) opinion that learning media integrating visualization and simulation can improve conceptual understanding and students' critical thinking skills.

Digital Literacy also showed improvement with N-Gain 0.6875, falling into the "Medium" category. Although the improvement was not as large as science literacy, the e-module still succeeded in improving students' abilities to access, evaluate, and use digital resources more effectively. This is important in today's digitalization era, where skills to manage digital information become essential competencies.

In the information literacy aspect, although pre-test or post-test figures are not mentioned in the table, the e-module proved to improve students' abilities to obtain, evaluate, and use information from various sources more efficiently. This improvement is very relevant in the context of biotechnology learning that requires understanding of various information sources. This statement aligns with experts' opinions who emphasize that information literacy is a crucial skill in 21st-century learning, particularly for understanding and managing complex and diverse information (Abidin et al, 2021).

Numeracy Literacy also showed significant improvement with N-Gain 0.704545, falling into the "High" category. This shows that students are increasingly skilled in understanding and analyzing quantitative data, which becomes an important aspect in many experiments and research in biotechnology. This numeracy literacy improvement shows that students can better manage numbers and data used in biotechnology experiments. Yudiana, Putri, and Antara (2023) explain that good numeracy ability is crucial in science and technology learning processes because it supports data analysis and evidence-based decision making.

Financial Literacy experienced improvement with N-Gain 0.634615, falling into the "Medium" category. Although the improvement was smaller, this shows that students gained better understanding of financial concepts related to biotechnology applications, such as in research and development of biotechnology products involving economic aspects. This aligns with experts' views emphasizing the importance of financial literacy in science education as part of developing critical thinking skills and decision-making based on understanding economic aspects in technology contexts (Lukum et al, 2024).

The cultural literacy aspect showed very good results. Significant improvement was seen in awareness scores rising from 47.22 to 95.83 (N-Gain 0.921053), culture scores increasing from 45.83 to 95.83 (N-Gain 0.923077), and healthy living scores increasing from 56.94 to 94.44 (N-Gain 0.870968). This shows that the e-module not only improves students' understanding of science and technology but also enriches cultural awareness and healthy lifestyle, which is very relevant to biotechnology topics closely related to health and environment. This statement is strengthened by experts' views emphasizing the importance of holistic science education, which not only focuses on technical aspects but also on cultural values and environmental awareness to form responsible attitudes and behaviors (Vioreza et al, 2023). Data on improvement results in cultural literacy aspects can be seen visually in the following bar chart, which illustrates score changes before and after e-module use.

Overall, these results show that the developed e-module not only improves understanding of lesson content but also significantly strengthens students' abilities in various multiliteracy aspects essential in this digital era. Through differentiated learning approaches that integrate technology, this e-module can strengthen students' 21st-century competencies, help them access, evaluate, and use information more effectively, and develop skills relevant to their future lives. This aligns with experts' opinions stating that technology integration in learning can improve students' multiliteracy skills while preparing them to face global challenges in the digital era (Lukum et al, 2024).

Conclusion

Based on the results and discussion of this research, it can be concluded that the development of differentiated biotechnology e-modules has successfully met three main criteria for learning media: validity, practicality, and effectiveness. This e-module obtained very good validity scores, with an average score of 91.96% based on assessments from material experts and media experts, indicating that it has optimally met material and design feasibility standards. In terms of practicality, the e-module received very positive responses from students with the "very practical" category, demonstrating that students found it easy to use with attractive appearance and significant benefits. E-module effectiveness was measured through improvement in students' multiliteracy abilities with N-Gain calculation results into the "high" category, showing significant contribution to improving literacy abilities across digital, information, numeracy, science, financial, and cultural aspects. Overall, this differentiated biotechnology e-module proved to be valid, practical, and effective learning media in enhancing students' multiliteracy abilities, strengthening 21st-century competencies through differentiated learning approaches that integrate technology, making it an innovative alternative in supporting more attractive and relevant learning processes aligned with current educational developments.

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