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FEASIBILITY OF A GUIDED INQUIRY-BASED BIOTECHNOLOGY E-MODULE IN ENHANCING SCIENTIFIC LITERACY

Kelayakan E-Modul Bioteknologi Berbasis Inkuiri Terbimbing dalam Melatihkan Literasi Sains

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Abstract
Scientific literacy is essential in the 21st century, but Indonesian students' skills remain low, as shown by the 2022 PISA results. This study aims to develop a guided inquiry-based biotechnology E-Module to train students' scientific literacy skills. The research employed the ADDIE model and was conducted in the Biology Department of UNESA, with the module tested on 33 tenth-grade students at SMA Negeri 1 Puri. Validity was obtained through expert judgment, practicality was evaluated through observations of learning activity implementation and student responses, and effectiveness was assessed through improvements in pretest and posttest scores on scientific literacy skills. Data were analyzed using a quantitative approach. The validation results showed a 90% feasibility percentage, categorized as very valid. The E-Module demonstrated high practicality, with implementation scores of 98.05% and student response scores of 93.80%. Effectiveness was observed based on the N-Gain value for science literacy skills, with an average of 0.75, showing high improvement (≥ 0.7) in five of six scientific literacy indicators: identifying phenomena, formulating questions, designing experiments, collecting data, and drawing conclusions. One indicator, interpreting data and representing it in different forms, achieved an N-Gain score of 0.39 (moderate category). These results indicate that the E-Module effectively facilitates the development of scientific literacy skills. Therefore, the guided inquiry-based biotechnology e-module is considered valid, practical, and effective in training students' scientific literacy skills.
Keywords: E-Module, Biotechnology, Guided Inquiry, Scientific Literacy

Abstrak
Literasi sains merupakan keterampilan esensial abad ke-21, namun hasil PISA 2022 menunjukkan keterampilan literasi sains peserta didik di Indonesia masih tergolong rendah. Penelitian ini bertujuan untuk menghasilkan E-Modul Bioteknologi berbasis inkuiri terbimbing untuk melatihkan keterampilan literasi sains yang layak ditinjau dari aspek validitas, kepraktisan, dan keefektifan. Penelitian ini menggunakan metode Research and Development (R&D) dengan model ADDIE (Analyze, Design, Develop, Implement, Evaluate). Penelitian dilakukan di Jurusan Biologi UNESA dan diujicobakan secara terbatas pada 33 peserta didik kelas X SMA Negeri 1 Puri. Validitas diperoleh melalui penilaian oleh tiga validator ahli, kepraktisan ditinjau dari observasi keterlaksanaan aktivitas pembelajaran serta respon peserta didik, dan keefektifan ditinjau dari peningkatan nilai pretest dan posttest keterampilan literasi sains. Data dianalisis secara deskriptif kuantitatif. Hasil validasi menunjukkan persentase kelayakan sebesar 90% dengan kategori sangat valid. Kepraktisan E-Modul tergolong sangat tinggi, dengan skor keterlaksanaan sebesar 98,05% dan respons peserta didik sebesar 93,80%. Efektivitas dilihat dari nilai N-Gain keterampilan literasi sains dengan rata-rata 0,75, yang menunjukkan peningkatan tinggi (≥ 0,7) pada lima dari enam indikator literasi sains: mengidentifikasi fenomena, merumuskan pertanyaan, merancang eksperimen, mengumpulkan data, dan menyusun kesimpulan. Satu indikator, yaitu menginterpretasikan data dan mengubahnya dalam bentuk lain, memperoleh N-Gain 0,39 (kategori sedang). Hasil tersebut menunjukkan bahwa E-Modul ini mampu melatihkan keterampilan literasi sains secara optimal. Dengan demikian, E-Modul bioteknologi berbasis inkuiri terbimbing dinyatakan valid, praktis, dan efektif dalam melatihkan keterampilan literasi sains.
***Kata Kunci**: E-Modul, Bioteknologi, Inkuiri Terbimbing, Literasi Sains*

INTRODUCTION

21st-century education requires students to develop critical thinking, creativity, collaboration, and communication skills (4Cs). In line with the direction of the Ministry of Education, Culture, Research, and Technology, strengthening soft skills and mastering various forms of literacy are key pillars in preparing a generation capable of facing the challenges of globalization. One of the essential competencies emphasized in science education is scientific literacy. Scientific literacy refers to an individual's ability to understand, use, and evaluate scientific information and concepts critically, enabling them to make decisions based on scientific understanding in daily life (Putri & Wulandari, 2022).

However, current data shows that Indonesian students' science literacy skills are still relatively low. The 2022 Programme for International Student Assessment (PISA) results indicate that Indonesian students' science literacy scores were only 383. This is far below the international average of 485 (OECD, 2023). Various studies have shown that students perform poorly in understanding scientific phenomena, designing and evaluating investigations, and interpreting scientific data and evidence (Azizah et al., 2021; Sari et al., 2022). These results suggest that science education in schools should focus not only on conveying conceptual knowledge, but also on developing practical scientific literacy skills.

The OECD (2024) identified three key competencies in scientific literacy when developing the PISA 2025 framework: explaining phenomena scientifically, designing and evaluating scientific investigations, and critically interpreting scientific data and facts. These competencies underscore the significance of educational approaches that engage students in the process of scientific thinking. Consequently, a pedagogical approach that prioritizes active student engagement and the cultivation of scientific process skills is imperative. One such approach is the guided inquiry learning model, which has been demonstrated to facilitate the development of these competencies.

The guided inquiry model offers students the opportunity to engage in scientific exploration and investigation, encompassing the formulation of problems, the design of experiments, the analysis of data, and the drawing of conclusions, with systematic guidance provided by educators. A multitude of studies have demonstrated the efficacy of this model in enhancing scientific literacy. The model integrates three domains of learning: cognitive, affective, and psychomotor (Sujudi et al., 2020; Faidah & Mahanal, 2019; Shellawati et al., 2018).

Active involvement in the discovery process has been shown to enhance student motivation and responsibility for their own learning. Additionally, students are instructed to cultivate autonomy in problem-solving, eschewing the tendency to rely excessively on teachers for assistance. This approach aligns with constructivist theory, which posits that students develop new understandings by integrating existing knowledge with learning experiences acquired during the inquiry process. This pedagogical approach has been shown to facilitate a more profound and enduring comprehension of concepts (Aditya et al., 2022).

In the context of biology education, the integration of biotechnology material through the implementation of a guided inquiry approach has proven to be highly efficacious. Biotechnology is defined as an applied, contextual field of science with close ties to everyday life. The inquiry learning model, when applied to this material, enables students to engage in active participation in scientific processes such as observation, experimentation, and the formulation of conclusions. This finding lends further support to the notion that the development of holistic scientific literacy skills is indeed attainable.

To facilitate guided inquiry learning in biotechnology material, the development of specially designed teaching materials is imperative. One such material is electronic teaching modules (e-modules). An e-module is a digital teaching material that presents learning content in a structured, self-paced, and interactive manner. In comparison to printed modules, e-modules have been shown to be more environmentally friendly, cost-effective, and engaging due to their capacity to incorporate visual media, audio, and other interactive features (Puspitasari, 2019; Efendi & Nugraha, 2024). E-modules designed according to guided inquiry syntax can also facilitate students in practicing scientific literacy skills through exploratory activities, thought provoking questions, and scientific reflection.

The development of guided inquiry-based biotechnology e-modules has been shown to effectively train students' scientific literacy skills in accordance with the indicators published by the OECD (2024). Six indicators of scientific literacy will be trained. These indicators are as follows: (1) the ability to identify a phenomenon that occurs in the world; (2) the ability to identify questions in the scientific study given; (3) the ability to design experiments in accordance with scientific procedures to answer research questions; (4) the ability to collect data to support accurate scientific conclusions; (5)

the ability to interpret data presented in different representations; and (6) the ability to draw appropriate conclusions based on data.

The guided inquiry-based biotechnology E-Module developed contains various interactive features that are systematically designed to train students' scientific literacy skills. The Did You Know? feature presents information about biotechnology events or phenomena that occur in the surrounding environment and is supported by scientific references such as journals or reliable sources. This feature helps students connect biotechnology concepts with real-world realities and develop the ability to explain phenomena scientifically. Additionally, the "Let's Discuss" feature encourages students to share their opinions and engage in discussions with peers about current biotechnology issues.

The What If? feature presents a contextual biotechnology problem or issue around students, then guides them to formulate questions that can be scientifically investigated. Furthermore, the How To Do? feature directs students to design experimental procedures or scientific investigations to answer the questions they have formulated. At this stage, students are trained to think logically, systematically, and methodologically in designing an experiment, which is the core of scientific skills.

The Let's Create feature provides a data collection worksheet to document the results of experiments or scientific investigations. This activity enhances students' ability to organize and collect data accurately. Furthermore, through the Let's Conclude feature, students are encouraged to formulate conclusions based on the results of the experiment or data that has been analyzed. This activity trains students' skills in interpreting data and drawing conclusions based on scientific evidence critically.

The literature supporting this research includes the concept of scientific literacy based on the PISA framework (OECD, 2019; 2024), guided inquiry learning theory as an effective approach to developing scientific skills (Nurfahzuni & Budiyanto, 2023; Anam, 2017), and the potential of e-modules as innovative digital teaching media (Sirate & Risky, 2017). Based on this study, the developed biotechnology E-Module is expected to be an innovative solution in efforts to improve students' scientific literacy in the 21st century.

This study aims to develop a guided inquiry-based biotechnology E-Module that is suitable for use in science learning. The suitability is reviewed in terms of validity, practicality, and effectiveness in training students' scientific literacy skills.

METHOD

The present study was conducted using a research and development (R&D) approach, incorporating quantitative descriptive methods in accordance with the ADDIE model (Analyze, Design, Develop, Implement, Evaluate).The research was conducted from August 2024 to May 2025, with the E-Module development taking place in the Biology Department of FMIPA at UNESA.

In the Analysis phase, we examined the curriculum, student characteristics, and biotechnology learning needs to design an appropriate E-Module. The Design phase involved structuring the E-Module according to the Merdeka Curriculum. The E-Module includes several key components: a cover, preface, table of contents, concept map, usage instructions, feature descriptions, learning objectives, subject material, guided inquiry-based activities, and student reflection sections (Abdullah, 2022).

The Development phase began with creating an initial draft, which was reviewed by the supervising lecturer (Draft I). It was then presented in a seminar to get feedback from the examining lecturers (Draft II). In the Implementation phase, Draft II was validated by material experts, education experts, and biology teachers. Revisions based on this validation resulted in Draft III, which was the final product. This final version was then limitedly tested with 33 tenth-grade students at SMA Negeri 1 Puri Mojokerto. The aim was to assess the E-Module's practicality, effectiveness, and student responses.

Data collection focused on three main aspects: validity, practicality, and effectiveness of the E-Module. Validity data was obtained through validation sheets filled out by three expert validators to assess the feasibility of the E-Module content and pretest-posttest instruments. The E-Module was considered valid if it obtained a percentage score of ≥ 71%. Practicability was assessed through observation of the E-Module implementation using observation sheets and student responses through respond questionnaires. The E-Module is considered practical if it achieves a percentage of ≥ 71%. In the meantime, effectiveness data was collected from the pretest and posttest results of the students, which were analyzed using the N-Gain formula:

$$<g> = \frac{Skor\ post\ test - Skor\ pre\ test}{Skor\ maksimal - Skor\ pre\ test}$$

with interpretation criteria: high (≥ 0.7), medium (0.3 ≤ g < 0.7), and low (< 0.3). Students are considered to have succeeded if they achieve a score of ≥ 75%. These techniques and instruments are used in an integrated manner to measure the feasibility of the E-Module in

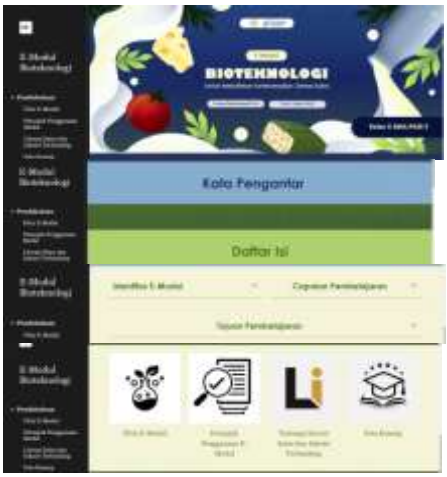
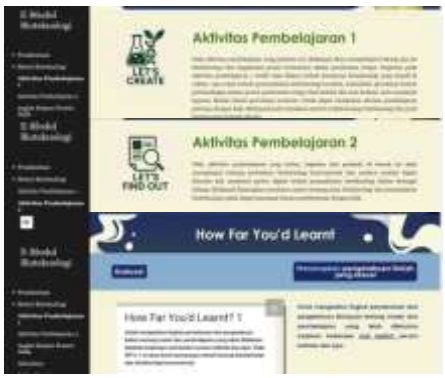
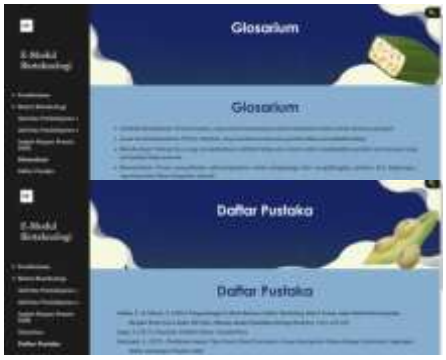
terms of content, implementation, and its impact on students' scientific literacy skills (Sugiyono, 2021).

RESULTS AND DISCUSSION

E-Module Profile

This development research produced a biotechnology E-Module that is feasible in terms of validity, practicality, and effectiveness for enhancing scientific literacy skills. This biotechnology E-Module contains various features that provide activities to train the six indicators of scientific literacy according to OECD 2024. The E-Module was designed using Google Sites, giving it a web-based appearance so that all activities can be easily integrated. This platform allows for the creation of interactive and accessible content without the need for programming skills. The feature of linking third-party pages or applications, such as Canva, YouTube, and Google Forms, which are used as media for discussion, visual presentation, as well as formative assessment and evaluation, provides flexibility in presenting material that supports various student learning styles. The display of the developed biotechnology E-Module can be seen in Table 1.

Table 1. Appearance of the Biotechnology E-Module

No.	Tampilan E-Modul
1.	 The appearance of the introductory section containing the cover, foreword, table of contents, E-Module identity, learning outcomes, learning objectives, E-Module features, usage instructions, about science literacy and guided inquiry, concept map, and sparking questions.
2.	
	 The presentation of biotechnology material consists of three main sections: concepts, types, and applications of biotechnology.
3.	 In the learning activity section, students will conduct experiments to make tempeh from various raw materials in learning activity 1. In learning activity 2, students will make posters. Then there are practice questions in the "How far have you learnt?" feature to assess students' understanding of biotechnology.
4.	 The closing section contains a glossary and bibliography.

One of the advantages of the developed E-Module is its multiplatform capability. Since it is web-based, the entire content of the E-Module can be accessed using a laptop, tablet, or smartphone as long as the device is connected to the internet. This accessibility helps students to study anytime and anywhere, including during independent study at home. All display elements have been adjusted to be responsive across various screen sizes, ensuring a comfortable experience when reading or interacting with the content, whether on desktop, tablet, or mobile view. The discussion in this article aims to: (1)

answer the research questions and problems; (2) show how the findings were obtained; (3) interpret the results; (4) relate the findings to the existing body of knowledge; and (5) propose new theories or modify existing ones. This model is highly suitable for secondary education levels, where students still need guidance in exploring scientific concepts independently (Aulia et al., 2022).

The development of this biotechnology E-Module includes features designed to train science literacy skills during learning activities. These features are divided into two categories: main features and supporting features. The main features are created to specifically train science literacy skills, while the supporting features aim to enhance the overall learning experience. Further details regarding the features available in the E-Module can be seen in Table 2.

Table 2. Features of the Biotechnology E-Module

Fitur	Deskripsi
 Did you know?	By presenting scientific articles related to biotechnology, students recognize phenomena or events that occur around them. The scientific literacy indicator trained in this feature is identifying phenomena that occur in the world.
 Let's discuss	A whiteboard from the Canva website is provided as a platform for students to express their opinions. Students can also exchange opinions and comment on each other's opinions. In this feature, the scientific literacy indicator being taught is identifying phenomena that occur.
 What if?	Presented as a platform for students to formulate problems. This feature can help students achieve the skill of formulating questions in given scientific studies.
 How to do?	Presented as a platform for students to practice scientific literacy skills, namely designing an appropriate experiment to answer research questions. This experimental design includes designing hypotheses, research variables, determining tools, materials, and scientific experiment procedures.
 Let's Create?	Presented as a platform for students to conduct scientific experiments. This allows students to practice collecting, processing, and analyzing research data. The scientific literacy indicator trained in this feature is collecting data to support accurate scientific conclusions from a set of data.
 So What?	Presented to help students process and interpret the data that has been collected. So that they can test the hypotheses made and answer the research questions. The scientific literacy indicator trained in this feature is interpreting data presented in different representations.
 The conclusion	Presented as a platform for students to draw conclusions from the experiment based on the data analysis conducted. This feature helps to achieve the indicator of drawing accurate conclusions based on data.
 Recall knowledges	This is a supporting feature as a platform for students to recall the biotechnology material that has been learned.

Fitur	Deskripsi
 How far you'd learnt?	This is a supporting feature as a platform to measure students' ability to understand the biotechnology material that has been taught.

E-Module Validity

Validity is used to assess the feasibility of the developed E-Module based on its characteristics, which include the feasibility of presentation, content, Syntactic suitability of guided inquiry learning models, achievement of scientific literacy skills and language. The validation sheet was completed by expert validators consisting of a lecturer in education, a subject matter expert, and a senior high school biology teacher. The validation results are presented in Table 3 below.

Table 3. Biotechnology E-Module Validation Results

No.	Aspect	Scoring			Validity (%)
		V1	V2	V3	
Presentation					
1	E-Module Usability or Operability Quality	4	3	4	91.67
2	E-Module Cover Display Quality	4	3	4	91.67
3	Layout Quality	4	3	4	91.67
4	Presentation Support Quality (Images)	3	3	4	83.33
Content					
5	E-Module Component Completeness	4	3	4	91.67
6	Foreword	3	3	4	83.33
7	Usage Instructions	4	3	4	91.67
8	Material Concept Quality	4	4	4	100.00
9	Biotechnology Material Completeness	4	3	4	91.67
Syntactic suitability of guided inquiry learning models					
10	Problem Orientation	4	3	4	91.67
11	Formulating the problem	4	3	4	91.67
12	Designing the experiment	3	3	4	83.33
13	Collecting data	4	3	4	91.67
14	Analyzing data	4	3	4	91.67
15	Drawing conclusions	4	3	4	91.67
Achievement of Scientific Literacy Skills					
16	The Conformity of E-Modules with Scientific Literacy Indicators	3	3	4	83.33
17	The Achievability of Scientific Literacy Skills Using Guided Inquiry Syntax	3	4	4	91.67
Language					
18	Usage of Language	4	3	4	91.67
19	Usage of Words	4	3	4	91.67
20	Usage of Sentences	4	3	4	91.67
Average Presentation Aspect					**89.58**
Average Content Aspect					**91.67**
Average Aspect of Syntax Suitability of Guided Inquiry Learning Model					**89.58**
Average Aspect of Scientific Literacy Skill Achievement					**87.50**
Average Language Aspect					**91.67**
Total Average Score					**90.00**

The validity of the biotechnology E-Module was evaluated across five main aspects: content, presentation, language, guided inquiry syntax, and science literacy attainment. The validation results show that all aspects received an average score above 87%, falling into the "very valid" category. The content aspect achieved the highest score (91.67%). This reflects the completeness of the material, its alignment with the curriculum, and the

systematic structure of the module. The presentation aspect was also rated very good (89.58%), indicating an attractive and functional interface and layout. However, the visual illustrations still have some room for improvement.

In terms of language, the E-Module was considered communicative and suitable for students' cognitive levels (91.67%), showing appropriate, scientific, and unambiguous word and sentence choices. The validity of the guided inquiry syntax aspect was also high (89.58%), reflecting the consistent integration of inquiry learning steps. All stages of inquiry, from problem orientation to conclusion, were systematically accommodated in the learning activities, although the experiment design stage may require slight adjustments.

The scientific literacy aspect scored 87.50%, indicating that the E-Module supports the development of students' scientific skills, such as formulating questions, designing experiments, analyzing data, and drawing evidence-based conclusions. These results confirm that the E-Module is not only appropriate as a learning resource but also effective in training scientific literacy skills through the guided inquiry approach.

E-Modul's practicality

The practicality of the biotechnology E-Module was tested using two main instruments: an implementation questionnaire completed by observers and a student response questionnaire filled out after using the E-Module. The results of the E-Module implementation are presented in Figure 1, while Figure 2 shows the results of the student response questionnaire.

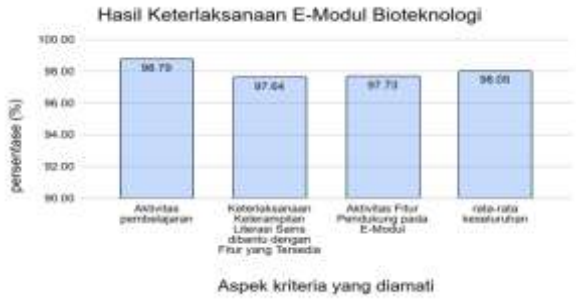


Figure 1. Results of E-Module Implementation

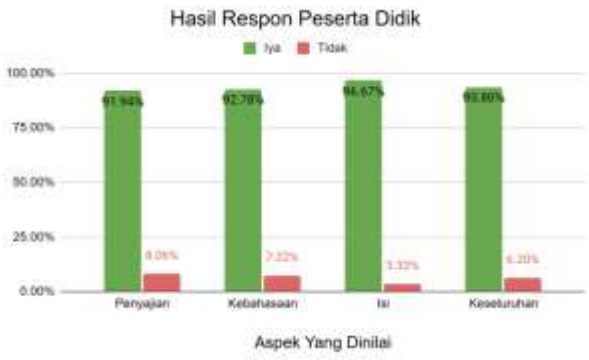


Figure 2. Student Response Results

The practicality of the E-Module was measured through observation of learning implementation and student response questionnaires. Observation results showed an average percentage of 98.05%. This indicates that the E-Module was very easy to implement and optimally supported learning activities. Students were able to access, understand, and carry out all stages of guided inquiry, such as formulating problems, designing experiments, and analyzing data, achieving a score of 100%. Interactive features like "How Far You'd Learnt" and "Let's Find Out" also demonstrated high effectiveness. However, students' written reflections showed a slightly lower score (90.91%), possibly due to differences in learning styles and writing habits.

Student responses were also positive, with an average practicality score of 93.80%. The content aspect received the highest score (96.67%), followed by language (92.78%) and presentation (92.14%). Students found the E-Module informative, communicative, and enjoyable, although some feedback suggested improvements in the quality of visual illustrations. Overall, the E-Module was considered highly practical, as it effectively supports inquiry-based learning, is easy to operate, and facilitates active student engagement in developing scientific literacy.

E-module effectiveness

The effectiveness of the E-Module is defined as its ability to achieve the predetermined learning objectives, which include improving student learning outcomes and achieving the scientific literacy skill indicators that are being trained. The results of the E-Module's effectiveness are presented in Figure 3 and Table 4.

The effectiveness of the E-Module is demonstrated by the improvement in learning mastery and scientific literacy skills. Before using the E-Module, none of the students had reached the mastery level. However, after the learning process, 87.9% of students achieved mastery. This shows that the E-Module significantly supports the achievement of learning objectives, in line with the

constructivist approach in guided inquiry (Brooks & Brooks, 1999).

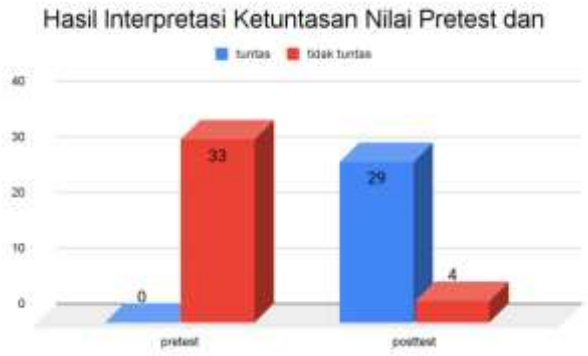


Figure 3. Interpretation of Student Achievement Results

Table 4. Test Results Based on Scientific Literacy Indicators

Indicator	Pretest	Posttest	N-Gain Pretest and Posttest	Category
1	71.0	92.8	0.75	High
2	36.6	87.1	0.80	High
3	23.5	99.0	0.99	High
4	25.1	77.7	0.77	High
5	21.3	52.3	0.39	Medium
6	41.2	89.9	0.83	High
Average	31.8	83.1	0.74	High

Details:

1. Identify the phenomenon that occurs.
2. Formulate questions in the given scientific study.
3. Design an experiment that is in accordance with scientific procedures to answer the research questions.
4. Collect data to support accurate scientific conclusions.
5. Interpret data presented in different representations.
6. Draw accurate conclusions based on the data.

Analysis of scientific literacy indicators shows high N-gain in almost all aspects. The indicators for identifying phenomena achieved an N-gain of 0.75; formulating scientific questions, 0.80; designing experiments, 0.99; and drawing conclusions, 0.83. Features such as Did You Know?, What If?, How to Do?, and The Conclusion have proven effective in guiding students through the stages of scientific inquiry (Sadler et al., 2007; Harlen, 2010). Data collection and analysis through the Let's Create and So What? features also strengthen scientific argumentation skills (Kuhn, 2010).

However, the indicator interpreting visual data and converting it into different representations gained a moderate N-gain (0.39). Based on the task analysis and tests conducted, students showed that they could interpret data but had difficulty when asked to convert it into other forms of representation. This is an important note for the development of future E-Modules, which should include exercises in converting data into more varied and targeted forms of representation.

As a whole, the developed biotechnology E-Module is effective in training scientific literacy skills, as proven by the improvement in students' learning outcomes and scientific literacy skills, as well as the high achievement of learning objectives. The use of Google Sites as a platform also supports accessibility and an optimal learning experience.

CLOSING

Conclusions

The developed guided inquiry-based biotechnology e-module proved to be valid, practical, and effective in training scientific literacy skills. The validity of the E-Module was in the highly valid category with an average score of 90%, covering aspects of content, presentation, language, inquiry syntax, and scientific literacy indicators. The practicality of the biotechnology E-Module was evident from the results of learning implementation observations, which were 98.05%, and student responses, with 93.80%, classified as highly practical. The effectiveness of the module is shown by the average N-Gain learning completeness score of 0.77 and the scientific literacy indicator achievement score of 0.75, which are in the high category. This shows that the E-Module has succeeded in significantly improving students' scientific literacy and skills.

Suggestions

In learning activities using this web-based biotechnology E-Module, during discussion activities, it is suggested that students express their opinions directly or write them on the board. This is because when students express their opinions on the Canva, it is less effective.

The E-Module can be improved by adding exercises to convert data into other forms of representation. It is expected to enhance students' scientific literacy skills at converting data into other form indicators.

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