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Development of a Science Literacy-Based E-Module to Enhance Students' Conceptual Understanding and Concept Analysis in Plant Diversity Learning towards Sustainable Development Goals (SDGs)

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Abstract: This study aims to develop a scientific literacy-based e-module to enhance students' conceptual understanding and concept analysis skills in plant diversity learning. Conventional text-based materials often fail to support students in analyzing and classifying plant morphological characteristics; therefore, an interactive digital learning medium is needed. This study employed a Research and Development (R&D) method using the ADDIE model, including analysis, design, development, implementation, and evaluation. The developed e-module integrates scientific literacy components, such as data analysis and problem-solving activities, to support meaningful and independent learning. Validation results by media and material experts showed high feasibility with scores of 88.78% and 89.52%, while practicality test results by teachers and students reached 90.68% and 89.34%, indicating that the e-module is very feasible and practical. The effectiveness test showed that both students' conceptual understanding and concept analysis skills achieved an N-gain score of 0.69, categorized as moderate. These findings indicate that the e-module is effective in improving students' conceptual understanding and concept analysis skills. In addition, the integration of scientific literacy components in the e-module has the potential to support students' scientific literacy. Therefore, this e-module can be used as an effective learning medium in biology learning and contributes to improving the quality of education, particularly in supporting Sustainable Development Goal 4 (Quality Education).

Keywords: Concept analysis; Conceptual understanding; E-module; Plant diversity; Scientific literacy

Introduction

Learning is a process of interaction between educators, students, and learning resources within a learning environment aimed at optimally developing students' potential (Hamdani & Sari, 2023; Sanjaya, 2013; Susanto, 2016). In secondary school biology, learning not only focuses on mastering concepts but is also directed toward helping students understand natural phenomena and develop scientific skills applicable to everyday life (Depdiknas, 2006; Novita & Kurniawan, 2022; Rustaman, 2011). Biology learning includes several key aspects, including scientific context, scientific attitudes, scientific processes, and content knowledge, as emphasized in science education frameworks (Bybee, 2013; OECD, 2022). Therefore, the success of biology learning is greatly influenced by the availability of relevant, systematic learning resources that support meaningful learning processes (Arsyad, 2017; Pribadi, 2017). Previous studies have shown that the use of innovative, technology-based learning resources can improve the quality of science learning and enhance

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student engagement (Aldilla & Usmeldi, 2024; Fitria et al., 2023) Crompton et al., 2021). In line with these developments, the integration of digital learning resources has become increasingly important in supporting effective biology learning.

In addition, several studies indicate that digital learning resources such as e-modules can facilitate deeper conceptual understanding and support students' active learning processes (Putri et al., 2023; Sugianto et al., 2023). Studies published in JPPIPA also confirm that e-module development based on scientific literacy and problem-based learning significantly improves students' understanding and engagement in science learning. Furthermore, international studies highlight that digital learning environments enhance higher-order thinking skills and self-directed learning in science education (Martin & Bolliger, 2018; Sung et al., 2019) (Crompton et al., 2021;. These developments are closely related to the rapid advancement of information and communication technology in education (Fitri et al., 2022; Musdalifah et al., 2024).

The development of information and communication technology has had a significant impact on the use of learning media in education. In the 21st century and the era of the Industrial Revolution 4.0, the integration of technology into learning has become essential to support the development of students' higher-order thinking skills, particularly concept analysis skills (Anggraeni et al., 2021; Mardiana et al., 2020). The use of digital learning media has also been shown to increase students' learning motivation through a scientific literacy approach by presenting materials in a more interactive manner. This is supported by findings from JPPIPA and other national journals which show that technology-integrated learning significantly improves students' engagement and conceptual understanding (Mayasari et al., 2023). In addition, international research confirms that technology-enhanced learning environments contribute to the development of analytical thinking and scientific reasoning skills (Mayasari et al., 2023; OECD, 2022; Sugianto et al., 2023). Despite these advancements, various reports indicate that students' literacy levels in Indonesia remain relatively low, resulting in limited ability to understand and analyze scientific concepts (OECD, 2022; Sape et al., 2024). This condition highlights the need for innovation in developing learning media that facilitate more interactive and contextual learning (Ayani et al., 2025; Suryanti & Festiyed, 2023).

This issue is also reflected in the local context. Empirical evidence from SMAN 1 Maja indicates that students' conceptual understanding and concept analysis skills in plant diversity remain relatively low. Classroom observations show that approximately 50% of students experience difficulties in understanding plant diversity concepts, while the average score is 67, which is below the minimum Criteria for Achieving Learning Objectives (KKTP) of 70. This condition reflects a gap between actual learning outcomes and the expected level of achievement. This study is important because students' conceptual understanding and concept analysis skills in plant diversity are still limited, even though these competencies are essential for supporting meaningful learning. These difficulties are related to the characteristics of plant diversity material, which require students not only to understand classification concepts but also to distinguish between plant groups such as Bryophyta, Pteridophyta, and Spermatophyta, as well as to analyze their specific morphological characteristics (Etobro & Fabinu, 2017). These demands make the material relatively complex, especially when learning is still dominated by memorization rather than meaningful concept analysis (Clark & Mayer, 2016; Lestari et al., 2020; Lumbantobing, 2023).

One of the contributing factors to this condition is that the learning process is still largely dominated by lecture-based methods and the use of less engaging printed textbooks, causing students to be passive and less involved in learning activities. This condition contributes to low conceptual understanding and concept analysis skills in biology learning. Other studies also indicate that the limited variety of learning media negatively impacts student engagement and participation in science learning. Studies from JPPIPA further show that conventional teaching methods without interactive media limit students' opportunities to develop inquiry skills and scientific reasoning.

Therefore, to address these challenges, various studies have shown that the use of digital teaching materials such as e-modules can improve learning effectiveness by presenting content in a more engaging and interactive manner through the integration of text, images, animations, videos, and interactive evaluations (Munir, 2017; Putri et al., 2023; Sahni & Singh, 2020; Sari et al., 2022). The development of e-modules in science learning has been shown to enhance students' conceptual understanding and concept analysis skills by providing more contextual and independent learning experiences (Aldilla & Usmeldi, 2024; Sugianto et al., 2023). Furthermore, e-modules can increase student engagement and support independent learning, as they can be accessed flexibly through digital devices (Branch, 2009; Kamila et al., 2024).

In addition to the use of digital media, the integration of appropriate learning approaches is also essential. The integration of a scientific literacy approach into learning is a crucial factor in supporting students'

concept analysis skills. Scientific literacy is not only related to understanding scientific concepts but also includes the ability to analyze data, evaluate scientific information, and apply scientific concepts in various everyday contexts (OECD, 2022). Research shows that scientific literacy-based learning can improve students' data analysis and interpretation skills in understanding scientific phenomena (Anwar et al., 2024). Furthermore, the application of scientific literacy in learning can support students' ability to analyze and interpret scientific information (Fadha et al., 2023).

However, previous studies have not fully integrated scientific literacy approaches with digital e-modules specifically to improve both conceptual understanding and concept analysis skills simultaneously, particularly in plant diversity learning. In this context, the integration of scientific literacy into the e-module plays a crucial role in bridging students' conceptual understanding and concept analysis skills in plant diversity learning. Plant diversity learning involves understanding the classification and characteristics of various plant groups, which are often considered complex due to their abstract nature and reliance on memorization. To address these challenges, the developed e-module integrates scientific literacy through interactive features such as observation videos of plant phenomena, links to scientific articles, data interpretation activities, and PISA-based assessment tasks. In addition, the e-module is equipped with high-quality macro-photo visualizations of plant structures as well as explanatory videos, which are not available in conventional printed textbooks (Pratama et al., 2025). These features enable students to observe and analyze plant morphological characteristics more clearly, thereby helping to transform abstract concepts into more concrete understanding. By incorporating contextual phenomena, inquiry-based activities, and problem-solving tasks, the e-module encourages students to actively engage in concept analysis processes. Therefore, the developed e-module not only serves as a content delivery medium but also facilitates the development of students' conceptual understanding and concept analysis skills, in line with the principles of 21st-century education and the Sustainable Development Goals (SDGs) (Astuti et al., 2022; Hayati et al., 2023).

Based on these considerations, the development of a scientific literacy-based e-module on plant diversity is essential. The developed e-module is designed using digital technology to enable a more systematic, interactive, and accessible presentation of the material. By utilizing a scientific literacy approach, this e-module is expected not only to help students understand plant diversity concepts but also to train their concept analysis skills in identifying and classifying plant morphological characteristics. Therefore, this study aims to develop a scientific literacy-based e-module on plant diversity and to evaluate its feasibility and effectiveness in improving students' conceptual understanding and concept analysis skills (Firdaus, 2023; Mayasari et al., 2023; Suryanti & Festiyed, 2023).

The novelty of this study lies in the integration of scientific literacy components into a digital e-module specifically designed for plant diversity learning, which facilitates both conceptual understanding and concept analysis skills through interactive and contextual learning features. This integrated approach has not been widely explored in previous studies, particularly in the context of simultaneously enhancing these two competencies.

Method

The method used is R & D (*Research and Development*) and uses the ADDIE development model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation with the aim of developing an e-module on plant diversity.

The first stage is the analysis stage. At this stage, an analysis of learning conditions and needs is conducted as the basis for developing learning resources in the form of e-modules. This includes the analysis of biology material, student characteristics, and existing learning media. Data for the needs analysis are obtained through questionnaires distributed to students and interviews with biology teachers. The results of this stage serve as the foundation for designing a scientific literacy-based plant diversity e-module.

The next stage is the design stage. At this stage, the researchers develop the structural framework of the e-module, the system for presenting the material, and the evaluation instruments. The design integrates scientific literacy contexts to enable students to connect plant diversity concepts with real-life phenomena in their environment.

The development stage involves creating the e-module based on the designed framework. At this stage, the e-module is developed by integrating various features such as scientific literacy-based activities, observation videos, macro-photo visualizations, and data interpretation tasks. The developed e-module is then validated by subject matter experts, media experts, and instructional experts to assess its validity in terms of content, design, and usability. The results of this validation process are used to revise and improve the e-module before implementation (Indra & Sari, 2023; Rahmawati et al., 2022).

The results of the validation process were used to revise and improve the e-module. Subsequently, a

limited trial was conducted with a small group of students to assess the practicality, usability, and clarity of the e-module. The findings from this stage were used for further revisions before proceeding to the implementation stage.

The developed e-module was validated by two subject matter experts, two media experts, two biology teachers, and students to assess its validity in terms of content, design, and usability. The validation process was conducted using a Likert-scale questionnaire. The obtained scores were then converted into percentages and interpreted based on the following criteria: 81–100% (Very Worthy), 61–80% (Eligible), 41–60% (Quite Decent), and ≤40% (Not Feasible). The results of this validation were used as the basis for revising and improving the e-module before further testing.

The research instruments used in this study included validation sheets, questionnaires, and test instruments. The validation sheets were used by experts to assess the validity of the e-module in terms of content, media, and instructional design. Questionnaires were used to collect data on students' responses and to evaluate the practicality of the e-module during the limited trial. Meanwhile, test instruments in the form of pretest and posttest were used to measure students' conceptual understanding and concept analysis skills before and after the implementation of the e-module.

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The implementation stage involves applying the e-module in biology learning activities with students. The effectiveness of the e-module was tested using a pre-experimental method with a one-group pretest–posttest design involving 36 tenth-grade students at SMAN 1 Maja. The trial was conducted on a small scale. The sampling technique used was total sampling, as all students in the class were involved in the study. Data were collected through pretest and posttest and analyzed using the N-gain formula to determine the improvement in students' conceptual understanding and concept analysis skills.

The final stage is the evaluation stage. This stage involves a comprehensive review of each stage of the development process, including analysis, design, development, and implementation. The evaluation aims to assess the overall feasibility of the e-module in terms of validity, practicality, and effectiveness, and to determine whether further revisions are needed before the final product is established.

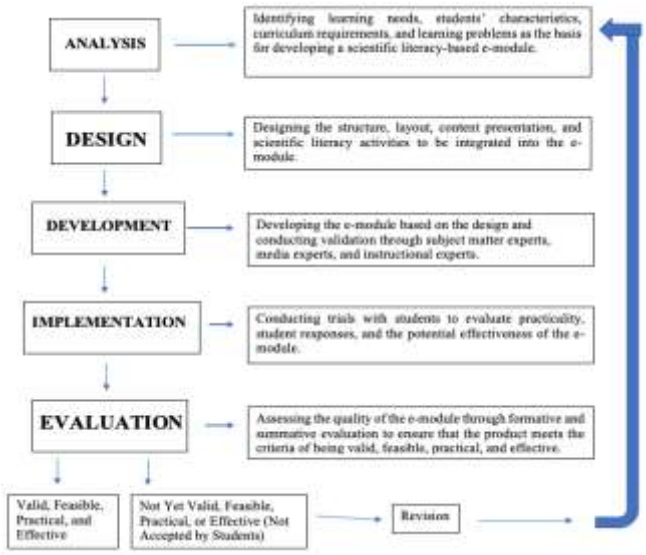

Figure 1. ADDIE model development flowchart

Result and Discussion

The findings from the research and development (R&D) stages conducted by the researchers in developing the e-module. The process began with the research and information gathering stage, which involved a needs analysis. At this stage, it was found that e-learning materials are essential for plant diversity learning in high school. Initial findings indicate that teachers require learning media that support the characteristics of modern students who are highly dependent on internet-based resources. (Helen, 2021). Previous studies also show that the use of information technology (IT)-based learning can be more engaging and enjoyable for students. Furthermore, the industrial revolution era demands the integration of technology into the learning process (Lestari et al., 2020; Martin & Bolliger, 2018).

The design stage was carried out based on the results of the analysis stage. The findings indicated that students needed biology instruction on plant diversity. Furthermore, the results also showed that students had a low level of conceptual understanding, which helped

the researchers determine the appropriate materials for the design of the developed e-module.

In addition, the e-module is equipped with interactive features such as evaluation questions and multimedia content that support students' engagement. These features allow students to interact directly with the learning materials and receive immediate feedback.

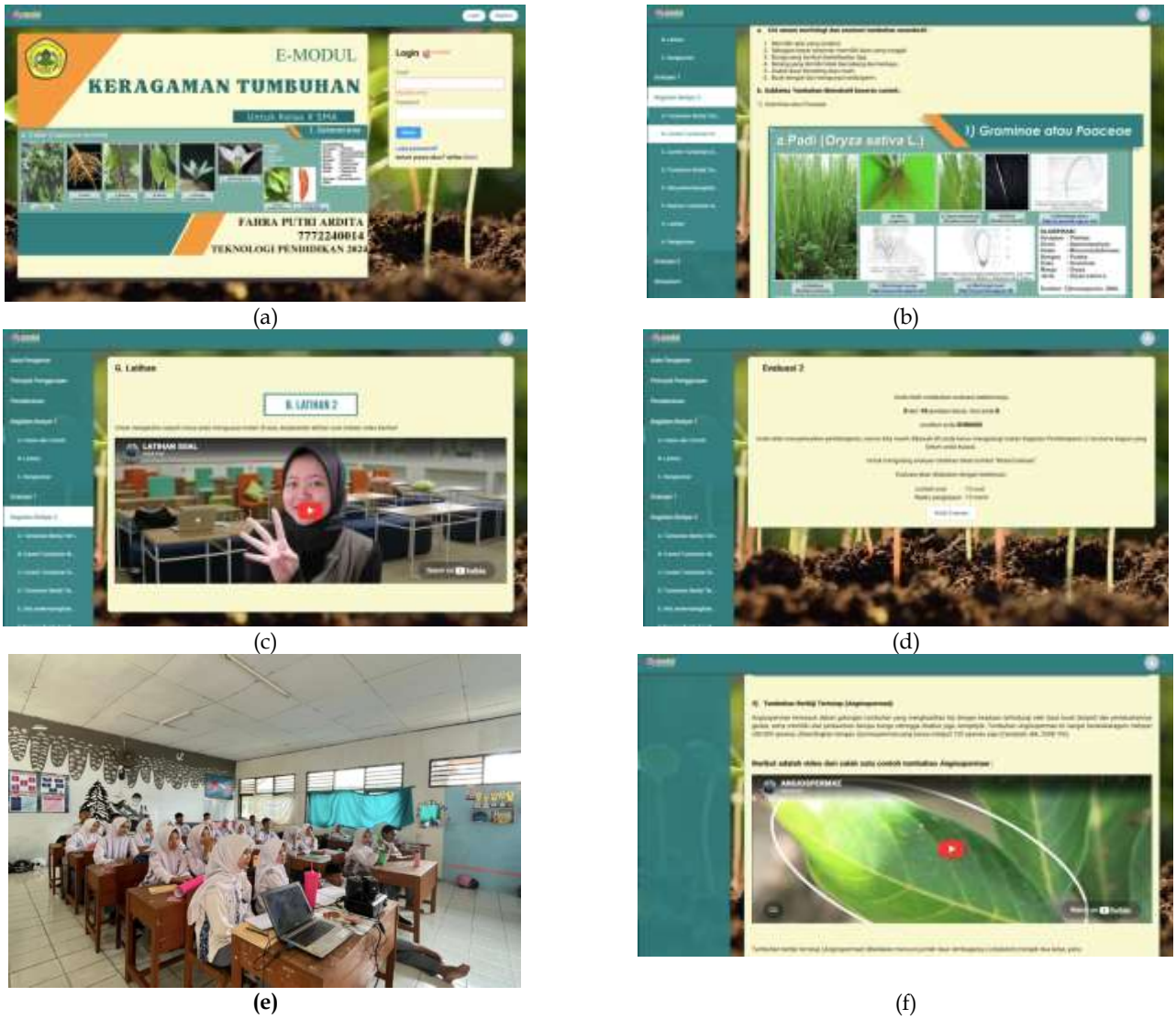

Figure 2. E-modul based scientific literacy display: (a) Main page; (b) Content display of plant diversity material; (c) Video-based exercise feature; (d) Pretest and posttest feature; (e) Students' activities during the small-scale; and (f) e-module trial results.

Once the e-module is completed, the next step is to conduct a product (e-module) trial. The expert trial consists of a trial by material experts and a trial by learning media experts. After being declared suitable by the experts, a field trial is conducted with users, namely teachers and students (Mayer, 2002). This trial is conducted to determine the accuracy and relevance of the material outlined in the developed e-module, as well as its effectiveness. The following is a summary of the results of the assessment by material experts, learning media experts, and users of the scientific literacy-based plant diversity e-module product (Branch, 2009).

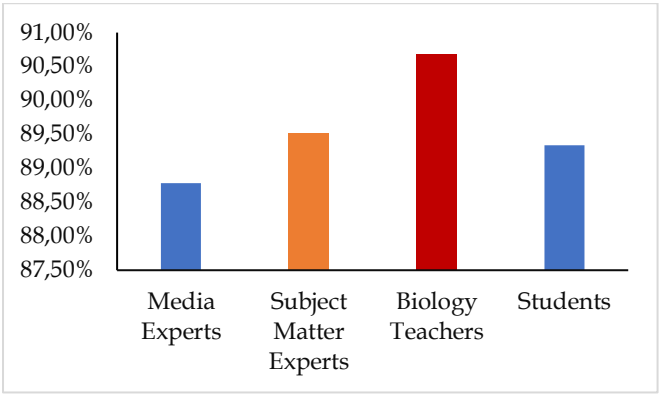

Figure 3. Validity results of the e-module

After obtaining the scores from the trial results of material experts, media experts and users (teachers and students), they are then converted to the values on Table 1.

Table 1. Percentage Scale (Arikunto, 2019)

Trial Result Value %	Criteria
0 – 20	Totally Unworthy
21 – 40	Not feasible
41 – 60	Quite Decent
61 – 80	Eligible
81 – 100	Very Worthy

Based on the results of the assessment by 2 media experts, 2 learning material experts, and users (2 teachers and 36 students) using a closed questionnaire, the figures obtained were 88.78%, 89.52%, 90.68%, and 89.34%, respectively. If entered into the test results criteria table, it can be said that the interactive e-module product based on *Firebase* which has been developed to be very worthy for use in learning (Hwang et al., 2020) Nugroho, 2021). The use of Firebase enhances the functionality of the e-module by enabling real-time data synchronization and efficient data management, which supports continuous assessment and interactive learning (Sung et al., 2019).

This research was conducted by 36 students of class X-4 at SMAN 1 Maja in the odd semester of the 2025/2026 academic year. This research was conducted in 4 class meetings.

Table 2. Scientific Literacy Results in Conceptual Understanding

Indicator	Pre Test (%)	Post Test (%)	N-Gain	Category
Explaining scientific phenomena	46.20	83.40	0.69	Moderate
Understanding scientific concepts	48.10	85.20	0.71	High
Applying scientific knowledge	47.50	82.50	0.67	Moderate
Identifying scientific facts	49.30	87.10	0.75	High
verage	47.83	84.66	0.69	Moderate

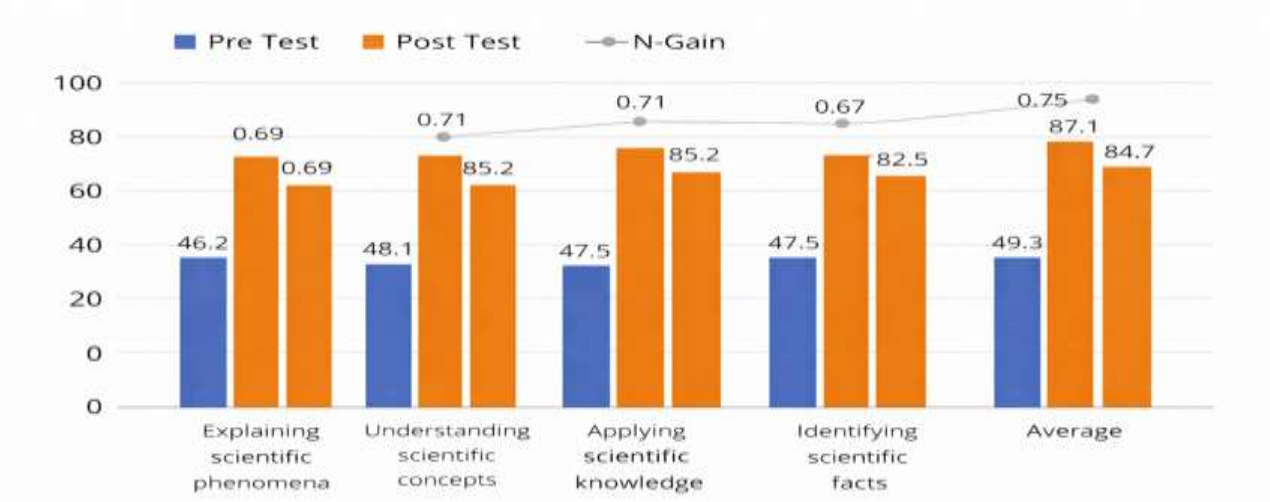

Figure 4. Comparison of students' pretest and posttest scores in scientific literacy for conceptual understanding

Table 2 and Figure 4 shows that students' conceptual understanding improved across all indicators. The average pretest score increased from 47.83% to 84.66% in the posttest, with an N-Gain value of 0.69 categorized as moderate. The highest improvement was observed in identifying scientific facts and understanding scientific concepts.

Improvement in learning outcomes, including conceptual understanding and concept analysis skills. Thus, the developed e-module has a positive contribution to improving the quality of biology learning. These findings confirm that the developed e-module is both feasible and effective in improving students' conceptual understanding. The increase in pretest to posttest scores and the N-gain value in the moderate category indicate that the research objectives have been achieved, especially in terms of the product's effectiveness on students' learning outcomes (conceptual understanding and concept analysis skills) (Haryanto et al., 2025; Nurjanah et al., 2022).

The increase in average scores from pretest to posttest indicates that learning using scientific literacy-based e-modules not only improves understanding but also helps students improve their conceptual analysis. Concept analysis (C4) require students to not only understand concepts but also be able to describe,

connect, and evaluate the information obtained. In the context of plant diversity material, this ability is reflected in students' skills in identifying morphological characteristics and classifying plants based on certain characteristics.

The results of this study are in line with research findings published in JPPIPA which show that the use of digital-based teaching materials such as e-modules can improve students' conceptual understanding and concept analysis skills, including analytical and problem-solving abilities (Aldilla & Usmeldi, 2024).

The e-module developed in this research is designed by integrating various components of scientific literacy, such as the presentation of contextual phenomena, data analysis activities, and problem-solving-based practice questions. This combination provides students with the opportunity to actively build understanding through deeper thinking processes.

Table 3. Scientific Literacy Results in Concept Analysis (C4)

Indicator	Pre Test (%)	Post Test (%)	N-Gain	Category
Interpreting data and evidence	45.80	81.70	0.66	Moderate
Evaluating scientific inquiry	47.20		0.68	Moderate
Analyzing relationships	48.00	85.50	0.72	High
Drawing conclusions	46.30	82.90	0.68	Moderate
verage	46.83	83.30	0.69	Moderate

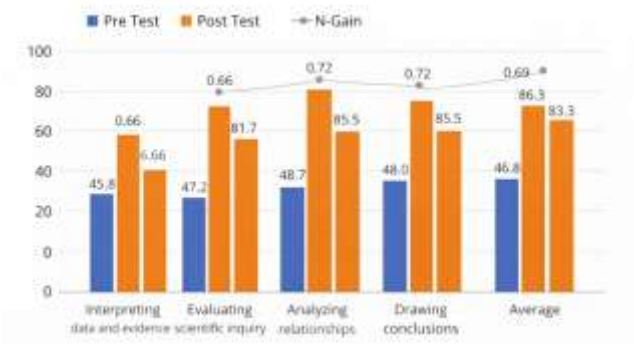

Figure 5. Comparison of students' pretest and posttest scores in scientific literacy for concept analysis (C4)

Table 3 and figure 5 indicates that students' concept analysis skills (C4) also improved significantly. The average score increased from 46.83% to 83.30%, with an N-Gain value of 0.69 in the moderate category. The most notable improvement occurred in analyzing relationships between concepts.

The improvement occurred in the cognitive domain at both the comprehension level (C2) and the analysis level (C4). In terms of the learning process, the scientific literacy-based e-module provides a more interactive learning experience compared to conventional methods. Students are not only passive recipients of information but are also actively involved in observing, analyzing, and drawing conclusions. These activities support the development of concept analysis skills as students are engaged in tasks that require critical thinking.

Furthermore, improved learning outcomes (conceptual understanding and concept analysis skills) are also influenced by the flexible nature of e-modules, which can be accessed anytime. This allows students to study independently at their own pace. This gives them a greater opportunity to understand the material in depth, especially in areas they find difficult.

The findings of this study reinforce previous research showing that integrating scientific literacy into learning can improve students' critical thinking and concept analysis. Therefore, the use of scientific literacy-based e-modules can be an alternative solution to address students' low concept analysis in biology, particularly in complex topics such as plant diversity.

A closer look reveals that improving students' concept analysis is influenced not only by the presentation of the material but also by the learning activities designed within the e-module. Activities such as analyzing plant morphological images, classifying them, and interpreting data provide cognitive stimulation that encourages students to think at a higher level. In this study, a scientific literacy-based e-module facilitated this process through contextual and problem-based presentation of material.

Although the N-Gain results were in the moderate category, this still indicates that learning was effective. The moderate N-Gain result may be influenced by factors such as limited learning time, differences in students' initial abilities, and adaptation to digital media.

Conclusion

The developed scientific literacy-based e-module is feasible, practical, and effective for use in biology learning within the scope of this study. The e-module was found to be highly feasible with an average validation score of 89.58% and effective in improving learning outcomes (conceptual understanding and concept analysis skills), as indicated by an N-Gain value of 0.69 (moderate category). These findings indicate that the e-module meets the predetermined success criteria

and can effectively improve students' conceptual understanding and concept analysis skills.

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Author Contributions
Designed the research, collected and analyzed the data, wrote the initial draft of the article manuscript, wrote the article manuscript and conducted editing, F.P.A.; reviewed the research results, Y.R.; reviewed the research results, N.A.

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Conflicts of Interest
The authors declare that they have no conflict of interest related to this research.

References

Aldilla, E., & Usmeldi. (2024). Validity and practicality of physics e-module based on OIDDE model. *Jurnal Penelitian Pendidikan IPA*, *10*(8), 5768–5774. https://doi.org/10.29303/jppipa.v10i8.7719

Anggraeni, S. W., Alpian, Y., Prihamdani, D., & Winarsih, E. (2021). Pengembangan multimedia pembelajaran interaktif berbasis video untuk meningkatkan minat belajar siswa sekolah dasar. *Jurnal Basicedu*, *5*(6), 5313–5327. https://doi.org/10.31004/basicedu.v5i6.1636

Anwar, Z., Bayani, F., & Hulyadi. (2024). Fostering student competence in data interpretation and environmental literacy through E-PjBL model assisted by computational simulation. *Jurnal Penelitian Pendidikan IPA*, *10*(11), 8869–8874. https://doi.org/10.29303/jppipa.v10i11.9159

Arikunto, S. (2019). *Prosedur penelitian: Suatu pendekatan praktik*. Jakarta: Rineka Cipta.

Arsyad, A. (2017). *Media Pembelajaran*. Jakarta: PT RajaGrafindo Persada.

Astuti, C., Wiguna, A., Latifa, F. N., & Olvyya, A. (2022). Development of Android-based "Mbarengi" statistics e-module. *BAREKENG*, *16*(2), 515–524. https://doi.org/10.30598/barekengvol16iss2pp515-524

Ayani, N. I., Ratnawulan, R., Fauzi, A., Emiliannur, E., & Yulia, D. (2025). Learners' needs for e-modules in dynamic fluid learning. *Jurnal Penelitian Pendidikan IPA*, *11*(2), 1053–1062. https://doi.org/10.29303/jppipa.v11i2.4383

Branch, R. M. (2009). *Instructional Design: The ADDIE Aproach*. Springer International Publishing. https://doi.org/10.1007/978-0-387-09506-6

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. Virginia: NSTA press.

Clark, R. C., & Mayer, R. E. (2016). *E-learning and the science of instruction*. Wiley. https://doi.org/10.1002/9781119239086

Depdiknas. (2006). *Kurikulum tingkat satuan pendidikan*. Jakarta: Depdiknas.

Etobro, A. B., & Fabinu, O. E. (2017). Students' perceptions of difficult concepts in biology in senior secondary schools in Lagos state. *Global Journal of Educational Research*, *16*(2), 139–147. Retrieved from https://www.ajol.info/index.php/gjedr/article/view/162440/151948

Fadha, G. S., Purwianingsih, W., & Solihat, R. (2023). Use of E-Modules Based on Socio-Scientific Issues in Efforts to Improve Argumentation and Decision-Making Skills of High School Students. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 7591–7598. https://doi.org/10.29303/jppipa.v9i9.3507

Firdaus, L. (2023). Scientific literacy skills of prospective biology teachers. *Jurnal Penelitian Pendidikan IPA*, *9*(1). https://doi.org/10.29303/jppipa.v9i1.1891

Fitri, Y., Hidayat, A., & Wulandari, R. (2022). Multimedia interaktif IPA. *Jurnal Basicedu*, *6*(3), 3026–3035. https://doi.org/10.31004/basicedu.v6i3.3026

Fitria, A. S., Ramdani, A., & Hadiprayitno, G. (2023). Effectiveness of e-learning in biology. *Journal of Classroom Action Research*, *5*(1), 265–270. https://doi.org/10.29303/jcar.v5i2.2868

Hamdani, M., & Sari, D. P. (2023). Android learning media. *Journal of Software Engineering and Robotics*, *1*(1), 7. https://doi.org/10.62759/jser.v1i1.7

Haryanto, E., Putri, D. A., & Lestari, N. (2025). Pengembangan e-modul Flipbook Maker. *Jurnal MathEdu*, *8*(2), 1–12. https://doi.org/10.37081/mathedu.v8i2.7153

Hayati, R., Alberida, H., Arsih, F., & Fajrina, S. (2023). Keterampilan berpikir reflektif. *Jurnal Ilmiah Profesi Pendidikan*, *8*(3), 1479–1486. https://doi.org/10.29303/jipp.v8i3.1479

Hwang, G. J., Sung, H. Y., Chang, S. C., & Huang, X. C. (2020). Learning analytics-based approach. *Computers & Education*, *142*, 103647. https://doi.org/10.1016/j.compedu.2019.103647

Indra, A., & Sari, N. P. (2023). Media video animasi. *Didaktik*, *9*(2). https://doi.org/10.36989/didaktik.v9i2.962

Kamila, U., Wilujeng, I., & Rahmawati, L. (2024). Science literacy and cultural awareness. *Jurnal Penelitian Pendidikan IPA*, *10*(9), 6677–6689. https://doi.org/10.29303/jppipa.v10i9.7578

Lestari, H., Setiawan, W., & Siskandar, R. (2020). Science Literacy Ability of Elementary Students Through

Nature of Science-based Learning with the Utilization of the Ministry of Education and Culture's. *Learning House"*. *Jurnal Penelitian Pendidikan IPA*, *6*(2), 215–220. https://doi.org/10.29303/jppipa.v6i2.410

Lumbantobing, S. S. (2023). Modul elektronik Sigil. *Jurnal JP2F*, *14*(2), 222–230. https://doi.org/10.26877/jp2f.v14i2.16946

Mardiana, R., Siregar, N. C., & Nasution, H. (2020). Project-based learning physics tools. *Journal of Physics: Conference Series*, 12067. https://doi.org/10.1088/1742-6596/1481/1/012067

Martin, F., & Bolliger, D. U. (2018). Engagement matters. *Online Learning Journal*, *22*(1), 205–222. https://doi.org/10.24059/olj.v22i1.1092

Mayasari, M., Hamidah, A., & Subagyo, A. (2023). E-LKPD gastropods. *Jurnal Penelitian Pendidikan IPA*, *9*(4), 1578–1584. https://doi.org/10.29303/jppipa.v9i4.3453

Mayer, R. E. (2002). Multimedia learning. *Psychology of Learning and Motivation*, *41*, 85–139. https://doi.org/10.1016/S0079-7421(02)80005-6

Munir. (2017). *Pembelajaran digital*. Bandung: Alfabeta.

Musdalifah, M., Lumowa, S. V. T., & Rambitan, V. M. M. (2024). Canva-based e-LKPD. *Jurnal Penelitian Pendidikan IPA*, *10*(3), 1093–1104. https://doi.org/10.29303/jppipa.v10i3.6929

Novita, R., & Kurniawan, D. (2022). Multimedia interaktif IPA. *Jurnal Kiprah Pendidikan*, *1*(1), 24. https://doi.org/10.33578/kpd.v1i1.24

Nurjanah, N., Surani, D., Riani, L., Nugraha, C., & Oktapiani, E. (2022). E-modul trigonometri. *Jurnal Eduscience*, *9*(2), 315–323. https://doi.org/10.36987/jes.v9i2.2663

OECD. (2022). *PISA 2022 results*. https://doi.org/10.1787/19963777

Pratama, W. P., Werdhiana, I. K., Haeruddin, H., Muslimin, M., & Napitupulu, N. D. (2025). Pengembangan E-Modul Berbasis Model Experiential Learning dengan Pendekatan Berdiferensiasi untuk Meningkatkan Pemahaman Konsep dan Keterampilan Kolaborasi Peserta Didik. *Ideguru: Jurnal Karya Ilmiah Guru*, *10*(2), 1143–1151. https://doi.org/10.51169/ideguru.v10i2.1730

Pribadi, B. A. (2017). *Media & teknologi dalam pembelajaran*. Prenada Media.

Putri, A. J., Sukmono, T., & Wicaksana, E. J. (2023). STEM PBL biology learning. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 7056–7063. https://doi.org/10.29303/jppipa.v9i9.4568

Rahmawati, S., Suyatno, & Wahyuni, D. (2022). Video animasi. *Jurnal Basicedu*, *6*(2), 2207–2215. https://doi.org/10.31004/basicedu.v6i2.2207

Rustaman, N. (2011). *Strategi pembelajaran biologi*. UPI Press.

Sahni, M., & Singh, A. (2020). Facial expression recognition. *IEEE Conference*. https://doi.org/10.1109/FG47880.2020.00081

Sanjaya, W. (2013). *Strategi pembelajaran*. Kencana.

Sape, H., Ridwan, M., & Fuad, M. (2024). Artificial intelligence in learning. *Jurnal Pendidikan Dan Pembelajaran*, *4*(2), 105–112. https://doi.org/10.62388/jpdp.v4i2.522

Sari, D. P., Wahyuni, R., & Kurniawan, D. (2022). Video animasi learning. *Jurnal Basicedu*, *6*(4), 3421–3430. https://doi.org/10.31004/basicedu.v6i4.3421

Sugianto, S., Liunokas, A. B., Listari, N., Dewi, N. P. Y. A., Rasyid, A., & Chaidir, D. M. (2023). Development of Human Reproductive System E-Module Teaching Materials using the Flip Pdf Corporate Application. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 10965–10972. https://doi.org/10.29303/jppipa.v9i12.4573

Sung, Y.-T., Lee, H.-Y., Yang, J.-M., & Chang, K.-E. (2019). The quality of experimental designs in mobile learning research: A systemic review and self-improvement tool. *Educational Research Review*, *28*, 100279. https://doi.org/10.1016/j.edurev.2019.05.001

Suryanti, E., & Festiyed. (2023). PBL worksheet. *Jurnal Penelitian Pendidikan IPA*, *9*(7), 5673–5681. https://doi.org/10.29303/jppipa.v9i7.3672

Susanto, A. (2016). *Teori belajar dan pembelajaran*. Prenadamedia Group.