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Building Scientific Reasoning Using a Data Literacy Module in Higher Education

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Abstract

Scientific reasoning is a fundamental skill that must be developed in higher education, particularly in science-related disciplines. However, existing learning resources often lack an explicit focus on data interpretation and evidence-based analysis, both essential for scientific reasoning. This study aimed to develop and evaluate the validity, practicality, and effectiveness of a data literacy-based e-module designed to enhance undergraduate students' scientific reasoning skills. Employing a design and development approach based on the ADDIE model, the research included analysis, design, development, implementation, and evaluation stages. The e-module was developed by aligning curriculum needs, scientific reasoning indicators, and core data literacy principles. Content and construct validity were assessed through expert reviews, yielding high validity scores (above 3.7) and strong reliability (α = 0.83-0.94). Small-scale trials with undergraduate science education students demonstrated high levels of learning activity (72%-94%) and consistent student engagement throughout the learning phases. Students' scientific reasoning improved significantly, with N-Gain scores ranging from 0.49 to 0.74, categorized as moderate to high, particularly in indicators such as proportional thinking. Statistical tests indicated no significant differences between class groups, suggesting consistent effectiveness across cohorts. Student feedback was overwhelmingly positive, with agreement levels reaching 100% on most evaluation indicators. This research contributes to the advancement of pedagogical design by integrating data literacy into the scientific reasoning process, offering a replicable learning resources that can be adapted across science disciplines to better prepare students for data-driven scientific inquiry in the digital era.

Keywords: Scientific Reasoning, Data Literacy, E-module, Learning Resource, Undergraduate Education
SDGs: Goal 4 (Quality Education), Goal (Industry, Innovation, and Infrastructure), and Goal 17 (Partnerships for the Goals)

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INTRODUCTION

In the midst of the Fourth Industrial Revolution, data literacy has emerged as a fundamental skill for university students, serving as a basis for critical thinking, scientific inquiry, and informed decision-making. Data literacy refers not only to the ability to comprehend and analyze data but also to the competence to utilize data critically within scientific and real-world contexts. At the same time, scientific reasoning, a complex cognitive ability involving the logical and creative identification, analysis, and resolution of problems, has been widely acknowledged as an essential competency in higher education (Krell et al., 2020; Speirs et al., 2021). Research has consistently shown that scientific reasoning is integral to fostering deep understanding and creativity in science learning (Edelsbrunner & Dablander, 2019; Glaze, 2018).

In the era of digital transformation and global challenges, there is a growing demand for educational innovations that foster students' critical thinking, scientific reasoning, and data literacy. These competencies are crucial not only for academic success but also for preparing students to become informed citizens in an increasingly data-driven world. This aligns with the Sustainable Development Goals (SDGs), particularly Goal 4 (Quality Education), which emphasizes inclusive, equitable, and quality education for all. The integration of digital learning media that enhances data literacy supports the achievement of sustainable and inclusive learning outcomes in line with global education priorities. Furthermore, the improvement of data literacy and scientific skills embedded in this approach can also advance other SDG targets, such as fostering innovation (Goal 9) and strengthening partnerships in education (Goal 17), both of which are crucial to achieving social and economic progress on a global scale.

The current state of the art in educational research highlights a growing interest in developing both assessment instruments and instructional strategies to cultivate these competencies. At various educational levels, several studies have introduced tools to measure students' scientific reasoning (Novia & Riandi, 2017; Zimmerman et al., 2019; Krell et al., 2020), while research in data literacy emphasizes the importance of collecting, organizing, and evaluating data for evidence-based conclusions (Lin et al., 2023; Wolff et al., 2019). In addition, recognizing anomalous data, data that conflict with prior beliefs or expectations, is considered a critical element in fostering advanced reasoning and conceptual change (Crujeiras-Pérez & Jiménez-Aleixandre, 2019).

Despite ongoing advancements in education and digital learning tools, a significant gap remains in how the two essential constructs, data literacy and scientific reasoning, are integrated into higher education settings. Most previous studies tend to address them separately, which often leads to fragmented instructional designs and limited learning impact (Fielding et al., 2025; McGowan et al., 2022). Empirical studies have shown that many university students, both in Indonesia and internationally, continue to exhibit weak competencies in these two domains. In terms of data literacy, students often struggle to read and interpret data representations such as tables, graphs, and charts, as well as to extract meaningful conclusions from statistical information (Novia & Riandi, 2017). Meanwhile, in scientific reasoning, common weaknesses include difficulties in formulating hypotheses, designing controlled experiments, evaluating evidence, reasoning logically, and understanding causal versus correlational relationships (Hrouzková & Richterek, 2021; Marušić & Dragojević, 2020). These deficiencies limit students' ability to engage in inquiry-based learning and problem-solving tasks that require analytical thinking. As a result, their readiness to participate in digital and science-driven environments remains inadequate, particularly in disciplines that demand evidence-based reasoning and data-informed decisions (Shofiyah et al., 2025).

To address these issues, integrating data literacy into digital learning modules is a promising educational strategy. Several studies show that interactive e-modules (Lastariwati et al., 2021; Saraç, 2018), particularly those featuring simulations and real-life case studies, can significantly enhance student engagement, conceptual understanding, and reasoning capabilities (Engelmann et al., 2016; Lazonder et al., 2021). However, studies that explicitly develop and evaluate e-modules aimed at improving scientific reasoning through data literacy, especially in Indonesian higher education contexts, are still scarce.

This study responds to that gap by offering a novel approach: the development of a data literacy-based e-module specifically designed to strengthen students' scientific reasoning skills. Unlike previous research that tends to focus on separate assessments or conventional instructional formats (Fielding et al., 2025; Ow-Yeong et al., 2023), this study emphasizes the integration of data analysis practices within an interactive digital learning environment, contextualized for the Indonesian science education curriculum.

The purpose of this research is to design and evaluate the validity, practicality, and effectiveness of a data literacy-based e-module aimed at enhancing scientific reasoning among undergraduate students in science education programs. The outcomes are expected to provide meaningful contributions to the development of innovative, technology-based learning media that align with 21st-century educational needs and support curriculum transformation in response to the challenges of the Fourth Industrial Revolution.

METHOD

Research Design

This study employed a Research and Development (R&D) approach using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) to develop a data literacy-based e-module aimed at improving scientific reasoning among undergraduate science education students. The iterative R&D process combined qualitative and quantitative methods to ensure validity, practicality, and effectiveness.

Research Procedure

This research adopted the ADDIE model, consisting of five systematic phases. The overall research procedure was presented in Figure 1. The research was conducted through five main phases:

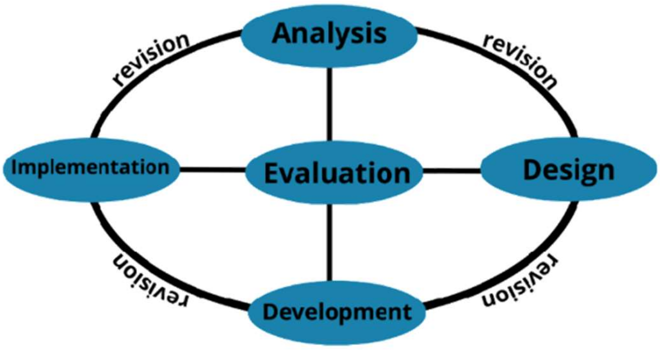

Figure 1. Schematic of the ADDIE Model stages (Panggalih & Handayani, 2023).

Figure 1 illustrates the stages of the ADDIE Model, which includes Analysis, Design, Development, Implementation, and Evaluation as a systematic framework for developing instructional materials such as e-modules. In this research, the analysis phase involved needs assessment through tests and interviews to identify gaps in data literacy and scientific reasoning. The design phase focused on creating an instructional blueprint that integrates multimedia, interactive features, and real-world cases aligned with curriculum goals. The development phase consisted of producing the e-module prototype, validating it with content and media experts, and preparing assessment instruments. The implementation phase was carried out through small-scale trials with students, followed by revisions based on feedback. Finally, the evaluation phase analyzed pretest-posttest results, N-Gain scores, validator input, and student engagement data to determine the effectiveness of the e-module.

Data Sources

This study involved 29 Science Education students at Universitas Muhammadiyah Sidoarjo (11 males; 18 females, aged 19-22) selected through purposive sampling. Most were early-semester students with prior digital learning experience, a homogeneous academic background, and origins from urban or semi-urban areas, which supported the consistent implementation of the e-module. In addition, three experts in learning innovation, science content, and educational technology served as validators.

Data Collection

Data were collected using several instruments, including validation sheets completed by experts to assess the validity of the e-module, observation sheets by two observers to record student activities and engagement, and pretests and posttests to measure scientific reasoning skills. In addition, a Likert-scale questionnaire was used to obtain student feedback on the clarity, relevance, ease of use, and the impact of the e-module on scientific reasoning and learning motivation.

Data Analysis

The data analysis techniques were tailored to the type and purpose of each data set.

1. Validity and Reliability Analysis

   The validity of the e-module was evaluated through expert assessments using a 4-point Likert scale validation sheet, covering aspects of content, design, language, and media quality. Scores from three expert validators were averaged, and the e-module was considered valid if the average score reached

≥2.75. Inter-rater agreement was calculated using the percentage agreement formula, and reliability was assessed using Cronbach's Alpha coefficient, with α ≥ 0.70 indicating acceptable reliability.

2. Observation Data Analysis (Qualitative):
   Observation sheets recorded student activities during each learning phase: engagement, exploration, explanation, elaboration, and evaluation. These activities were categorized and analyzed descriptively. The Student Participation Percentage (*PA*) was calculated using Equation 1.

$$PA = \frac{Number\ of\ students\ actively\ participating}{Total\ number\ of\ students}\ x\ 100\% \quad (1)$$

   Descriptive comparison across learning phases helped interpret the practical use of the e-module.

3. Pretest and Posttest Data Analysis (Quantitative):
   Students' scientific literacy scores from pretests and posttests were analyzed using mean, standard deviation, and normalized gain (*N-Gain*) calculated as in Equation 2.

$$NGain = \frac{(Posttest\ score - Pretest\ score)}{(Maximum\ score - Pretest\ score)} \quad (2)$$

   N-Gain analysis was used to measure the improvement in scientific literacy before and after the learning intervention. The N-Gain values were categorized as follows: high (>0.70), medium (0.31-0.70), and low (0.0-0.30).
   To assess the significance of the improvement, an independent samples t-test was conducted using SPSS to compare the control and experimental groups. A *p-value* < 0.05 indicated statistically significant differences in learning outcomes.

RESULTS AND DISCUSSION

Description of the Data Literacy-Based E-Module

The data literacy-based e-module developed in this study functions as an innovative learning medium aimed at strengthening students' conceptual understanding of mixtures and separation techniques, while simultaneously fostering scientific reasoning skills through data analysis. This e-module is designed to align with Science learning outcomes, emphasizing not only content mastery but also the development of data literacy as a core scientific skill. Furthermore, Figure 2 presents the content of the e-module, which integrates theoretical concepts of separation methods with data literacy.

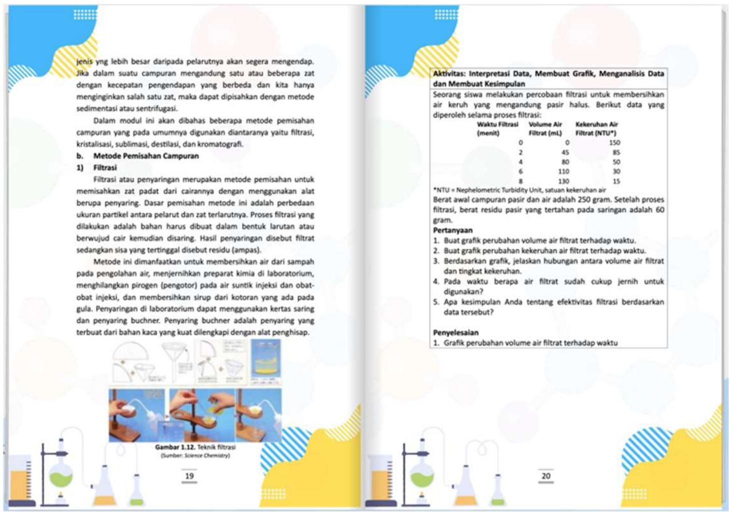

Figure 2. Theoretical Concept of Separation Methods: Filtration Integrated with Data Literacy

According to Figure 2, the structured activities in the e-module proved effective in guiding students to analyze experimental data, identify patterns, and draw evidence-based conclusions, thereby enhancing scientific thinking skills (Eshach & Kukliansky, 2016); Potvin, 2021). The application of data literacy in science learning has also been shown to improve engagement, conceptual understanding, and the application of knowledge to new problems (Kjelvik & Schultheis, 2019). In chemistry learning, the integration of data

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analysis not only enhances cognitive performance but also students' metacognitive awareness (Cook et al. (2013).

Furthermore, a guided inquiry-based laboratory model combined with blended learning has great potential to enhance analytical skills and research practices (Suárez et al., 2018). Technological support such as laboratory simulations and learning analytics enables real-time monitoring of students' progress (Jiang et al., 2022; Engelmann et al., 2016). The guided inquiry approach with digital feedback promotes productive failure, allowing students to learn more deeply through exploration and error correction (Sinha & Kapur, 2021). In addition, peer review activities and evidence-based assessments, such as video demonstrations, can strengthen students' confidence and practical competence (Dewi et al., 2024). Thus, this module not only delivers instructional content but also facilitates the development of scientific skills through data literacy.

In addition, project-based tasks were incorporated within the module to provide students with authentic experiences in conducting separation experiments, collecting and processing data, and presenting results using tools like Excel or Google Sheets.Data visualization activities in the e-module have been shown to enhance practical skills while simultaneously strengthening students' scientific reasoning processes. Project-based learning with a focus on data visualization improves concept retention and problem-solving abilities (Chistyakov et al., 2023), while the integration of spreadsheet-based analysis fosters the identification of experimental errors (O'Connor et al., 2025). Data literacy as a core component also reinforces analytical skills, decision-making, and students' confidence in understanding complex information (Ow-Yeong et al., 2023).

Furthermore, activities of creating and interpreting data visualizations train students to connect data with scientific concepts while enhancing reflection and evaluation (Vance et al., 2022). The integration of visual analytics encourages higher-order thinking through the interactive exploration of complex data (Andrienko et al., 2018). Modules with interactive data visualization exercises have been proven to improve statistical understanding, infographic interpretation, and data mapping (Higgins & Carter, 2025). Overall, positioning data literacy and visualization as the core of the e-module effectively enhances students' practical competence, critical analysis, and scientific reasoning, in line with contemporary science education standards (Nurussalamah et al., 2025). Therefore, e-modules that place data literacy and visualization at the core of learning are effective in improving students' practical, analytical, and scientific thinking skills.

Results of the Validity of the Data Literacy-Based E-Module

The validity results of the Data Literacy-Based E-Module on the topic of Separation of Mixtures are presented in Table 1, which shows the validation scores along with assessment components for content and construct validity.

Table 1. Content and Construct Validity Results of the Data Literacy-Based E-Module

Validation Aspect	Validation Score	Validation Score	Criteria	Percentage of Agreement (PA %)	Cronbach's Alpha (α)	Reliability
Content Validity	Alignment with Learning Outcomes (CPMK)	3.8	Very Valid	96.4	0.83	High Reliability (HR)
	Accuracy and Correctness of Content	3.5	Very Valid	88.6	0.83	High Reliability (HR)
	Completeness of Content	4.0	Very Valid	100.0	0.83	High Reliability (HR)
	Integration of Content with Data Literacy	3.7	Very Valid	92.8	0.83	High Reliability (HR)
	Clarity and Appropriateness of Language	3.3	Very Valid	100.0	0.83	High Reliability (HR)
	Average	**3.7**		**93.9**	**0.83**	
Construct Validity	Alignment of Learning Model with Data Literacy	4.0	Very Valid	100.0	0.94	Excellent Reliability (ER)
	Coherence of Module Structure	3.3	Very Valid	85.7	0.94	Excellent Reliability (ER)
	Consistency Between Objectives, Content, and Assessment	3.7	Very Valid	92.8	0.94	Excellent Reliability (ER)

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Validation Aspect	Validation Score	Validation Score	Criteria	Percentage of Agreement (PA %)	Cronbach's Alpha (α)	Reliability
	Development of Critical and Analytical Thinking Skills	3.7	Very Valid	100.0	0.94	Excellent Reliability (ER)
	Use of Learning Activities Supporting Data Literacy	3.3	Very Valid	85.7	0.94	Excellent Reliability (ER)
	Appropriateness of Material Difficulty for Target Learners	3.6	Very Valid	90.5	0.94	Excellent Reliability (ER)
	Continuous Evaluation	4.0	Very Valid	100.0	0.94	Excellent Reliability (ER)
	Average	**3.7**		**93.5**	**0.94**	

According to Table 1, the e-module obtained an average validation score of 3.7, with expert agreement above 93% and Cronbach's Alpha values of 0.83 (content) and 0.94 (construct), indicating high reliability. This aligns with Puspitasari et al. (2020), who emphasized that valid and reliable modules form a strong foundation for effective learning. Content validity aspects such as alignment with learning objectives (CPMK), content accuracy, completeness of material, integration of data literacy, and language clarity are crucial in ensuring the effectiveness of the module in supporting learning outcomes. Accurate, well-structured material integrated with data literacy, such as the ability to collect, analyze, and interpret data, not only strengthens scientific thinking processes but also promotes deeper cognitive engagement (Cui et al., 2023). This is supported by Nasip & Ong, (2021), who found that accurate and systematically structured learning materials enhance students' understanding and learning motivation. Moreover, high content validity also received positive responses from students, who considered the module to be practical and easy to use in the learning process.

In line with these results, previous studies have shown that learning materials with strong content validity, especially those designed to foster data literacy and critical thinking, lead to improvements in students' ability to analyze, synthesize, and apply information in real-world contexts (Yasa et al., 2024). Project-based and authentic data analysis modules enhance motivation and participation, as seen in research on computer and network e-modules, which reported high practicality (average 85.03/100) and preference for interactive, data-based media over traditional methods (Rahayu & Sukardi, 2021). These findings align with the current study, confirming that data literacy integration strengthens comprehension and skill application.

Construct validity, reflected in structural coherence and consistency across objectives, content, activities, and assessments, plays a key role in supporting critical thinking (Setiawan et al., 2017; Lastariwati et al., 2021). This supports Pereira et al., (2024), who argued that instructional design must align outcomes, activities, and assessments, while Kapur (2015) highlighted that such coherence enables "productive failure," deepening understanding, a principle embedded in this module's inquiry-based, data-driven tasks.

The module's uniqueness lies in integrating data literacy with interactive features such as videos, simulations, and visualizations (see: https://heyzine.com/flip-book/f824a1055b.html). These adaptive and technology-based features differentiate it from conventional materials (Adri & Suwarjono, 2023) and have been shown to improve analytical skills, conceptual understanding, and retention (Firat et al., 2022; Sander, 2020; Andani et al., 2023). This supports Mayer's Cognitive Theory of Multimedia Learning, which emphasizes that combining verbal and visual information improves efficiency and outcomes (Mayer, 2024).

Nevertheless, aspects of language, visual quality, and interface structure still require improvement to enhance clarity and learning comfort (Özdeniz et al., 2023; Fragou & Papadopoulou, 2020). Embedding continuous evaluation tools such as quizzes, feedback, and progress tracking, recommended by Liao et al. (2024), has also been implemented to sustain skill mastery.

In conclusion, the Data Literacy-Based E-Module is highly feasible for higher education, meeting essential quality standards and contributing to students' scientific reasoning and data-driven decision-making (Özel, 2023).

Results of the Practicality of the Data Literacy-Based E-Module

Student activity observations during learning with the Data Literacy-Based E-Module are shown in Table 2. The observed student activities include: (1) Listening to explanations delivered by the lecturer; (2)

Interpreting data; (3) Formulating problems; (4) Reading the E-Module; (5) Answering problems based on the reviewed information; (6) Conducting experiments/demonstrations/observations; (7) Writing answers in student worksheets; (8) Presenting and communicating discussion results; (9) Participating in group discussions; (10) Responding to and answering questions; (11) Applying new labels, definitions, explanations, and skills in new contexts; and (12) Evaluating personal progress and knowledge.

Table 2. Student Activities During Learning with the Data Literacy-Based E-Module

Activities in Each Learning Phase	PA Class A (%)	PA Class B (%)
Phase 1 (Activities 1, 2, 10)	93.6	91.6
Phase 2 (Activities 3, 4, 5)	80.0	71.8
Phase 3 (Activities 4, 5, 6, 7, 8, 9, 10)	89.2	87.2
Phase 4 (Activities 9, 10, 11)	85.8	86.0
Phase 5 (Activities 4, 12)	75.0	73.6

Based on Table 2, student activities in Phase 1 show a very high level of participation in both classes, particularly in listening to teacher explanations, interpreting data, and responding to questions. This reflects that the initial phase of data literacy-based learning effectively encourages active student engagement (Ong et al., 2021). This is consistent with Bolkan & Goodboy (2024), who emphasized that clear instructions at the beginning enhance students' confidence and readiness. However, participation declined in Phase 2, especially in Class B, as tasks required higher-order thinking. While complex tasks may challenge students, scaffolding, peer interaction, and feedback are crucial to sustain engagement (Zeitlhofer et al., 2024;Aditomo & Klieme, 2020).

Participation rose again in Phase 3 through problem-solving, experiments, and group discussions, confirming that project-based and exploratory learning improves understanding and involvement (Freeman Turrin, 2015; Tian et al., 2023). In Phase 4, discussions strengthened scientific communication, knowledge transfer, and higher-order thinking (Williams & Svensson, 2020; Waruwu et al., 2023). By contrast, Phase 5 showed a decline in participation, likely due to the high intrinsic motivation and metacognitive effort required for reflection (Siwawetkul & Koraneekij, 2020). Research suggests that reflective journals and structured frameworks can enhance critical reflection and ownership of learning (Ahmed (2019; Lin et al., 2024; Whelan & Paez, 2019).

Overall, the findings of this study indicate that the Data Literacy-Based E-Module demonstrates practicality in supporting student learning activities, especially during exploratory and collaborative phases. These findings support previous research by Higgins & Carter (2025), which states that integrating data literacy into digital learning can enhance student engagement and scientific literacy. Furthermore, these results are consistent with the views of Jaya &Nurqamarani (2023), who argue that when students engage in direct data manipulation and visualization, they not only develop technical skills but also critical thinking and problem-solving abilities, leading to more meaningful and active learning experiences.

Effectiveness of the Data Literacy-Based E-Module

The effectiveness of the Data Literacy-Based E-Module is demonstrated through the improvement in students' scientific reasoning skills and their responses to the module's implementation. The students' pre-test and post-test scores for scientific reasoning are summarized in Table 3.

Table 3. Summary of Pre-test and Post-test Scores in Scientific Reasoning

Description	*Class A*		*Class B*	
	Pre-Test	*Post Test*	*Pre-Test*	*Post Test*
Mean	55.11	82.11	51.67	82.26
Standard Error	0.75	1.14	0.78	1.13
Median	56.67	81.67	52.50	81.67
Mode	56.67	81.67	53.33	81.67
Standard Deviation	2.92	4.43	2.92	4.22
Minimum	50.00	75.00	46.67	76.67
Maximum	58.33	91.67	56.67	91.67
Count Students	15.00	15.00	14.00	14.00
N-Gain Average	0.60		0.63	
N-Gain Category	Moderate		Moderate	

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According to Table 3, students' scientific reasoning scores improved significantly after using the e-module, with Class A rising from 55.11 to 82.11 and Class B from 51.67 to 82.26. The increase in median, mode, minimum, and maximum scores, along with relatively small standard deviation and error values, indicates consistent improvement. The average N-Gain values of 0.60 (Class A) and 0.63 (Class B) fall into the "moderate" category (Hake, 1999), confirming the module's effectiveness in enhancing learning outcomes. These results demonstrate that the data literacy-based e-module supports the development of higher-order thinking, particularly scientific reasoning and critical thinking (Nurissamawati et al., 2015).

This finding is consistent with Espinoza-Cedeño et al. (2024), who showed that digital learning resources such as interactive applications and simulators improve motivation, comprehension, and independent problem-solving by adapting to learners' needs. Similarly, Ningsih et al. (2023) reported that inquiry- and data-based electronic books incorporating scaffolding, problem-based learning, and interactive simulations significantly strengthen students' reasoning and problem-solving skills in science and technology. The consistent evidence suggests that the integration of contextual data tasks and interactive features in the e-module is a key driver of cognitive improvement.

In addition to the increase in the overall score of scientific reasoning, this study also examined student achievement on five specific scientific reasoning indicators. Furthermore, Table 4 presents the average *N-Gain* scores based on scientific reasoning indicators in Class A and Class B.

Table 4. Average *N-Gain* Scores by Scientific Reasoning Indicator

No	PI Indicator	Class	Average Pre-Test	Average Post-Test	*N-Gain*	Category
1	CT	A	68.33	88.33	0.62	Moderate
		B	60.71	85.12	0.62	Moderate
2	PPT	A	55.56	88.33	0.74	High
		B	54.17	87.50	0.72	High
3	PBT	A	57.22	78.33	0.49	Moderate
		B	51.19	82.14	0.63	Moderate
4	HDR	A	40.56	73.33	0.54	Moderate
		B	42.86	75.60	0.56	Moderate
5	CV	A	53.89	82.22	0.60	Moderate
		B	49.40	80.95	0.61	Moderate

According to Table 4, all scientific reasoning indicators in both Class A and Class B showed increased N-Gain scores. The highest improvement was in Proportional Thinking (PPT), categorized as high, with N-Gain scores of 0.74 (Class A) and 0.72 (Class B), supporting Erlina et al. (2018), who found that the use of data and evidence enhances proportional reasoning. Other indicators, Control of Variables (CV), Hypothesis Data Relationship (HDR), Probabilistic Thinking (PBT), and Correlation Thinking (CT), also improved in the moderate category (0.49-0.63), showing that the Data Literacy-Based E-Module effectively strengthens multiple dimensions of scientific reasoning.

These findings align with Kanari & Millar (2004), who noted that active engagement in data-based activities fosters logical and analytical skills, and Meister et al. (2020), who emphasized the role of data integration in evidence-based reasoning. The strong gains in proportional reasoning also reflect Vahey et al. (2012), who demonstrated that cross-disciplinary digital modules with quantitative tasks enhance proportional thinking. Similarly, Ningrum et al. (2024) highlighted the importance of hypothesis testing and variable control for reinforcing scientific reasoning, while Masnick and Morris (2022) showed that exposure to statistical variation supports probabilistic reasoning. Broader evidence from Vermeire et al. (2025) and Schreiter et al. (2024) further confirms that data literacy-based approaches enhance higher-order thinking and problem-solving.

Subsequently, statistical analysis using the independent samples t-test (SPSS) confirmed the assumptions of normality (Shapiro-Wilk) and homogeneity (Levene's test). As shown in Table 5, the results indicate no significant difference in N-Gain scores between Class A and Class B, reinforcing the consistency of the module's effectiveness across groups.

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Table 5. Statistical Test Results of *N-Gain* Scores

Statistical Tests Classification	Statistics	p-value	Decision
Shapiro-Wilk Class A	0.957	0.648	Data are normally distributed (p > 0.05)
Shapiro-Wilk Class B	0.924	0.251	Data are normally distributed (p > 0.05)
Levene's Test	0.171	0.682	Variances are homogeneous (p > 0.05)
Independent T-Test	0.127	0.900	No significant difference (p > 0.05)

Based on Table 5, the Shapiro-Wilk normality test and Levene's Test of homogeneity both show that the N-Gain data are normally distributed and homogeneous ($p > 0.05$), making the independent t-test appropriate. The t-test result ($p = 0.900 > 0.05$) indicates no significant difference between the average N-Gain scores of Class A and Class B, meaning the improvement in students' scientific reasoning after using the data literacy-based e-module is statistically equivalent across both groups.

This outcome supports Handayani et al. (2023), who found that digital learning interventions with strong pedagogical scaffolding provide consistent learning benefits across diverse student groups. Similarly, Kumi-Yeboah et al. (2020) showed that digital technologies, multimedia, and collaborative tools facilitate engagement and academic success among learners from varied cultural and linguistic backgrounds, helping them navigate systems and construct knowledge regardless of initial differences.

Students' Responses to the Implementation of the Data Literacy-Based E-Module

Table 6 presents the results of students' responses to the implementation of the data literacy-based e-module, which were collected through a questionnaire to assess their perceptions regarding the content, presentation, and usefulness of the learning media.

Table 6. Students' Responses to the Data Literacy-Based E-Module

No	Statement Description	N	Percentage of Student Response (%)			
			SA	A	DA	SDA
	Ease and Clarity of Material					
1	The module content is presented in language that is easy to understand.	29	14	86	0	0
2	The explanations in the module helped me understand the concept of data literacy.	29	21	79	0	0
3	Examples and illustrations in the module support material comprehension.	29	21	79	0	0
4	The structure of the module content is systematic and logical.	29	7	86	0	0
	Relevance and Appropriateness of Content					
5	The module content aligns with my learning needs and objectives.	29	21	79	0	0
6	The activities and exercises are relevant to data literacy concepts.	29	28	72	0	0
7	The case studies help me understand real-world applications of data literacy.	29	21	79	0	0
	Usability and Accessibility					
8	The module interface is easy to navigate and visually appealing.	29	14	86	0	0
9	The module can be accessed smoothly without technical issues.	29	14	86	0	0
10	The instructions for using the module are clear and helpful.	29	21	79	0	0
11	The module features support active learning and interaction.	29	21	79	0	0
	Impact on Skills and Learning Motivation					
12	The module has improved my ability to analyze and interpret data.	29	21	79	0	0
13	I feel more confident in using data literacy after using this module.	29	14	86	0	0
14	The module encourages me to learn independently and actively.	29	7	86	7	0
15	I feel motivated to complete the learning process using this module.	29	14	86	0	0

Note: SA= Strongly Agree; A= Agree; DA= Disagree; SDA= Strongly Disagree

Table 6 shows that students' responses to the data literacy-based e-module were overwhelmingly positive across four aspects: Ease and Clarity of Material, Relevance and Appropriateness of Content,

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Usability and Accessibility, and Impact on Skills and Learning Motivation. No students selected negative options (DA/SDA), indicating a strong overall acceptance.

For Ease and Clarity, all students agreed that the language, explanations, and examples were clear and systematic, supporting comprehension of data literacy concepts. Similarly, in Relevance and Appropriateness, 100% of students found the content aligned with their needs, the exercises relevant, and the case studies helpful in linking theory to practice. Usability and Accessibility also scored highly, with students unanimously agreeing on the ease of navigation, smooth access, visual appeal, and active-learning features. Finally, for Impact on Skills and Motivation, nearly all students reported improved ability to analyze and interpret data, greater confidence in applying data literacy, and higher motivation for independent learning.

These findings demonstrate that the module effectively integrates clarity, relevance, usability, and motivational impact, confirming its practicality as a digital learning tool to foster data literacy in higher education. Beyond the immediate benefits, the implications align with the Sustainable Development Goals (SDGs). Specifically, the module supports Goal 4 (Quality Education) by promoting equitable, inclusive, and lifelong learning, while also contributing to Goal 9 (Industry, Innovation, and Infrastructure) through strengthening scientific and analytical skills, and Goal 17 (Partnerships for the Goals) by advancing digital learning initiatives that enhance global collaboration. Thus, this innovation not only enhances academic outcomes but also supports broader sustainable development priorities.

These findings indicate that the Data Literacy-Based E-Module offers an effective, accessible, and engaging learning experience. It supports the development of students' motivation and data literacy competencies. The integration of data literacy into science learning through this structured module has been shown to significantly enhance scientific reasoning, as supported by prior studies (Handayani et al., 2023).

The consistency of these results shows that the module is adaptive and inclusive across various student groups. It also fulfills content and construct validity criteria, making it suitable for classroom implementation. The use of project-based learning and real-world case studies encourages evidence-based thinking and data interpretation (Tian et al., 2023; Wright et al., 2024). Therefore, this module holds strong potential as an innovative tool in higher education science learning. This study also offers implications for educators and curriculum designers to further strengthen the integration of data literacy in digital learning activities. Future research may explore the long-term impact of the module on data-driven decision-making across disciplines and educational levels (Geel et al., 2017).

This study has limitations in terms of sample size, as it involved only two classes within a limited timeframe, making the results not yet generalizable to a broader population. Additionally, the evaluation was based solely on student responses, without further quantitative measurement of improvements in data literacy skills. For future development, it is recommended that the e-module be tested in more classes and institutions using an experimental design involving pre-tests and post-tests, accompanied by more comprehensive assessment instruments to objectively measure its impact on data literacy skills and scientific reasoning.

CONCLUSION

The data literacy-based e-module developed in this study serves as a relevant and feasible learning resource for enhancing scientific reasoning in undergraduate science education. It addresses the increasing need to integrate data literacy into learning processes, enabling students to critically engage with scientific information and evidence in a structured and meaningful way. However, the implementation of this module was limited to a specific topic, sample size, and institutional setting, which may affect the extent to which the findings can be generalized. Further research is recommended to explore the application of similar modules across broader scientific domains and educational contexts, as well as to evaluate their long-term impact on students' reasoning and data-driven decision-making in science learning.

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AUTHOR CONTRIBUTIONS

Noly Shofiyah: Conceptualization, Methodology, Supervision, Writing - Original Draft, Funding Acquisition; **Fitria Eka Wulandari**: Data Curation, Investigation, Writing - Review & Editing; **Choirun Nisak Aulina**: Validation, Resources, Writing - Review & Editing; **Suci Prihatiningtyas**: Formal Analysis, Project Administration, Visualization; **Khoirun Nisa'**: Formal Analysis, Project Administration, Visualization; and **Janatul Firdausi Nuzula**: Data Curation, Investigation, Visualization. All authors have read and approved the final version of this manuscript.

DECLARATION OF COMPETING INTEREST

The authors declare no known financial conflicts of interest or personal relationships that could have influenced the work reported in this manuscript.

DECLARATION OF ETHICS

The authors declare that the research and writing of this manuscript adhere to ethical standards of research and publication, in accordance with scientific principles, and are free from plagiarism.

DECLARATION OF ASSISTIVE TECHNOLOGIES IN THE WRITING PROCESS

The authors declare that generative artificial intelligence (Gen AI) and other AI-assisted tools were used prudently, not excessively, during the research and preparation of this manuscript. Specifically, ChatGPT was used appropriately for brainstorming, drafting, refining text, and answering conceptual questions. All AI-generated material was reviewed and edited for accuracy, completeness, and compliance with ethical and scholarly standards. The authors accept full responsibility for the final content of the manuscript.

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