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Research and Development in Education (RaDEn)

Research Article

Development of contextual interactive e-modules on the human organ system to support SDGs

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Abstract: Technology-based learning is one of the outcomes of the 4.0 industrial revolution that supports the implementation of Sustainable Development Goals (SDGs) in education The use of teaching materials in the form of contextual-based interactive e-modules is still rarely used in schools. The use of teaching materials that are common in schools are teaching materials that have been provided by the government and book publishers so that they are less in accordance with student needs. This study aims to produce contextual-based interactive e-modules on the material of the human organ system. This research is included in Research and Development (R&D), by following the Four-D development model consisting of the define, design, development, and disseminate stages. However, this study was limited to the development stage. The subjects of this study were two grade XI biology teachers at SMAN in Indramayu Regency, West Java, seven doctors, and four validators. The results of the study showed that the developed e-module obtained validation results in the context of material, language, and digital teaching materials that were very good with an average score of 96.82%. Further research can be continued at the disseminate stage to see the effectiveness of the e-module.

Keywords: biology learning; cross platform; organ system; science literacy; SDGs

1. Introduction

Driven by technological progress and evolving pedagogical landscapes, the 21st century biology education faces a novel set of challenges and prospects. This digital age demands the implementation of innovative teaching strategies that enable students to transition from theoretical comprehension of biology to the practical application of this knowledge in authentic, real-life situations (Aliqulovna, 2024). Technology-based learning is one of the outcomes of the 4.0 industrial revolution that supports the implementation of Sustainable Development Goals (SDGs) in education (Dito & Pujiastuti, 2021). The program aims to ensure inclusive and equitable quality education, support lifelong learning opportunities for all, and promote education for sustainable development. The target for 2030 is to ensure that all adolescents and a certain proportion of adults, both men and women, have numeracy and literacy skills.

Literacy has various types, one of which is science literacy. Science literacy is a person's ability to understand science, communicate science, and apply science knowledge to solve problems, so that it can improve attitudes and sensitivity to the surrounding environment (Virtič, 2022). Science literacy can help students understand and use science effectively, think critically, and make balanced and appropriate decisions regarding problems related to life (Hanson, 2022). Students need science literacy skills to analyze problems and relate them to various science facts (Oliver & Adkins, 2020). This ability is used to make decisions about problems related to natural phenomena and their impact on human life (Card, 2014).

The current condition of student science literacy in Indonesia is relatively low compared to other countries (OECD, 2023). The reality is that Indonesian students are not

yet able to understand science concepts and processes (Wiraputra et al., 2023). The low level of students' science literacy is one of the educational problems in Indonesia. Although the importance of science literacy has been recognized by all educators, it does not mean that students' science literacy is well trained (Elhai, 2023). This is supported by data on the achievement of Indonesian students' science literacy in the PISA science literacy assessment. Indonesia is ranked 68th with a science literacy score of 398 in 2022. The data shows that Indonesia's science literacy ranking has increased by 6 positions compared to before, but the decline in science literacy ability has fallen by 13 points, almost equivalent to the international average of 12 points. As many as 52% of countries participating in PISA in 2022 experienced a decline in science literacy scores compared to PISA in 2018 (Kemendikbudristek, 2023). There are factors that influence the lack of students' science literacy, namely the lack of materials or teaching materials circulating in Indonesia, when compared with other countries in developing students' science literacy (Agustin & Supahar, 2021).

To foster profound conceptual understanding and scientific literacy, pedagogical approach necessitates commencing with concrete socioscientific problems and progressing to active, evidence-centered practices, thereby ensuring the integration of content with sustained student engagement in the location, interpretation, and application of scientific evidence (Appiah-Adjei, 2025). Improving science literacy skills can be done by focusing on science argumentation, understanding science phenomena, and the process of science discovery. Additionally, factors like guidance level, teaching strategy, gender, and intervention domain significantly influence effectiveness (Han, 2021; van Leeuwen & Janssen, 2019). Many previous researchers have done this as an effort to improve science literacy, including the use of problem-based learning models, SSI integrated PjBL-STEAM (Reswara et al., 2024), learning media such as interactive multimedia (Sari et al., 2022), QR code-based learning, interactive learning media, web-based resources. In addition, there is a need for support in learning to improve science literacy skills, one of which is using teaching materials or modules.

Modules are basically teaching materials created for the purpose of independent learning for students with complete content (Kizi, 2022). The 21st century learning in the Industrial Revolution 4.0 requires innovation and optimal use of technology, technological developments change the orientation of learning from conventional to digital learning (Khan et al., 2024). Therefore, it is necessary to develop teaching modules such as digital teaching modules or e-modules.

The benefits of e-modules can be presented interactively to visualize the material clearly through images, videos and animations, designed attractively and can interact with students (Sidiq et al., 2021). Digital e-modules can be in the form of systematically structured textbooks that can present material (Mulyadi et al., 2020). The development of interactive e-modules has been carried out by Herawati and Muhtadi (2020) in chemistry subjects and accessed using Compact Disk (CD). However, web-based E-modules are more efficient when they can be accessed from various digital devices such as PCs, laptops, tablets, and smartphones using the same application or called cross-platform. The term cross-platform is used in information technology to describe software that can run on various operating systems, such as Microsoft Windows, Linux, Mac OS, BSD and mobile versions, including Android, iOS, Windows Mobile (Robianto, 2020). Cross-platform in making digital teaching materials can be used on various platforms and operating systems, so it is not limited to one type of device (Segun-Falade et al., 2024). The use of cross-platform considers technology as a communication tool so that it supports students to learn, do assignments, and search for various information (Krause et al., 2022). In addition, data integration in the system can provide students with broad insights and increase learning effectiveness (Evenddy et al., 2021). Therefore, the development of e-

modules that have been carried out previously can be developed again by presenting contextual-based materials and using Cross Platform applications.

The implementation of e-modules using Cross Platform can be implemented on contextual materials. Contextual-based interactive e-modules are interactive electronic teaching materials that contain academic materials and real-life contexts (Marta et al., 2023). The learning process involves students being able to relate academic learning to the real-life context faced by students (Haryanto & Arty, 2019). However, the use of contextual-based teaching modules is still rarely found in schools. Nurhamdiah et al. (2020) stated that currently teachers are still using textbooks provided by the government (schools) and private book publishers. In addition, the textbooks currently used are mostly not based on local content or the context surrounding students' lives (Flores, 2021). This is supported by Barus et al (2024) which states that until now there has been no book/teaching module found that is in accordance with students' needs and is able to link the material being studied with contextual and real-life-oriented learning characteristics.

Many contextual-based e-modules on organ systems have been developed. However, so far there are no e-modules that contain interviews with doctors and disease case data. The contextual e-module in this study was developed based on research findings regarding data on diseases suffered by the people of West Java and interviews with doctors about the causes, transmission/mechanism of disease, and treatment of these diseases.

Contextual-based interactive e-modules on various organ system materials are combine context-based learning and technology to create an easy, engaging, and effective learning experience. This is an innovative solution to improve student science literacy, thereby supporting the SDGs. The purpose of this study is to determine the feasibility of contextual-based e-modules as an effort to improve students' science literacy skills to support SDGs.

2. Materials and Methods

2.1 Types of research

This study uses a Research and Development (R&D) approach based on 4D development research with four stages: Define, Design, Development, and Disseminate (Thiagarajan et al., 1974). At the define stage, researchers conducted preliminary research including needs analysis both theoretically and empirically, curriculum analysis, and learning material analysis. At the design stage, researchers began designing contextual-based interactive digital module products using the Cross Platform application, creating storyboards, and preparing science literacy instruments. The literacy instruments used were instruments developed by Luzyawati et al. (2025) which can be accessed at https://books.biounwir.ac.id/instrumen-literasi-sains.html. At the development stage, the researcher began to validate (content and construct) to four validators (two expert validators and two practitioners) to assess the developed product, in addition, at this stage a scale test was carried out involving 72 high school students in West Java who were taken using the proportional random sampling technique.

2.2 Research subjects and objects

The subjects of this study were determined by proportional random sampling. The subjects of the study at the define stage were two biology teachers of grade XI of SMAN in West Java Province, Indonesia and six doctors. The subjects of the study at the development stage were four validators, consisting of one lecturer expert in human anatomy and physiology, and one lecturer expert in digital learning, and two biology teachers as practitioners. The population for the small-scale test was grade XI of 264

students at SMAN 1 Indramayu with a total research sample of 72 students as the control and experimental classes.

2.3 Data types and sources

The type of data used in this study is primary data. Primary data consists of: Primary data consists of: the results of needs analysis interviews and contextual material analysis, observation sheets, product validation sheets validated by four validators, and science literacy test instruments and questionnaires.

2.4 Data collection technique

The instruments used in this study were interview sheets, observation sheets, product validation sheets, science literacy test instruments, and questionnaires. Interview and observation sheets were used in preliminary research for needs analysis and contextual material analysis. Structured interviews were conducted to determine the teaching materials used by teachers in the subject of biology for grade XI, the availability of contextual-based interactive e-modules and teacher knowledge about Cross Platform. Structured interviews were conducted using a list of questions that had been created based on the objectives to be known in the study (Taherdoost, 2022). Contextual analysis was conducted at the Hospital and Health Office using observation sheet instruments and semi-structured interviews. Semi-structured interviews aim to find more open problems, where the interviewees are asked for their opinions and ideas (Sugiyono, 2021). Interviews with seven doctors were administered to provide contextual material for the module, eliciting information on disease causes, transmission mechanisms, and strategies for management or control.

Expert validation instruments are used at the development stage to assess the products being developed. This validation focuses on human organ system materials, language, and digital teaching materials. The science literacy test instrument is used to measure students' science literacy skills in the experimental and control classes. Meanwhile, the questionnaire instrument is used to determine students' responses to the cross-platform interactive digital module based on contextual which is distributed to students at the end of the learning.

2.5 Data Analysis Techniques

The data analysis technique of this research uses the atlas.ti application for qualitative data from interviews. The results of the validity of experts or experts in assessing the products developed using a Likert scale of 1-5 in the form of scores from the assessment of six validators. The data is then analyzed and categorized using the validation Formula 1 proposed by Purwanto (2020).

$$\frac{Score\ obtained \times 100\%}{Total\ Score} \quad (1)$$

Then, a conversion of the achievement level scale is carried out to determine the level of product feasibility (validity) in Table 1.

Table 1. Scale of achievement levels (Riduwan, 2015)

Percentage	Validity Level
81% - 100%	Very valid
61% - 80%	Valid
41% - 60%	Quite valid
21% - 40%	Not valid
0%-20%	Very invalid

The data of the results of students' science literacy abilities measured from the post-test results of the experimental class and control class were processed using the SPSS 25 application. The prerequisite analysis test used the Kolmogorov Smirnov normality test to determine whether the population sample was normally distributed or not. Furthermore, because the research data produced by both were not normally distributed, it was continued using non-parametric statistics, namely the Mann Whitney Test. Meanwhile, the questionnaire data obtained were the responses of students in the experimental class who were given treatment in the form of a contextual-based interactive digital module with 10 statement items in the questionnaire measured on a Likert scale (1 to 4). The percentage of student responses is calculated using the Formula 2.

$$P = \frac{\sum x}{\sum i} \times 100\% \quad (2)$$

Information:
P = Percentage
∑x = Total number of respondents' answers in all items
∑i = The total number of ideal scores per item

To determine the criteria based on each indicator with the interpretation criteria contained in Table 2 (Mardianto et al., 2022).

Table 2. Student response criteria

Percentage	Category
85% ≤ RS	Very Positive
70% ≤ RS < 85%	Positive
50% ≤ RS < 70%	Less Positive
RS < 50%	Not Positive

3. Results

At the define stage, researchers conducted a needs analysis. Based on the results of interviews with biology teachers in West Java, it was shown that their schools did not have biology teaching modules in printed or electronic form. They have never developed teaching materials in the form of teaching modules independently because the teaching materials used during biology learning are only textbooks, independent books, learning videos, and worksheets. The results of interviews with teachers stated that electronic teaching materials have benefits in learning such as being fast and easy to apply, easy to carry and practical because they can be used anywhere and anytime, interesting, and presented and explained in the form of real images and movements. However, they do not yet know the cross-platform application that can be used to help them in making teaching materials. Material analysis is carried out based on contextual analysis and curriculum analysis.

Contextual analysis was obtained from observations at Hospitals and Health Offices regarding data on diseases affecting the people of West Java, as well as interviews with seven doctors, including both general practitioners and specialists. While the curriculum analysis is based on the learning achievements of phase F class XI in the independent learning curriculum and contextual indicators. The results of the analysis of the human organ system curriculum for making e-modules can be seen in Table 3.

Head of the education standards, curriculum and assessment agency of the Ministry of Education, Culture, Research and Technology (Kementerian Pendidikan, Kebudayaan, Riset, 2024) states that there are two elements of learning achievement in phase F of class XI, namely the element of understanding biology and the element of process skills. Table 3 shows that the learning achievement in the element of understanding biology is the relationship between the structure of organs in the organ system and their functions in

responding to internal and external stimuli. While the learning achievement in the element of process skills is observing, questioning and predicting, planning and conducting investigations, processing, analyzing data and information, evaluating and reflecting, and communicating the results.

Table 3. Analysis of human organ system curriculum for e-module creation

Understanding Biology: Structure of organs in the organ system with their functions in responding to internal and external stimuli.		
Process Skills	Contextual Indicators	E-module Material Content
-	Encourage students to make connections between knowledge and its application.	1. Analytical questions about various organs, and application questions about breathing situations in the mountains 2. Videos about the processes, mechanisms, and work of organs 3. Doctor's actions
	Modeling	Example of procedural questions
Observing	- Relating the material taught to the real world situations of students. - Constructivism	1. Information on cases of human diseases 2. Videos of daily human activities
Questioning and predicting	- Finding - Constructivism - Learning society	- Diskusi kelompok untuk membuat rumusan masalah dan hipotesis dari fenomena berbagai penyakit pada organ.
Planning and conducting investigations	- Asking - Constructivism - Learning society	- Practical and quizzes
Processing, analyzing data and information	- Relate the material taught to the real world situations of students. - Asking - Constructivism - Learning community	- Graphs and tables of data on various human diseases to be discussed with the group - Quiz to read tables about data on cases of disorders and abnormalities in human organs
Evaluating and reflecting	- Asking - Learning community Learning community	Questions about the practicum Instructions for making a lab report

The design stage begins with creating a storyboard and e-module design. A cross-platform e-module application (compatible with iOS, Android, and Windows) is offered for installation via the website https://mebio.biounwir.ac.id/. This instructional module comprehensively covers the human organ system, including digestion, movement, excretion, circulation, reproduction, respiration, and coordination. Every e-modules design consiste of a cover, Instructions for use, foreword, list of contents, learning out comes, content, summary and references. In the e-module, images from international ebooks, videos from YouTube, quizzes from wordwall, group discussions and experiments via Google from, case information, and doctor's actions are added. can be seen in Figure 1.

The e-module that has been created is then validated by experts and practitioners. The validation results can be seen in Table 4. Based on Table 4 it can be seen that the validity of the digital module falls into the very valid criteria both in terms of material content, digital teaching material content, and language. The form of the e-module is presented in Figure 2, Figure 3 and Figure 4.

The product developed in the form of an e-module can be accessed both through cellphones and computer/laptop devices. The cover looks like in Figure 4. The e-module is contextually based which is based on the results of observation of public health data from health facilities spread across West Java and the results of interviews with seven doctors, both general practitioners and specialists. The results of the interview with the doctor are presented in the explanation of the disease or in the doctor's action column. Meanwhile, the results of observations are expressed in the form of case information. An example of the presentation in the e-module can be seen in Figure 3 and Figure 4.

The e-module that has been made is then tested on a small-scale test and sees the students' science literacy skills after learning. The results of the post-test are then analyzed using descriptive analysis and then the prerequisite test, namely the normality test using Kolmogorov Smirnov. The results of the prerequisite test show that the data from both classes are not normally distributed, so the hypothesis test uses non-parametric statistics, namely the U Mann Whitney test.

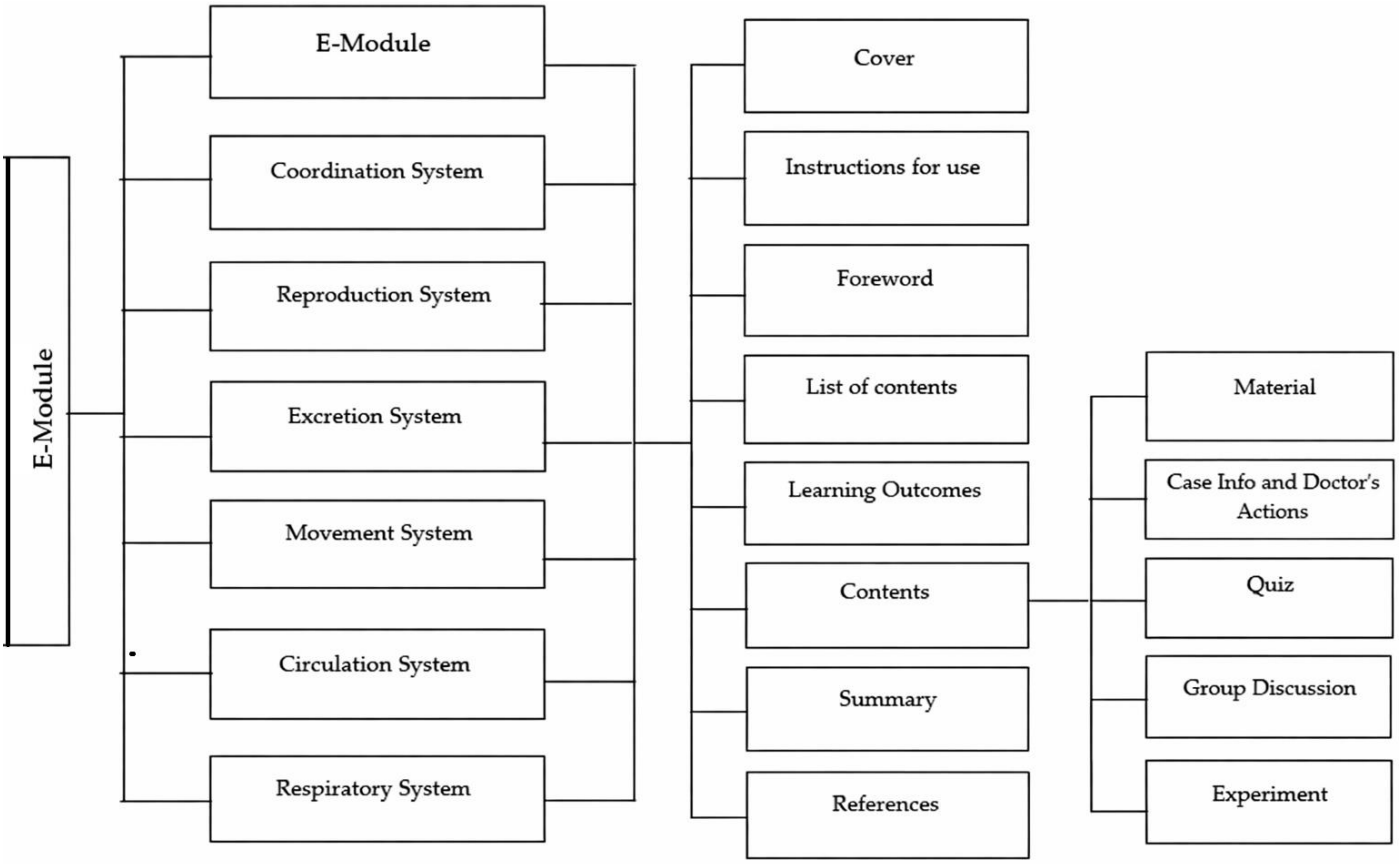

Figure 1. Contextual-based interactive e-module design using cross platform

Table 4. Validation results of interactive e-module products on human organ system material using Cross Platform by experts or specialists

Validator	Aspect		
	Human Organ System Material	Digital Teaching Materials	Linguistics
Material Expert	97.14 %	-	-
Digital Teaching Material Expert	-	85.19%	-
Language Expert	-	-	96.67%
Practitioner 1	100%	100%	100%
Practitioner 2	97.14%	98.52%	95%
Practitioner 3	97.14%	100%	95%
Average	97.86%	95.93%	96,67%
Criteria	Very Valid	Very Valid	Very Valid
Average	96.82%		
Criteria	Very Valid		

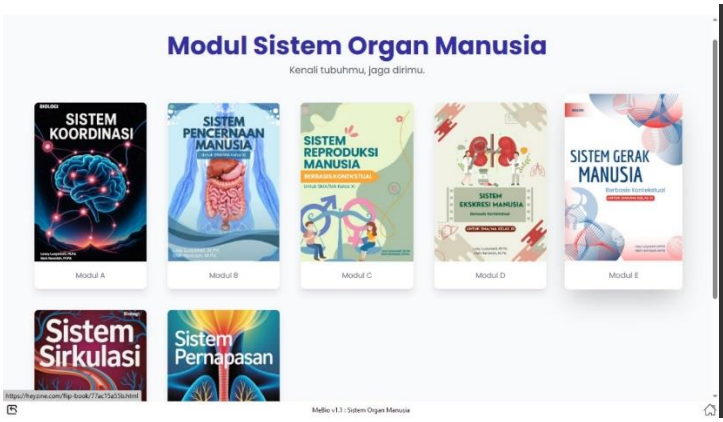

Figure 2. Cover e-module

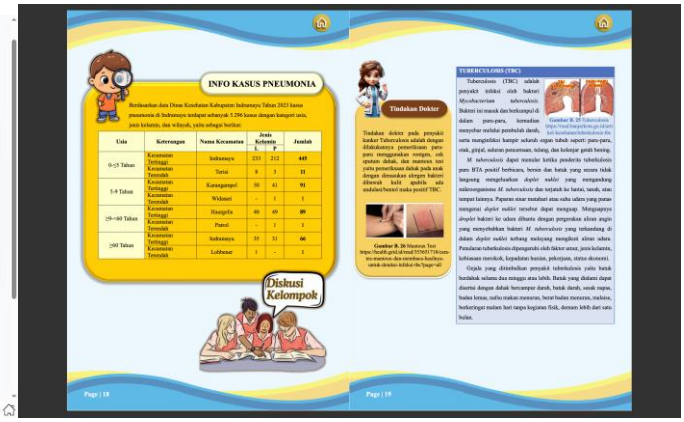

Figure 3. Case info of the content

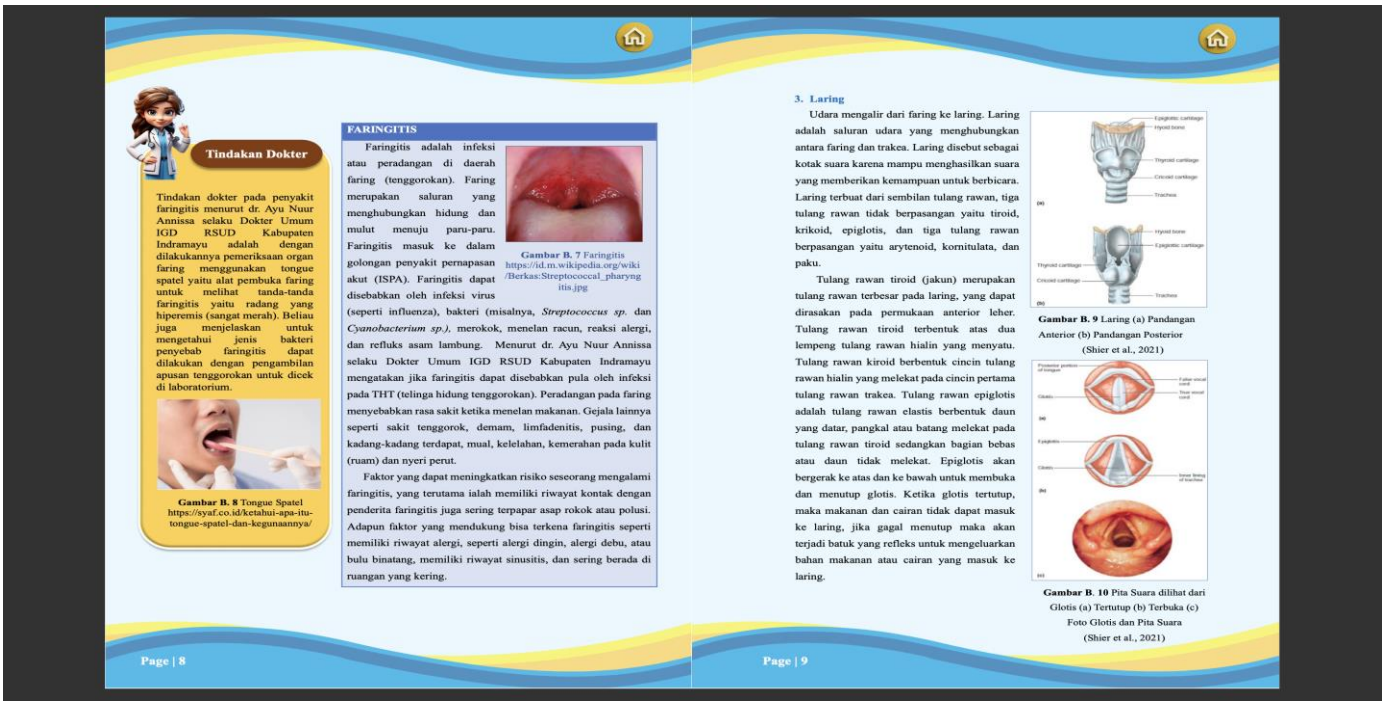

Figure 4. The content of e-module

Table 5. Descriptive analysis of posttest of experimental class and control class

Class	Experiment	Control
Valid	36	36
Mean	63.19	55.28
Std. Deviation	15.77	12.36
Variance	248.79	152.77
Range	60	55
Minimum	30	20
Maximal	90	75
Sum	2275	1990

Based on Table 5, the average value of the post-test results in the experimental class is greater than the control class because the experimental class uses teaching materials in the form of interactive e-modules based on contextual while the control class uses teaching materials from available textbooks. In addition, in the learning process, students are

involved creatively to improve their thinking skills which results in better learning outcomes.

Based on Table 6, it is known that the Asymp. Sig. value is 0.024 <0.05, then Ha is accepted, so it can be concluded that there is a difference in students' science literacy abilities between the control class and the control class. The difference in students' science literacy abilities is significant, so it can be said that there is an influence of the use of contextual-based interactive e-modules on the human respiratory system material on students' science literacy abilities.

Table 6. Mann Whitney Test Results

Test Statistics[a]	
	Student Science Literacy Ability Results
Mann-Whitney U	448.500
Wilcoxon W	1114.500
Z	-2.264
Asymp. Sig. (2-tailed)	.024

a. Grouping Variable: Class

Based on Figure 5, it shows the difference in the results of students' science literacy skills between the experimental class and the control class. The percentage of indicators explaining phenomena scienceally in the experimental class is better than the control class. The student response to the contextual-based interactive e-module can also be seen in Figure 6.

Based on Figure 6, it shows that student responses to contextual-based interactive e-modules are in the positive category for each indicator. Most students enjoy learning using contextual-based interactive e-modules because the learning materials are linked to real life around them and are flexible in their use.

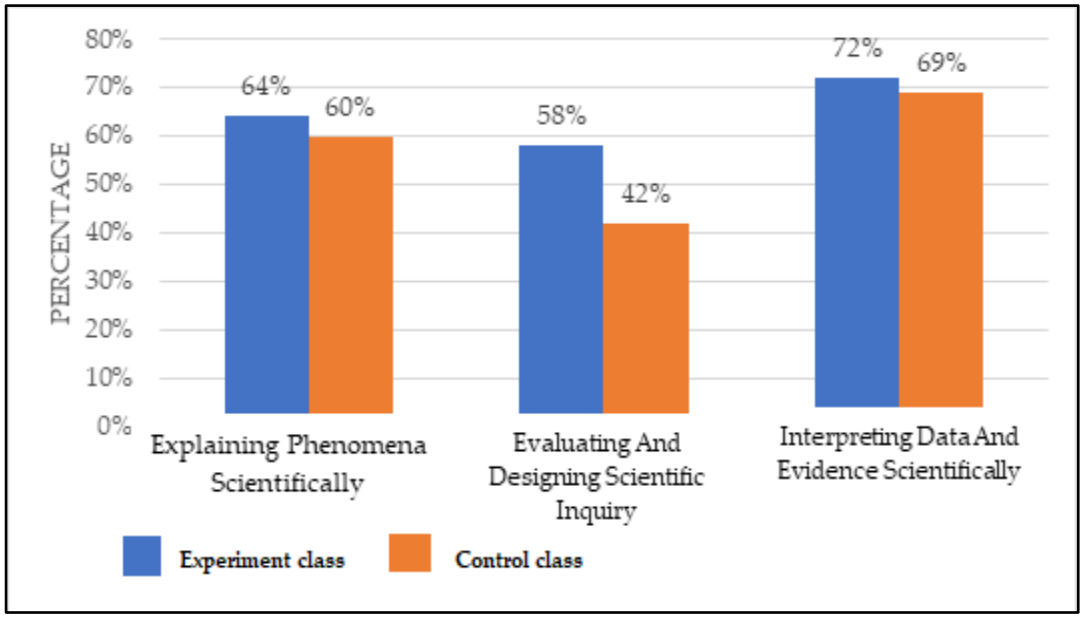

Figure 5. Percentage of science literacy ability results

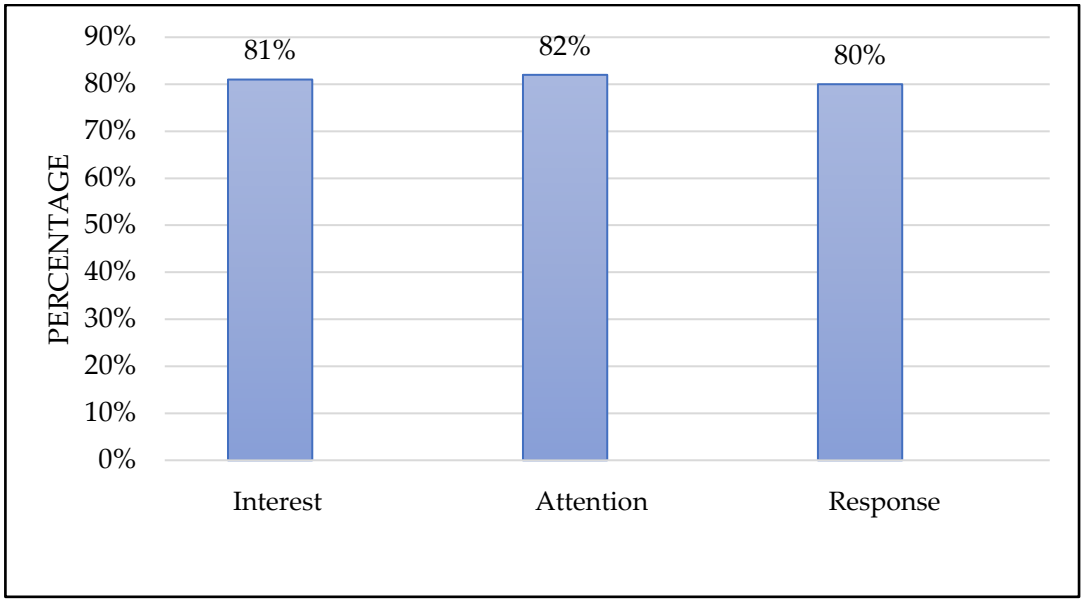

Figure 6. Results of student response questionnaire analysis

4. Discussion

Current scholarly literature successfully uncovers crucial perspectives regarding the cross-platform landscape in education, particularly those relevant to biology learning. The newly developed contextual interactive e-module demonstrates a robust fidelity to the core tenets of contextual teaching. This module seamlessly incorporates all seven critical contextual teaching components—constructivism, inquiry, questioning, learning community, modeling, reflection, and authentic assessment—across all its instructional activities (Aliyyah et al., 2020).

Dewi (2020) states that there are two contextual indicators, namely contextual nature and contextual components. Contextual nature is the relationship between the material taught and the real-world situation of students, as well as the ability to encourage students to make connections between the knowledge they have and its application in everyday life (Sujiono et al., 2023). A key example is the digestive system unit, where students are prompted to analyze their own dietary practices and establish connections between these habits and the functions of various digestive organs, thereby creating significant links between scientific concepts and real-world scenarios.

Expert evaluations on pedagogy confirmed the high relevance of the context, awarding a mean score of 96,82% ('very valid'). This validation affirms the module's success in grounding learning materials in the students' daily experiences. This outcome aligns with Andrews et al (2023) argument that learning becomes meaningful when students can relate academic content to authentic, practical situations.

The aspect of digital teaching materials in the developed e-module has a very good feasibility value. This shows that the module size is appropriate, the module cover design, and the module content design are good. Dini and Selina (2024) stated that the success of an attractive and unique design can create a strong visual appeal, thus encouraging reader interest. Meanwhile, the linguistic aspect of the e-module also has a good feasibility value. This shows that the e-module has a straightforward, communicative, dialogic and interactive language, in accordance with student development, in accordance with language rules, and the use of appropriate symbols or icons. In accordance with Nurlatifah and Suprihatiningrum (2023) states that the language used in the e-module must make it easier for students to understand the material by paying attention to the use of communicative, dialogic, interactive, straightforward, coherent language, in accordance with Indonesian language rules, and the accuracy of terms and symbols. However, in both

aspects there are improvements according to the validator's results, namely adding sentences of work commands or information to quizzes, group discussions, and experimental discussion results to make it easier for students to work. Fauzi et al. (2021) stating that the imperative sentence contains clear instructions on how to work on the problem so that it makes it easier for students to work on it.

Based on Table 3 on the elements of understanding biology can be combined with contextual indicators to encourage students to make connections between knowledge and its application. Its implementation in the e-module by providing analytical questions to be discussed, videos and learning materials, and doctor's actions. This is intended so that students can make connections between knowledge and its application. The relevance of learning to the real world of students and encouraging students to make connections between the knowledge they have and its application in everyday life (Morra, 2018; Akcay, 2017; Kamdi, 2015). Several examples of procedural questions are presented in the e-module as an implementation of modeling indicators. Modeling is a learning process by providing examples that can be imitated by students (Humeijia, 2021).

Furthermore, the contextual methodology employed in this e-module bolsters constructivist learning principles, empowering students to build personal understanding through digital exploration and critical reflection on current health challenges. Consequently, the e-module acts as both an educational resource and a vehicle for nurturing scientific thinking skills through genuine learning opportunities. Moreover, digital teaching materials can be presented interactively to visualize the material clearly through images, videos and animations, designed in an attractive way (Prextová & Knyblová, 2018). The components of the e-module can also attract students' interest in learning because it combines various media in the form of text, graphics, music, animation and video, so that students do not get bored just looking at writing (Aninditto et al., 2024; Talan & Widayati, 2023; Widiastuti, 2021).

Based on Table 6, it is known that the Asymp. Sig. value is 0.024 <0.05, then Ha is accepted, so it can be concluded that there is a difference in students' science literacy abilities between the control class and the control class. The difference in students' science literacy abilities is significant, so it can be said that there is an influence of the use of contextual-based interactive e-modules on the human respiratory system material on students' science literacy abilities. The greatest improvement occurred in the indicators of applying scientific knowledge in daily life and interpreting scientific data, demonstrating that e-module visibility for enhances students' ability to scientific literacy. Sitorus et al. (2023) states that contextual-based e-modules also help students experience what is being taught by referring to real-world phenomena or problems.

This finding is consistent with Sari and Prasetyo (2023), who found that contextual e-modules significantly improved scientific reasoning and awareness of global issues. In this study, the integration of quality education (SDGs 4) within the content proved crucial in fostering literacy development, as students not only learned physiological concepts but also examined how organ health is linked to sustainable lifestyles.

The e-modules provide convenience to students in the learning process because the description of the material and practice questions presented contain real problems (Fitriyani & Susanti, 2020). The presentation of materials that are related to the real world of students, and supported by images and videos, can encourage students to make connections between the knowledge they have and its application (Widiastuti, 2021). And in the e-module there are also various examples of questions that can help students master complex concepts. Constructivism in learning makes students able to connect each concept with the existing reality compared to how much students are able to remember the material (Nengsi et al., 2021). Isrok'atun and Rosmala (2018) states that providing questions that encourage students to present cases that occur in the surrounding environment that are related to the material being studied.

Indicators of science literacy are evaluating and designing science investigations and interpreting data and evidence scienceally in the experimental class better than the control class. This refers to the presence of contextual component indicators, namely asking and finding which are implemented in the e-module by displaying data in the form of graphs and tables, as well as the presence of practicums. This allows students to answer related questions from the results of reading tables, making practicum designs, reasons for choosing certain tools and materials in the experimental design, and determining sequentially the dependent variables, control variables, and independent variables in a practicum. The existence of practicums can hone students' science literacy skills in formulating problems, making hypotheses, designing practicums, conducting practicums, and formulating conclusions. This is a way for students to learn by searching for and finding their own answers to a problem that is questioned, which can make it easier for students to understand the concept (Muchindasari, 2016). The presence of sample questions and how to solve them in the e-module can also help students practice their problem-solving skills (Ramadayanty et al., 2021).

Meanwhile, the teaching materials used in the control class were non-electronic and non-contextual modules that did not contain case information and how to overcome organ system diseases based on research. The use of non-contextual teaching materials did not hone students' science literacy skills well. In fact, contextual teaching materials are very useful for students, where they can interpret lessons by linking material to events that occur in their environment (Fitriyani & Susanti, 2020).

Reflective activities such as "Science for Sustainability" further increased students' engagement and awareness of the social applications of science. These results support Bybee's (2016) view that scientific literacy is not limited to content mastery, but also involves the ability to use scientific knowledge responsibly in personal and societal decision-making.

Media and user validation results show that the e-module very valid for digital design, interactivity, and ease of navigation. Interactive features such as blood circulation simulations, auto-feedback quizzes, and 3D organ videos were highly effective in visualizing abstract biological processes. The student response survey based on figure 6 also indicated a high level of satisfaction (81% for interest, 82% for attention and 80% for response), confirming that the e-module is accessible across multiple devices (laptops, tablets, and smartphones). This demonstrates compliance with the Universal Design for Learning (UDL) framework, which emphasizes flexible, multimodal learning access for diverse learners (Novembli et al., 2024). Than based on Table 5, the average value of the post-test results in the experimental class is greater than the control class because the experimental class uses teaching materials in the form of interactive e-modules based on contextual while the control class uses teaching materials from the available textbooks.

The e-module's success in design can also be attributed to its user-centered design process, which incorporated direct feedback from teachers and students during development. The use of appealing visual layouts, comfortable color contrasts, and a simple yet content-rich interactive menu makes the e-module both technically and pedagogically feasible. Thus, the developed e-module not only meets the criteria for digital feasibility but also exemplifies a technology-enhanced learning model that aligns with the 21st-century educational demands. The design stage begins with creating a storyboard and e-module design. The e-module design can be seen in Figure 1. The e-module design consists of a cover, foreword, table of contents, list of images, learning outcomes, materials, case information, group discussions, quizzes, and experiments as well as summaries, and bibliographies. The e-module is equipped with images from international e-books, videos from YouTube, quizzes from Wordwall, group discussions and experiments via Google from, case information, and doctor's actions.

This study offers significant implications for both biology education and the advancement of the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education). By embedding SDG-related contexts into lessons on the human organ system, the e-module helps students move beyond conceptual understanding to internalize values of sustainability and social responsibility toward health.

For instance, activities in the respiratory system unit encourage students to analyze the effects of air pollution on lung function and relate them to SDG 13 (Climate Action). These contextual explorations foster scientific awareness and environmental ethics—key aspects of Education for Sustainable Development (ESD) (Samuelsson, 2022).

For biology teachers, the findings highlight that contextual interactive e-modules can effectively integrate scientific literacy and sustainability awareness simultaneously. This aligns with Indonesia's Merdeka Curriculum, which emphasizes project-based learning and the Pancasila Student Profile, particularly in fostering critical thinking and global awareness.

On a broader scale, implementing such e-modules supports the digital transformation of science education in Indonesia. Through the use of interactive and globally relevant digital media, biology learning can contribute directly to achieving the SDGs by promoting empowered, sustainability-oriented learners.

5. Conclusion

In conclusion, contextual-based interactive e-modules in biology learning can hone students' science literacy skills and increase students' interest and enthusiasm in learning biology. This study successfully connects biology learning with phenomena around students' environment, making abstract biological concepts more relevant and understandable to students. This study also shows that contextual-based interactive e-modules are well received by students and teachers, thereby increasing motivation and engagement in the learning process. In addition, e-modules effectively bridge the gap in biology education by combining real-world challenges and biological concepts. The implications of these results are enormous for the field of education, showing that integrating contextual elements into the curriculum can significantly improve students' science literacy skills. This research support SDGs program. The novelty of this study is seen in the application of cross-platform use in creating e-modules containing contextual-based biological concepts so that visibility for use.

Authors Contribution: I. Hamidah: methodology, conducting research at the define and design stage, and writing the original article, data analysis, and revision. **L. Luzyawati:** Research at the develop stage, making research instruments, Collecting quantitative and qualitative data, data analysis, and revision. **A. Ratnasari:** Quantitative and qualitative data processing, and revision.

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Research and Development in Education (RaDEn)

Research Article

Development of contextual interactive e-modules on the human organ system to support SDGs

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Abstract: Technology-based learning is one of the outcomes of the 4.0 industrial revolution that supports the implementation of Sustainable Development Goals (SDGs) in education The use of teaching materials in the form of contextual-based interactive e-modules is still rarely used in schools. The use of teaching materials that are common in schools are teaching materials that have been provided by the government and book publishers so that they are less in accordance with student needs. This study aims to produce contextual-based interactive e-modules on the material of the human organ system. This research is included in Research and Development (R&D), by following the Four-D development model consisting of the define, design, development, and disseminate stages. However, this study was limited to the development stage. The subjects of this study were two grade XI biology teachers at SMAN in Indramayu Regency, West Java, seven doctors, and four validators. The results of the study showed that the developed e-module obtained validation results in the context of material, language, and digital teaching materials that were very good with an average score of 96.82%. Further research can be continued at the disseminate stage to see the effectiveness of the e-module.

Keywords: biology learning; cross platform; organ system; science literacy; SDGs

1. Introduction

Driven by technological progress and evolving pedagogical landscapes, the 21st century biology education faces a novel set of challenges and prospects. This digital age demands the implementation of innovative teaching strategies that enable students to transition from theoretical comprehension of biology to the practical application of this knowledge in authentic, real-life situations (Aliqulovna, 2024). Technology-based learning is one of the outcomes of the 4.0 industrial revolution that supports the implementation of Sustainable Development Goals (SDGs) in education (Dito & Pujiastuti, 2021). The program aims to ensure inclusive and equitable quality education, support lifelong learning opportunities for all, and promote education for sustainable development. The target for 2030 is to ensure that all adolescents and a certain proportion of adults, both men and women, have numeracy and literacy skills.

Literacy has various types, one of which is science literacy. Science literacy is a person's ability to understand science, communicate science, and apply science knowledge to solve problems, so that it can improve attitudes and sensitivity to the surrounding environment (Virtič, 2022). Science literacy can help students understand and use science effectively, think critically, and make balanced and appropriate decisions regarding problems related to life (Hanson, 2022). Students need science literacy skills to analyze problems and relate them to various science facts (Oliver & Adkins, 2020). This ability is used to make decisions about problems related to natural phenomena and their impact on human life (Card, 2014).

The current condition of student science literacy in Indonesia is relatively low compared to other countries (OECD, 2023). The reality is that Indonesian students are not

yet able to understand science concepts and processes (Wiraputra et al., 2023). The low level of students' science literacy is one of the educational problems in Indonesia. Although the importance of science literacy has been recognized by all educators, it does not mean that students' science literacy is well trained (Elhai, 2023). This is supported by data on the achievement of Indonesian students' science literacy in the PISA science literacy assessment. Indonesia is ranked 68th with a science literacy score of 398 in 2022. The data shows that Indonesia's science literacy ranking has increased by 6 positions compared to before, but the decline in science literacy ability has fallen by 13 points, almost equivalent to the international average of 12 points. As many as 52% of countries participating in PISA in 2022 experienced a decline in science literacy scores compared to PISA in 2018 (Kemendikbudristek, 2023). There are factors that influence the lack of students' science literacy, namely the lack of materials or teaching materials circulating in Indonesia, when compared with other countries in developing students' science literacy (Agustin & Supahar, 2021).

To foster profound conceptual understanding and scientific literacy, pedagogical approach necessitates commencing with concrete socioscientific problems and progressing to active, evidence-centered practices, thereby ensuring the integration of content with sustained student engagement in the location, interpretation, and application of scientific evidence (Appiah-Adjei, 2025). Improving science literacy skills can be done by focusing on science argumentation, understanding science phenomena, and the process of science discovery. Additionally, factors like guidance level, teaching strategy, gender, and intervention domain significantly influence effectiveness (Han, 2021; van Leeuwen & Janssen, 2019). Many previous researchers have done this as an effort to improve science literacy, including the use of problem-based learning models, SSI integrated PjBL-STEAM (Reswara et al., 2024), learning media such as interactive multimedia (Sari et al., 2022), QR code-based learning, interactive learning media, web-based resources. In addition, there is a need for support in learning to improve science literacy skills, one of which is using teaching materials or modules.

Modules are basically teaching materials created for the purpose of independent learning for students with complete content (Kizi, 2022). The 21st century learning in the Industrial Revolution 4.0 requires innovation and optimal use of technology, technological developments change the orientation of learning from conventional to digital learning (Khan et al., 2024). Therefore, it is necessary to develop teaching modules such as digital teaching modules or e-modules.

The benefits of e-modules can be presented interactively to visualize the material clearly through images, videos and animations, designed attractively and can interact with students (Sidiq et al., 2021). Digital e-modules can be in the form of systematically structured textbooks that can present material (Mulyadi et al., 2020). The development of interactive e-modules has been carried out by Herawati and Muhtadi (2020) in chemistry subjects and accessed using Compact Disk (CD). However, web-based E-modules are more efficient when they can be accessed from various digital devices such as PCs, laptops, tablets, and smartphones using the same application or called cross-platform. The term cross-platform is used in information technology to describe software that can run on various operating systems, such as Microsoft Windows, Linux, Mac OS, BSD and mobile versions, including Android, iOS, Windows Mobile (Robianto, 2020). Cross-platform in making digital teaching materials can be used on various platforms and operating systems, so it is not limited to one type of device (Segun-Falade et al., 2024). The use of cross-platform considers technology as a communication tool so that it supports students to learn, do assignments, and search for various information (Krause et al., 2022). In addition, data integration in the system can provide students with broad insights and increase learning effectiveness (Evenddy et al., 2021). Therefore, the development of e-

modules that have been carried out previously can be developed again by presenting contextual-based materials and using Cross Platform applications.

The implementation of e-modules using Cross Platform can be implemented on contextual materials. Contextual-based interactive e-modules are interactive electronic teaching materials that contain academic materials and real-life contexts (Marta et al., 2023). The learning process involves students being able to relate academic learning to the real-life context faced by students (Haryanto & Arty, 2019). However, the use of contextual-based teaching modules is still rarely found in schools. Nurhamdiah et al. (2020) stated that currently teachers are still using textbooks provided by the government (schools) and private book publishers. In addition, the textbooks currently used are mostly not based on local content or the context surrounding students' lives (Flores, 2021). This is supported by Barus et al (2024) which states that until now there has been no book/teaching module found that is in accordance with students' needs and is able to link the material being studied with contextual and real-life-oriented learning characteristics.

Many contextual-based e-modules on organ systems have been developed. However, so far there are no e-modules that contain interviews with doctors and disease case data. The contextual e-module in this study was developed based on research findings regarding data on diseases suffered by the people of West Java and interviews with doctors about the causes, transmission/mechanism of disease, and treatment of these diseases.

Contextual-based interactive e-modules on various organ system materials are combine context-based learning and technology to create an easy, engaging, and effective learning experience. This is an innovative solution to improve student science literacy, thereby supporting the SDGs. The purpose of this study is to determine the feasibility of contextual-based e-modules as an effort to improve students' science literacy skills to support SDGs.

2. Materials and Methods

2.1 Types of research

This study uses a Research and Development (R&D) approach based on 4D development research with four stages: Define, Design, Development, and Disseminate (Thiagarajan et al., 1974). At the define stage, researchers conducted preliminary research including needs analysis both theoretically and empirically, curriculum analysis, and learning material analysis. At the design stage, researchers began designing contextual-based interactive digital module products using the Cross Platform application, creating storyboards, and preparing science literacy instruments. The literacy instruments used were instruments developed by Luzyawati et al. (2025) which can be accessed at https://books.biounwir.ac.id/instrumen-literasi-sains.html. At the development stage, the researcher began to validate (content and construct) to four validators (two expert validators and two practitioners) to assess the developed product, in addition, at this stage a scale test was carried out involving 72 high school students in West Java who were taken using the proportional random sampling technique.

2.2 Research subjects and objects

The subjects of this study were determined by proportional random sampling. The subjects of the study at the define stage were two biology teachers of grade XI of SMAN in West Java Province, Indonesia and six doctors. The subjects of the study at the development stage were four validators, consisting of one lecturer expert in human anatomy and physiology, and one lecturer expert in digital learning, and two biology teachers as practitioners. The population for the small-scale test was grade XI of 264

students at SMAN 1 Indramayu with a total research sample of 72 students as the control and experimental classes.

2.3 Data types and sources

The type of data used in this study is primary data. Primary data consists of: Primary data consists of: the results of needs analysis interviews and contextual material analysis, observation sheets, product validation sheets validated by four validators, and science literacy test instruments and questionnaires.

2.4 Data collection technique

The instruments used in this study were interview sheets, observation sheets, product validation sheets, science literacy test instruments, and questionnaires. Interview and observation sheets were used in preliminary research for needs analysis and contextual material analysis. Structured interviews were conducted to determine the teaching materials used by teachers in the subject of biology for grade XI, the availability of contextual-based interactive e-modules and teacher knowledge about Cross Platform. Structured interviews were conducted using a list of questions that had been created based on the objectives to be known in the study (Taherdoost, 2022). Contextual analysis was conducted at the Hospital and Health Office using observation sheet instruments and semi-structured interviews. Semi-structured interviews aim to find more open problems, where the interviewees are asked for their opinions and ideas (Sugiyono, 2021). Interviews with seven doctors were administered to provide contextual material for the module, eliciting information on disease causes, transmission mechanisms, and strategies for management or control.

Expert validation instruments are used at the development stage to assess the products being developed. This validation focuses on human organ system materials, language, and digital teaching materials. The science literacy test instrument is used to measure students' science literacy skills in the experimental and control classes. Meanwhile, the questionnaire instrument is used to determine students' responses to the cross-platform interactive digital module based on contextual which is distributed to students at the end of the learning.

2.5 Data Analysis Techniques

The data analysis technique of this research uses the atlas.ti application for qualitative data from interviews. The results of the validity of experts or experts in assessing the products developed using a Likert scale of 1-5 in the form of scores from the assessment of six validators. The data is then analyzed and categorized using the validation Formula 1 proposed by Purwanto (2020).

$$\frac{Score\ obtained \times 100\%}{Total\ Score} \quad (1)$$

Then, a conversion of the achievement level scale is carried out to determine the level of product feasibility (validity) in Table 1.

Table 1. Scale of achievement levels (Riduwan, 2015)

Percentage	Validity Level
81% - 100%	Very valid
61% - 80%	Valid
41% - 60%	Quite valid
21% - 40%	Not valid
0%-20%	Very invalid

The data of the results of students' science literacy abilities measured from the post-test results of the experimental class and control class were processed using the SPSS 25 application. The prerequisite analysis test used the Kolmogorov Smirnov normality test to determine whether the population sample was normally distributed or not. Furthermore, because the research data produced by both were not normally distributed, it was continued using non-parametric statistics, namely the Mann Whitney Test. Meanwhile, the questionnaire data obtained were the responses of students in the experimental class who were given treatment in the form of a contextual-based interactive digital module with 10 statement items in the questionnaire measured on a Likert scale (1 to 4). The percentage of student responses is calculated using the Formula 2.

$$P = \frac{\sum x}{\sum i} \times 100\% \quad (2)$$

Information:
P = Percentage
∑x = Total number of respondents' answers in all items
∑i = The total number of ideal scores per item

To determine the criteria based on each indicator with the interpretation criteria contained in Table 2 (Mardianto et al., 2022).

Table 2. Student response criteria

Percentage	Category
85% ≤ RS	Very Positive
70% ≤ RS < 85%	Positive
50% ≤ RS < 70%	Less Positive
RS < 50%	Not Positive

3. Results

At the define stage, researchers conducted a needs analysis. Based on the results of interviews with biology teachers in West Java, it was shown that their schools did not have biology teaching modules in printed or electronic form. They have never developed teaching materials in the form of teaching modules independently because the teaching materials used during biology learning are only textbooks, independent books, learning videos, and worksheets. The results of interviews with teachers stated that electronic teaching materials have benefits in learning such as being fast and easy to apply, easy to carry and practical because they can be used anywhere and anytime, interesting, and presented and explained in the form of real images and movements. However, they do not yet know the cross-platform application that can be used to help them in making teaching materials. Material analysis is carried out based on contextual analysis and curriculum analysis.

Contextual analysis was obtained from observations at Hospitals and Health Offices regarding data on diseases affecting the people of West Java, as well as interviews with seven doctors, including both general practitioners and specialists. While the curriculum analysis is based on the learning achievements of phase F class XI in the independent learning curriculum and contextual indicators. The results of the analysis of the human organ system curriculum for making e-modules can be seen in Table 3.

Head of the education standards, curriculum and assessment agency of the Ministry of Education, Culture, Research and Technology (Kementerian Pendidikan, Kebudayaan, Riset, 2024) states that there are two elements of learning achievement in phase F of class XI, namely the element of understanding biology and the element of process skills. Table 3 shows that the learning achievement in the element of understanding biology is the relationship between the structure of organs in the organ system and their functions in

responding to internal and external stimuli. While the learning achievement in the element of process skills is observing, questioning and predicting, planning and conducting investigations, processing, analyzing data and information, evaluating and reflecting, and communicating the results.

Table 3. Analysis of human organ system curriculum for e-module creation

Understanding Biology: Structure of organs in the organ system with their functions in responding to internal and external stimuli.		
Process Skills	Contextual Indicators	E-module Material Content
-	Encourage students to make connections between knowledge and its application.	1. Analytical questions about various organs, and application questions about breathing situations in the mountains 2. Videos about the processes, mechanisms, and work of organs 3. Doctor's actions
	Modeling	Example of procedural questions
Observing	- Relating the material taught to the real world situations of students. - Constructivism	1. Information on cases of human diseases 2. Videos of daily human activities
Questioning and predicting	- Finding - Constructivism - Learning society	- Diskusi kelompok untuk membuat rumusan masalah dan hipotesis dari fenomena berbagai penyakit pada organ.
Planning and conducting investigations	- Asking - Constructivism - Learning society	- Practical and quizzes
Processing, analyzing data and information	- Relate the material taught to the real world situations of students. - Asking - Constructivism - Learning community	- Graphs and tables of data on various human diseases to be discussed with the group - Quiz to read tables about data on cases of disorders and abnormalities in human organs
	- Asking - Learning community	Questions about the practicum
Evaluating and reflecting	Learning community	Instructions for making a lab report

The design stage begins with creating a storyboard and e-module design. A cross-platform e-module application (compatible with iOS, Android, and Windows) is offered for installation via the website https://mebio.biounwir.ac.id/. This instructional module comprehensively covers the human organ system, including digestion, movement, excretion, circulation, reproduction, respiration, and coordination. Every e-modules design consiste of a cover, Instructions for use, foreword, list of contents, learning out comes, content, summary and references. In the e-module, images from international ebooks, videos from YouTube, quizzes from wordwall, group discussions and experiments via Google from, case information, and doctor's actions are added. can be seen in Figure 1.

The e-module that has been created is then validated by experts and practitioners. The validation results can be seen in Table 4. Based on Table 4 it can be seen that the validity of the digital module falls into the very valid criteria both in terms of material content, digital teaching material content, and language. The form of the e-module is presented in Figure 2, Figure 3 and Figure 4.

The product developed in the form of an e-module can be accessed both through cellphones and computer/laptop devices. The cover looks like in Figure 4. The e-module is contextually based which is based on the results of observation of public health data from health facilities spread across West Java and the results of interviews with seven doctors, both general practitioners and specialists. The results of the interview with the doctor are presented in the explanation of the disease or in the doctor's action column. Meanwhile, the results of observations are expressed in the form of case information. An example of the presentation in the e-module can be seen in Figure 3 and Figure 4.

The e-module that has been made is then tested on a small-scale test and sees the students' science literacy skills after learning. The results of the post-test are then analyzed using descriptive analysis and then the prerequisite test, namely the normality test using Kolmogorov Smirnov. The results of the prerequisite test show that the data from both classes are not normally distributed, so the hypothesis test uses non-parametric statistics, namely the U Mann Whitney test.

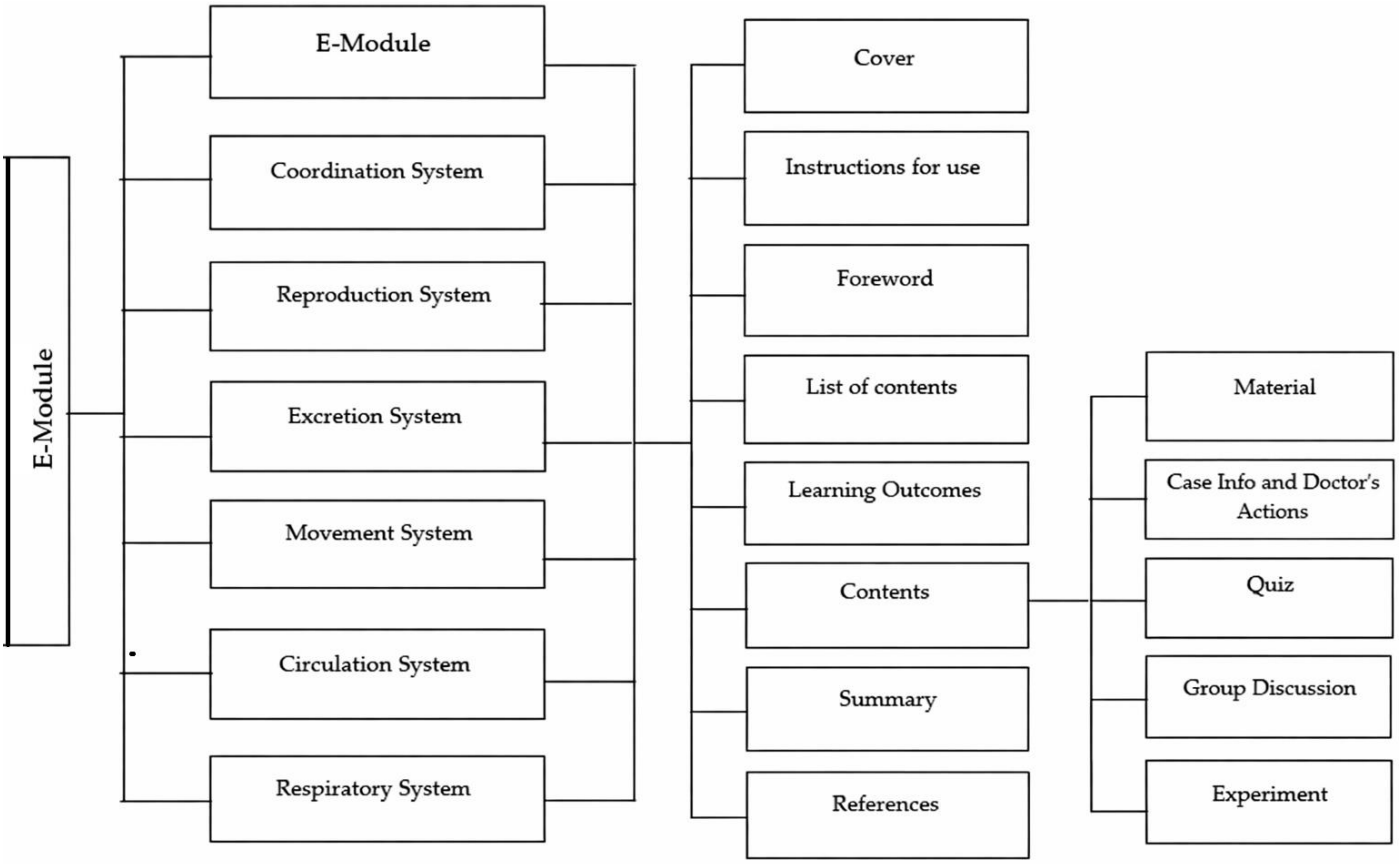

Figure 1. Contextual-based interactive e-module design using cross platform

Table 4. Validation results of interactive e-module products on human organ system material using Cross Platform by experts or specialists

Validator	Aspect		
	Human Organ System Material	Digital Teaching Materials	Linguistics
Material Expert	97.14 %	-	-
Digital Teaching Material Expert	-	85.19%	-
Language Expert	-	-	96.67%
Practitioner 1	100%	100%	100%
Practitioner 2	97.14%	98.52%	95%
Practitioner 3	97.14%	100%	95%
Average	97.86%	95.93%	96,67%
Criteria	Very Valid	Very Valid	Very Valid
Average	96.82%		
Criteria	Very Valid		

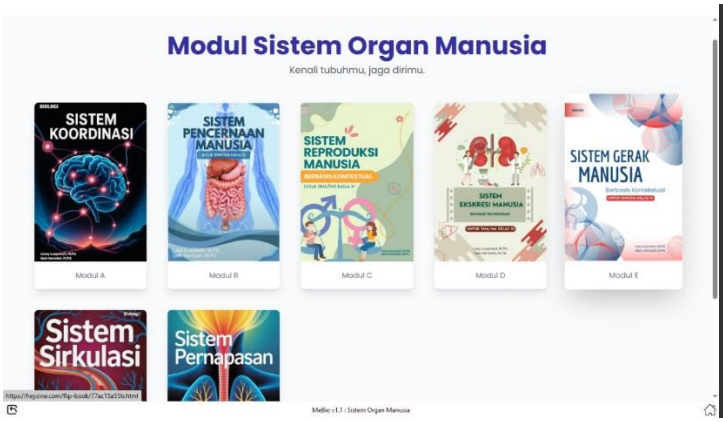

Figure 2. Cover e-module

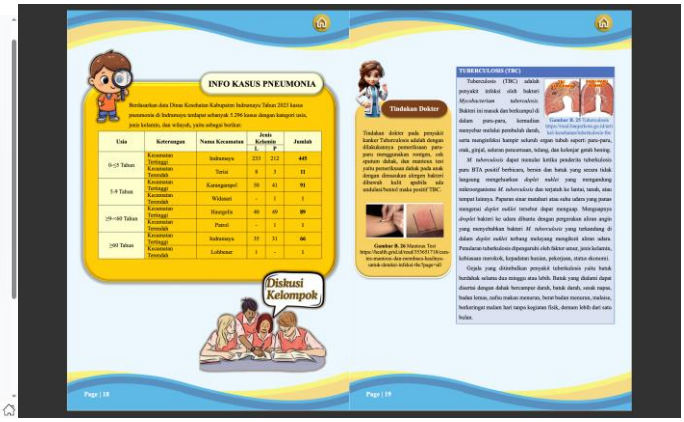

Figure 3. Case info of the content

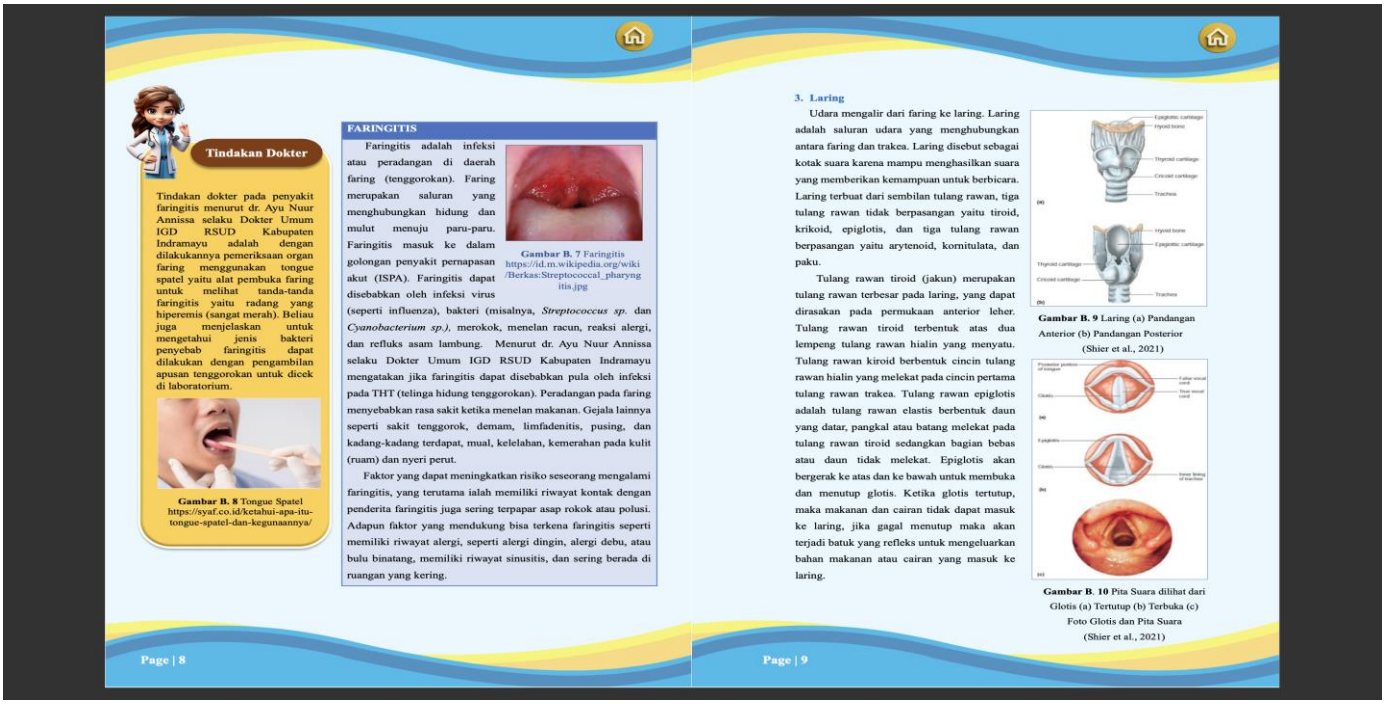

Figure 4. The content of e-module

Table 5. Descriptive analysis of posttest of experimental class and control class

Class	Experiment	Control
Valid	36	36
Mean	63.19	55.28
Std. Deviation	15.77	12.36
Variance	248.79	152.77
Range	60	55
Minimum	30	20
Maximal	90	75
Sum	2275	1990

Based on Table 5, the average value of the post-test results in the experimental class is greater than the control class because the experimental class uses teaching materials in the form of interactive e-modules based on contextual while the control class uses teaching materials from available textbooks. In addition, in the learning process, students are

involved creatively to improve their thinking skills which results in better learning outcomes.

Based on Table 6, it is known that the Asymp. Sig. value is 0.024 <0.05, then Ha is accepted, so it can be concluded that there is a difference in students' science literacy abilities between the control class and the control class. The difference in students' science literacy abilities is significant, so it can be said that there is an influence of the use of contextual-based interactive e-modules on the human respiratory system material on students' science literacy abilities.

Table 6. Mann Whitney Test Results

Test Statistics[a]	
	Student Science Literacy Ability Results
Mann-Whitney U	448.500
Wilcoxon W	1114.500
Z	-2.264
Asymp. Sig. (2-tailed)	.024

a. Grouping Variable: Class

Based on Figure 5, it shows the difference in the results of students' science literacy skills between the experimental class and the control class. The percentage of indicators explaining phenomena scienceally in the experimental class is better than the control class. The student response to the contextual-based interactive e-module can also be seen in Figure 6.

Based on Figure 6, it shows that student responses to contextual-based interactive e-modules are in the positive category for each indicator. Most students enjoy learning using contextual-based interactive e-modules because the learning materials are linked to real life around them and are flexible in their use.

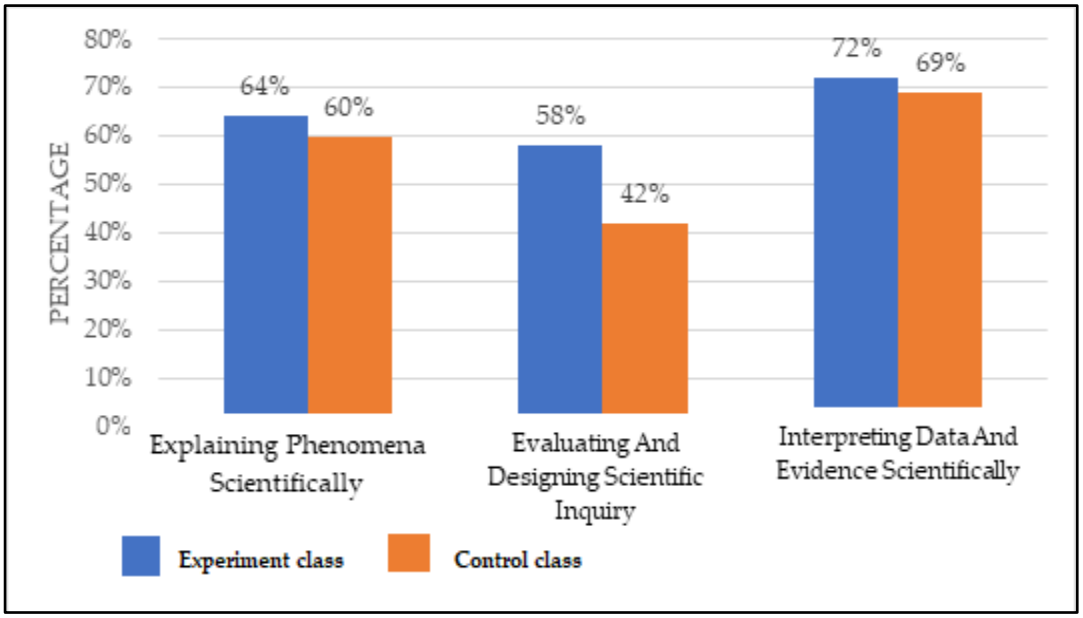

Figure 5. Percentage of science literacy ability results

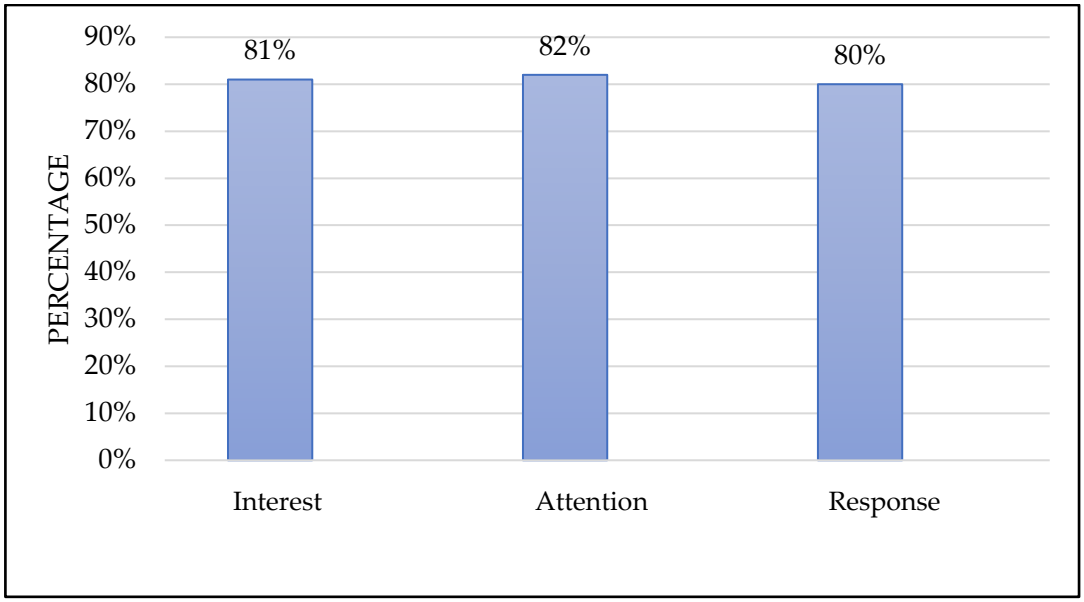

Figure 6. Results of student response questionnaire analysis

4. Discussion

Current scholarly literature successfully uncovers crucial perspectives regarding the cross-platform landscape in education, particularly those relevant to biology learning. The newly developed contextual interactive e-module demonstrates a robust fidelity to the core tenets of contextual teaching. This module seamlessly incorporates all seven critical contextual teaching components—constructivism, inquiry, questioning, learning community, modeling, reflection, and authentic assessment—across all its instructional activities (Aliyyah et al., 2020).

Dewi (2020) states that there are two contextual indicators, namely contextual nature and contextual components. Contextual nature is the relationship between the material taught and the real-world situation of students, as well as the ability to encourage students to make connections between the knowledge they have and its application in everyday life (Sujiono et al., 2023). A key example is the digestive system unit, where students are prompted to analyze their own dietary practices and establish connections between these habits and the functions of various digestive organs, thereby creating significant links between scientific concepts and real-world scenarios.

Expert evaluations on pedagogy confirmed the high relevance of the context, awarding a mean score of 96,82% ('very valid'). This validation affirms the module's success in grounding learning materials in the students' daily experiences. This outcome aligns with Andrews et al (2023) argument that learning becomes meaningful when students can relate academic content to authentic, practical situations.

The aspect of digital teaching materials in the developed e-module has a very good feasibility value. This shows that the module size is appropriate, the module cover design, and the module content design are good. Dini and Selina (2024) stated that the success of an attractive and unique design can create a strong visual appeal, thus encouraging reader interest. Meanwhile, the linguistic aspect of the e-module also has a good feasibility value. This shows that the e-module has a straightforward, communicative, dialogic and interactive language, in accordance with student development, in accordance with language rules, and the use of appropriate symbols or icons. In accordance with Nurlatifah and Suprihatiningrum (2023) states that the language used in the e-module must make it easier for students to understand the material by paying attention to the use of communicative, dialogic, interactive, straightforward, coherent language, in accordance with Indonesian language rules, and the accuracy of terms and symbols. However, in both

aspects there are improvements according to the validator's results, namely adding sentences of work commands or information to quizzes, group discussions, and experimental discussion results to make it easier for students to work. Fauzi et al. (2021) stating that the imperative sentence contains clear instructions on how to work on the problem so that it makes it easier for students to work on it.

Based on Table 3 on the elements of understanding biology can be combined with contextual indicators to encourage students to make connections between knowledge and its application. Its implementation in the e-module by providing analytical questions to be discussed, videos and learning materials, and doctor's actions. This is intended so that students can make connections between knowledge and its application. The relevance of learning to the real world of students and encouraging students to make connections between the knowledge they have and its application in everyday life (Morra, 2018; Akcay, 2017; Kamdi, 2015). Several examples of procedural questions are presented in the e-module as an implementation of modeling indicators. Modeling is a learning process by providing examples that can be imitated by students (Humeijia, 2021).

Furthermore, the contextual methodology employed in this e-module bolsters constructivist learning principles, empowering students to build personal understanding through digital exploration and critical reflection on current health challenges. Consequently, the e-module acts as both an educational resource and a vehicle for nurturing scientific thinking skills through genuine learning opportunities. Moreover, digital teaching materials can be presented interactively to visualize the material clearly through images, videos and animations, designed in an attractive way (Prextová & Knyblová, 2018). The components of the e-module can also attract students' interest in learning because it combines various media in the form of text, graphics, music, animation and video, so that students do not get bored just looking at writing (Aninditto et al., 2024; Talan & Widayati, 2023; Widiastuti, 2021).

Based on Table 6, it is known that the Asymp. Sig. value is 0.024 <0.05, then Ha is accepted, so it can be concluded that there is a difference in students' science literacy abilities between the control class and the control class. The difference in students' science literacy abilities is significant, so it can be said that there is an influence of the use of contextual-based interactive e-modules on the human respiratory system material on students' science literacy abilities. The greatest improvement occurred in the indicators of applying scientific knowledge in daily life and interpreting scientific data, demonstrating that e-module visibility for enhances students' ability to scientific literacy. Sitorus et al. (2023) states that contextual-based e-modules also help students experience what is being taught by referring to real-world phenomena or problems.

This finding is consistent with Sari and Prasetyo (2023), who found that contextual e-modules significantly improved scientific reasoning and awareness of global issues. In this study, the integration of quality education (SDGs 4) within the content proved crucial in fostering literacy development, as students not only learned physiological concepts but also examined how organ health is linked to sustainable lifestyles.

The e-modules provide convenience to students in the learning process because the description of the material and practice questions presented contain real problems (Fitriyani & Susanti, 2020). The presentation of materials that are related to the real world of students, and supported by images and videos, can encourage students to make connections between the knowledge they have and its application (Widiastuti, 2021). And in the e-module there are also various examples of questions that can help students master complex concepts. Constructivism in learning makes students able to connect each concept with the existing reality compared to how much students are able to remember the material (Nengsi et al., 2021). Isrok'atun and Rosmala (2018) states that providing questions that encourage students to present cases that occur in the surrounding environment that are related to the material being studied.

Indicators of science literacy are evaluating and designing science investigations and interpreting data and evidence scienceally in the experimental class better than the control class. This refers to the presence of contextual component indicators, namely asking and finding which are implemented in the e-module by displaying data in the form of graphs and tables, as well as the presence of practicums. This allows students to answer related questions from the results of reading tables, making practicum designs, reasons for choosing certain tools and materials in the experimental design, and determining sequentially the dependent variables, control variables, and independent variables in a practicum. The existence of practicums can hone students' science literacy skills in formulating problems, making hypotheses, designing practicums, conducting practicums, and formulating conclusions. This is a way for students to learn by searching for and finding their own answers to a problem that is questioned, which can make it easier for students to understand the concept (Muchindasari, 2016). The presence of sample questions and how to solve them in the e-module can also help students practice their problem-solving skills (Ramadayanty et al., 2021).

Meanwhile, the teaching materials used in the control class were non-electronic and non-contextual modules that did not contain case information and how to overcome organ system diseases based on research. The use of non-contextual teaching materials did not hone students' science literacy skills well. In fact, contextual teaching materials are very useful for students, where they can interpret lessons by linking material to events that occur in their environment (Fitriyani & Susanti, 2020).

Reflective activities such as “Science for Sustainability” further increased students’ engagement and awareness of the social applications of science. These results support Bybee’s (2016) view that scientific literacy is not limited to content mastery, but also involves the ability to use scientific knowledge responsibly in personal and societal decision-making.

Media and user validation results show that the e-module very valid for digital design, interactivity, and ease of navigation. Interactive features such as blood circulation simulations, auto-feedback quizzes, and 3D organ videos were highly effective in visualizing abstract biological processes. The student response survey based on figure 6 also indicated a high level of satisfaction (81% for interest, 82% for attention and 80% for response), confirming that the e-module is accessible across multiple devices (laptops, tablets, and smartphones). This demonstrates compliance with the Universal Design for Learning (UDL) framework, which emphasizes flexible, multimodal learning access for diverse learners (Novembli et al., 2024). Than based on Table 5, the average value of the post-test results in the experimental class is greater than the control class because the experimental class uses teaching materials in the form of interactive e-modules based on contextual while the control class uses teaching materials from the available textbooks.

The e-module’s success in design can also be attributed to its user-centered design process, which incorporated direct feedback from teachers and students during development. The use of appealing visual layouts, comfortable color contrasts, and a simple yet content-rich interactive menu makes the e-module both technically and pedagogically feasible. Thus, the developed e-module not only meets the criteria for digital feasibility but also exemplifies a technology-enhanced learning model that aligns with the 21st-century educational demands. The design stage begins with creating a storyboard and e-module design. The e-module design can be seen in Figure 1. The e-module design consists of a cover, foreword, table of contents, list of images, learning outcomes, materials, case information, group discussions, quizzes, and experiments as well as summaries, and bibliographies. The e-module is equipped with images from international e-books, videos from YouTube, quizzes from Wordwall, group discussions and experiments via Google from, case information, and doctor's actions.

This study offers significant implications for both biology education and the advancement of the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education). By embedding SDG-related contexts into lessons on the human organ system, the e-module helps students move beyond conceptual understanding to internalize values of sustainability and social responsibility toward health.

For instance, activities in the respiratory system unit encourage students to analyze the effects of air pollution on lung function and relate them to SDG 13 (Climate Action). These contextual explorations foster scientific awareness and environmental ethics—key aspects of Education for Sustainable Development (ESD) (Samuelsson, 2022).

For biology teachers, the findings highlight that contextual interactive e-modules can effectively integrate scientific literacy and sustainability awareness simultaneously. This aligns with Indonesia's Merdeka Curriculum, which emphasizes project-based learning and the Pancasila Student Profile, particularly in fostering critical thinking and global awareness.

On a broader scale, implementing such e-modules supports the digital transformation of science education in Indonesia. Through the use of interactive and globally relevant digital media, biology learning can contribute directly to achieving the SDGs by promoting empowered, sustainability-oriented learners.

5. Conclusion

In conclusion, contextual-based interactive e-modules in biology learning can hone students' science literacy skills and increase students' interest and enthusiasm in learning biology. This study successfully connects biology learning with phenomena around students' environment, making abstract biological concepts more relevant and understandable to students. This study also shows that contextual-based interactive e-modules are well received by students and teachers, thereby increasing motivation and engagement in the learning process. In addition, e-modules effectively bridge the gap in biology education by combining real-world challenges and biological concepts. The implications of these results are enormous for the field of education, showing that integrating contextual elements into the curriculum can significantly improve students' science literacy skills. This research support SDGs program. The novelty of this study is seen in the application of cross-platform use in creating e-modules containing contextual-based biological concepts so that visibility for use.

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