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Development of a Problem-Based Learning-Based E-Module to Facilitate Students' Scientific Literacy on the Topic of Excretory System Disorders Due to Imbalanced Nutritional Intake

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Abstract

Indonesian students' scientific literacy competence remains below the international average, partly due to teachers' limited optimization in training this competence during the learning process. This study aimed to develop a Problem Based Learning (PBL)-based e-module to facilitate students' scientific literacy competence on the topic of excretory system disorders due to imbalanced nutritional intake, and to examine its feasibility and practicality. This study employed a Research and Development (R&D) approach with the 4D model, limited to the Develop stage. The e-module was tested at a public junior secondary school in Malang City through validation, practicality, and readability tests. Data were analyzed using Likert and Guttman scales, as well as Inter-Rater Agreement (IRA). Validation by two experts yielded an average score of 93.36% (highly feasible), while practicality testing by four science teachers produced 99.8% (highly feasible). Readability testing among 35 students resulted in 88.76% (highly feasible). IRA results showed agreement levels of 100% for the alignment between learning activities and PBL syntax, and 88.88% for alignment with scientific literacy competence. These findings indicate that the developed PBL-based e-module is feasible and practical for facilitating students' scientific literacy competence on the topic of excretory system disorders due to imbalanced nutritional intake.

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1. INTRODUCTION

The 21st century has brought substantial change across many aspects of life, including education. These changes require students to master new competencies, one of which is scientific literacy (Mopara & Sanrattana, 2023). Scientific literacy competence helps students achieve better and more meaningful learning outcomes in science while deepening their understanding of various scientific concepts (Junanto et al., 2024). It also generates broad benefits for both individuals and society (Eviota & Liangco, 2020), making it a critical asset for finding appropriate solutions, particularly when addressing problems that require scientific understanding (Anggraeni et al., 2022).

Unfortunately, Indonesian students' scientific literacy competence remains below the international average and has tended to decline over the years. This is reflected in Indonesia's average scores in the PISA (Program for International Student Assessment) survey conducted by the OECD (Organisation for Economic Cooperation and Development) from 2006 to 2022, recorded at 393 in 2006, 383 in 2009, 382 in 2012, 403 in 2015, 396 in 2018, and back to 383 in 2022 (OECD, 2023a). One contributing factor is teachers' limited optimization in facilitating the development of scientific literacy competence during learning (Sarini et al.,

2024). The problem addressed in this study, therefore, concerns not only students' low scientific literacy achievement, but also the limited classroom practices designed to develop this competence.

This problem is also evident in classroom practice. A needs analysis conducted with teachers at a public junior secondary school in Malang City showed that science instruction remains dominated by lectures followed by note-taking from PowerPoint slides, assignments, textbook-based discussion questions, practical activities, and presentations. The topic of excretory system disorders, despite its importance, is still taught only to a limited extent because it is not covered in the science textbook used. Scientific literacy competence has likewise not been specifically trained and has only been introduced through student worksheets (LKPD). Furthermore, no technology-based learning resource is yet available to support the development of this competence. This condition aligns with findings indicating that learning remains largely teacher-centered through lectures and note-taking (Ndari et al., 2023) As a result, students tend to play a passive role and easily lose focus (Wulandari, 2022). Although discussion-based learning can enhance student engagement when effectively designed (Arhas et al., 2023), the development of scientific literacy in classrooms is still often confined to textbook reading activities and rarely connected to real-world problems relevant to students' daily lives (Husniyyah et al., 2023).

The topic of excretory system disorders becomes increasingly relevant when linked to the growing number of adolescents undergoing dialysis in recent years (Nasution et al., 2025), a trend largely driven by habits of consuming foods high in sugar, salt, and fat combined with insufficient physical activity (Kusumarini et al., 2025)**.** This phenomenon aligns with the health context within the PISA scientific literacy framework, which spans personal, local, and global issues (OECD, 2019). Students' understanding of excretory system disorders matters not only for their personal health, but also for broader public health concerns (Lasminawati et al., 2022).

A range of previous studies has shown that Problem Based Learning (PBL) is effective in enhancing students' scientific literacy, and PBL-based e-modules have likewise been developed across various learning topics. However, based on the literature reviewed, no study has been found that specifically develops a PBL-based e-module to facilitate scientific literacy on the topic of excretory system disorders due to imbalanced nutritional intake. This indicates a research gap that simultaneously constitutes the novelty of this study, namely: (1) the use of the excretory system disorder topic linked to the growing phenomenon of dialysis cases among adolescents; (2) the explicit integration of PBL syntax with scientific literacy competence in every learning activity; and (3) the development of an e-module equipped with technology-based interactive features to support flexible learning.

Building on this gap, the present study aims to develop a Problem Based Learning (PBL)-based e-module to facilitate students' scientific literacy competence on the topic of excretory system disorders due to imbalanced nutritional intake, and to examine its feasibility and practicality. Beyond facilitating scientific literacy, the e-module is also designed to support the development of 21st-century competencies, particularly communication, creativity, and collaboration, through the use of technology. This e-module is therefore expected to serve as an innovative alternative learning resource, as well as a reference for developing other PBL-based teaching materials on different topics.

2. LITERATURE REVIEW

Scientific Literacy

Scientific literacy is the ability to understand and assist in decision-making regarding the natural environment and the changes brought about by human activity, by using scientific knowledge, formulating questions, and drawing conclusions supported by data (OECD, 2023b). The Programme for International Student Assessment (PISA) 2025 framework describes scientific literacy through four interrelated components: context, knowledge, competence, and scientific identity. PISA 2025 also establishes three core indicators of scientific literacy: explaining phenomena scientifically; designing and evaluating scientific inquiry while critically interpreting data and evidence; and using scientific information to inform decisions and actions (OECD, 2023b). One context emphasized within this framework is the health context, which spans personal, local, and global issues (OECD, 2019) and is directly relevant to the topic examined in this study.

Problem Based Learning (PBL)

Problem Based Learning (PBL) is a learning model that helps students practice problem-solving competence and construct new knowledge through the investigation of real-world problems (Simanjuntak et al., 2021). This model follows a systematic syntax: 1) orienting students to a problem; 2) organizing students for learning; 3) guiding group investigation; 4) developing and presenting the outcome; and 5) analyzing and evaluating the problem-solving process (Arends, 2012; Tiara et al., 2024). Within this model, students take center stage as active learners in solving contextual, real-world problems, while teachers act as facilitators (Nurkolis, 2022). As a result, students are trained not only in critical thinking, but also in collaborating, communicating, and developing creativity in seeking solutions to the problems they face (Ali, 2019). PBL has

likewise been shown to be effective in training students' scientific literacy (Syamsinar et al., 2023). Through problem investigation, students learn to search for, comprehend, and evaluate scientific information from various sources, and to connect it with relevant scientific concepts. This process strengthens scientific reasoning, the ability to read scientific texts, and an understanding of the relationship between science, technology, and the environment, which are core components of scientific literacy (Malika, 2020). The effectiveness of PBL at the junior secondary level has also been demonstrated for a related competence, namely critical thinking, where it outperformed the Search, Solve, Create, and Share model (Laili et al., 2024).

E-Modules as a Learning Medium

Implementing PBL to train scientific literacy competence requires teachers who are able to utilize technology in learning, since mastery of both subject matter and technology is key to facilitating meaningful learning experiences (Dinelti Fitria et al., 2023). This need has encouraged the provision of digital-based teaching materials, one of which is the e-module, a form of teaching material that also serves as a digital learning medium accessible through devices such as smartphones, laptops, and PCs (Hasni et al., 2024). A similar need has also been found for other human body system topics, such as the respiratory system, where junior secondary students required technology-based supplementary materials to better understand the material (Nugroho et al., 2021).

As a learning resource, e-modules can stimulate learning activities and increase student motivation, making learning feel more interactive, enjoyable, and flexible due to ease of access (Aninditto et al., 2024). E-modules are also efficient in supporting learning activities for material considered difficult (Mulyadi et al., 2020). However, not all e-modules offer the same level of interactivity; some contain only text and images without interactive elements, which limits student engagement (Anwar et al., 2021). In contrast, interactive e-modules combine animated videos, images, quizzes, and audio that support 21st-century competencies such as collaboration, creativity, critical thinking, and communication, while also enabling independent learning, exploration of information from various digital sources, and collaboration both individually and in groups (Resmanti et al., 2024).

Excretory System Disorders as a Learning Topic

The excretory system is an important topic in science learning because it is directly related to the body's function in removing waste and maintaining health, encompassing the structure and function of excretory organs as well as the various disorders that may occur (Rizalia et al., 2024). The nature of this topic allows students to connect scientific concepts with various health issues occurring in their surrounding environment, making it a potentially effective context for training scientific literacy (Putri & Kuswanti, 2025). A similar potential has also been found for the respiratory system, which was shown to be effective in improving junior secondary students' scientific literacy (Antika et al., 2024), indicating that human body system topics in general are well suited as a context for scientific literacy learning. Unfortunately, science learning in schools often fails to connect scientific concepts with students' real-world experiences, leaving them less aware of the material's relevance to their own lives (Nakamura et al., 2024). Yet understanding excretory system disorders matters not only for students' personal health, but also for broader public health challenges (Lasminawati et al., 2022).

Relevant Prior Studies

Several studies have demonstrated the effectiveness of PBL in enhancing students' scientific literacy. A study conducted by (Dewi et al., 2023) found an increase in scientific literacy competence and engagement among tenth-grade high school students, while (Apriyani et al., 2021) reported similar results, showing that PBL positively influenced scientific literacy by connecting learning with everyday life. Both studies showed consistent findings; however, they were conducted at the senior high school level and did not examine a more specific health topic such as the excretory system. Beyond the learning model itself, PBL-based e-modules have also been developed for various topics. Research conducted by (Sagita, 2021) reported that a PBL-based e-module on biodiversity met the criteria of validity, practicality, and effectiveness in improving tenth-grade students' critical thinking skills. Similar results were obtained by (Vina Serevina et al., 2018) who found that a PBL-based e-module on temperature and heat was feasible for use and effective in enhancing eleventh-grade students' science process skills. In addition, (Hamimi et al., 2024) found that a PBL-based educational kit on conservation material was effective in enhancing students' critical thinking skills, demonstrating PBL's flexibility across various topics and product formats. Another study by (Humairah & Wahyuni, 2024) likewise found that a digital flipbook-based science e-module was practical, valid, and effective in improving scientific literacy competence among eighth-grade junior secondary students.

Nevertheless, these studies have largely focused on general biology, physics, or scientific literacy in a general sense. Moreover, most studies have examined the effectiveness of PBL or the development of e-modules separately. No study has been found that specifically integrates PBL, scientific literacy competence, and the

topic of excretory system disorders due to imbalanced nutritional intake within a single e-module product for junior secondary students. This gap forms the basis for conducting the present study.

3. RESEARCH METHOD

Research Design, Time, and Place

This study was conducted from January to March 2025 at a public junior secondary school in Malang City. The method used was Research and Development (R&D) with the 4D development model, consisting of four stages: Define, Design, Develop, and Disseminate (Johan et al., 2023; Thiagarajan et al., 1974). The 4D model was selected because it has systematic stages and involves expert validation, thereby producing a high-quality product. This model is also flexible, adaptive, and suitable for developing various types of learning tools (Alghiffari et al., 2024). However, due to time constraints, the development of this e-module was limited to the Develop stage, and the Disseminate stage was not carried out in this study.

Research Subjects

This study involved 68 eighth-grade students, two expert validators, and four science teachers. In the needs analysis stage, the subjects involved consisted of one science teacher and 33 students from class VIII-F. Subsequently, the practicality test was conducted by the four science teachers. The readability test involved 35 eighth-grade students from classes VIII-A, VIII-B, VIII-C, VIII-E, and VIII-G, with seven students representing each class. Subjects for the readability test were selected using purposive sampling, in which students were chosen by the science teacher based on variation in academic ability (high, moderate, and low), so that the input obtained could represent students' diverse characteristics.

Research Procedure

This study was carried out through three stages, as follows:

1) Define. This stage aimed to identify needs in the e-module development process (Wardani et al., 2019). Activities at this stage included: (a) a teacher needs analysis conducted through a questionnaire administered to one science teacher; (b) a student needs analysis conducted through a questionnaire administered to 33 students of class VIII-F
2) Design. This stage aimed to design the product and prepare the instruments needed for product assessment and testing (Yusuf, 2023). Activities at this stage included: (a) designing the e-module based on the results of the teacher and student needs analyses; (b) creating illustrations and compiling the components and content of the e-module, such as usage guidelines for teachers and students, learning outcomes and objectives, concept maps, feature guides, learning activities, materials, summaries, formative tests, answer keys, evaluation questions, a glossary, and a reference list, using the Canva application (Onsu et al., 2023); (c) completing the e-module with text, images, animated videos, audio, Google Form links, Google Drive links, and QR Codes; (d) converting the e-module from PDF format into a flipbook using the Heyzine PDF to Flipbook application (Ashari & Puspasari, 2024); (e) adding active links within the e-module to make it easier for users to access additional information and to increase the e-module's interactivity; (f) publishing the e-module in HTML format to make it more easily accessible across various devices.

Table 1. Integration of PBL Syntax and Scientific Literacy Competence

PBL Syntax	Scientific Literacy Sub-Indicator	Student Activity
Orienting students to a problem	Recalling and applying relevant scientific knowledge	Formulating a hypothesis based on the problem statement developed from a case, adjusted to the scientific literacy sub-indicator
	Explaining the potential implications of scientific knowledge for society	
	Constructing arguments to support an appropriate scientific conclusion from a set of data	
Organizing students for learning	-	Forming groups of 4–5 members and joining the group to discuss and solve a problem
Guiding group investigation	Recalling and applying relevant scientific knowledge	Answering all questions based on the earlier case, developed according to the scientific literacy sub-indicators, through literature study with group members
	Explaining the potential implications of scientific knowledge for society	
	Identifying questions in a given scientific study	

PBL Syntax	Scientific Literacy Sub-Indicator	Student Activity
	Interpreting data presented in different representations, drawing appropriate conclusions from the data, and evaluating its relative usefulness	
	Distinguishing claims based on strong scientific evidence, expert vs. non-expert opinion, and opinion, and providing reasons for the distinction	
	Constructing arguments to support an appropriate scientific conclusion from a set of data	
Developing and presenting the outcome	-	Creating a digital poster or digital work containing a solution to the previously presented case and presenting the results
Analyzing and evaluating the problem-solving process	-	Individually analyzing and evaluating the problem-solving process from the learning activities

3) Develop. This stage aimed to develop the product based on the design that had been created and to conduct validity testing on that product (Vadilah et al., 2024). Activities at this stage included: (a) validation testing of the e-module and the scientific literacy-based evaluation questions by two validators; (b) revision of the e-module based on validators' input; (c) practicality testing by four science teachers and readability testing by 35 eighth-grade students, using the e-module that had been declared valid and feasible.

Research Instruments

Data collection was carried out using questionnaire instruments designed according to the aspects of the study, namely for the teacher needs analysis, student needs analysis, e-module validation test, scientific literacy-based evaluation question validation test, teacher practicality test, and student readability test.

Table 2. Assessment Aspects of the E-Module Validation Instrument

E-Module Validation Instrument Aspects
Conceptual accuracy
Content feasibility
Presentation quality
Language quality
Graphic quality
Software engineering

Adapted from (Ningtyas & Rahmawati, 2023) and (Widiastika et al., 2020)

Table 3. Assessment Aspects of the Scientific Literacy-Based Evaluation Question Validation Instrument

Scientific Literacy-Based Evaluation Question Validation Instrument Aspects
Accuracy of the scientific literacy sub-indicator
Language quality
Accuracy of the answer key

Table 4. Scientific Literacy Competence Indicators and Sub-Indicators

Scientific Literacy Indicator	Scientific Literacy Sub-Indicator
Explaining phenomena scientifically	Recalling and applying relevant scientific knowledge
	Explaining the potential implications of scientific knowledge for society
Designing and evaluating scientific inquiry and critically interpreting data and scientific evidence	Identifying questions in a given scientific study
	Interpreting data presented in different representations, drawing appropriate conclusions from the data, and evaluating its relative usefulness

Scientific Literacy Indicator	Scientific Literacy Sub-Indicator
Researching, evaluating, and using scientific information for decision-making and action	Distinguishing claims based on strong scientific evidence, expert vs. non-expert opinion, and opinion, and providing reasons for the distinction
	Constructing arguments to support an appropriate scientific conclusion from a set of data

(OECD, 2023b)

Table 5. Assessment Aspects of the Teacher Practicality and Student Readability Test Instruments

Teacher Practicality and Student Readability Test Instrument Aspects
Content suitability
Presentation and appearance
Language quality
Usefulness

Adapted from (Nugroho et al., 2024)

The assessment instruments for the teacher practicality test and the student readability test differ in content under the presentation and appearance aspect. In the teacher practicality test, this aspect covers the alignment between learning activities and both PBL syntax and scientific literacy competence. In the student readability test, by contrast, this aspect covers the attractiveness of the e-module cover, the clarity of the video and audio, and the usability of the available features. All instruments were theoretically validated through expert judgment by two expert validators to ensure the alignment between the statement items and the aspects being measured. Reliability was tested using Inter-Rater Agreement (IRA) for the aspect concerning the alignment between learning activities and both PBL syntax and scientific literacy competence, whereas internal consistency reliability was not used, given that this instrument functions as a product feasibility assessment sheet completed by a small number of experts and practitioners, rather than as a construct measurement tool for a large sample.

Data Collection and Analysis Techniques

This study used both quantitative and qualitative data. Quantitative data are presented in the form of numbers obtained through measurement and calculation (Rassia, 2017). In this study, quantitative data were obtained from the scores of the student needs analysis, the e-module validation test by the validators, the scientific literacy-based evaluation question validation test by the validators, the teacher practicality test, the student readability test, and the assessment of the alignment between learning activities and both PBL syntax and scientific literacy competence by the validators and teachers. Qualitative data, by contrast, are presented in the form of sentences or descriptions rather than numbers (Taherdoost, 2021). In this study, qualitative data were obtained from the teacher needs analysis, comments from the e-module validation test by the validators, comments from the teacher practicality test, and comments from the student readability test.

Quantitative data were analyzed using three techniques: the Likert scale, the Guttman scale, and Inter-Rater Agreement (IRA), each suited to the type of data and the purpose of testing. The Likert scale was used to assess respondents' answers to a number of statements based on a particular rating scale (Koo & Yang, 2025). According to Hadi (1991), the Likert scale score ranges from 1 to 4, starting from "strongly disagree" to "strongly agree" to represent respondents' level of agreement (Wahyudi & Ratna Sari, 2019). A score of 1 represents "Strongly Disagree," 2 represents "Disagree," 3 represents "Agree," and 4 represents "Strongly Agree" (Taluke et al., 2019). This scale was used for the e-module validation test, the scientific literacy-based evaluation question validation test, the teacher practicality test, and the student readability test.

The Guttman scale was used to measure conceptual accuracy and validate the answer key within the test instrument. The Guttman scale ranges from a score of 0 to 1 (Ulya et al., 2019). where 0 represents "No" and 1 represents "Yes" (Yanto et al., 2021). This scale was used together with the Likert scale for the e-module validation test and the scientific literacy-based evaluation question test. The results of both scales were calculated using the following equation (Aulia et al., 2022), and the results were then compared against the feasibility criteria.

$$x_i = \frac{\sum s}{s_{max}} \times 100\%$$

Explanation:

x_i = feasibility percentage

$\sum s$ = total score obtained

s_{max} = maximum possible total score

Table 6. Feasibility Percentage Criteria

Feasibility Percentage	Criterion
<20%	Not Feasible
21%-40%	Less Feasible
41%-60%	Moderately Feasible
61%-80%	Feasible
81%-100%	Highly Feasible

(Ly et al., 2024)

Inter-Rater Agreement (IRA) was used to measure the level of agreement among raters regarding the alignment between learning activities and both the PBL syntax and scientific literacy competence in the developed e-module, by calculating the percentage of agreement among raters (O'Neill, 2017). These data were obtained from the assessments of two validators on the presentation feasibility aspect (validation test) and four science teachers on the presentation and appearance aspect (practicality test). The percentage of agreement among raters was calculated using the following equation (Fatiah et al., 2021; Shweta et al., 2015).

$$\text{Percentage of Agreement} = \frac{Number\ of\ matching\ responses}{Total\ number\ of\ responses} \times 100$$

In the equation above, the number of matching responses refers to the number of identical scores given by the raters, while the total number of responses refers to the total number of all assessments given by all raters for an item. The resulting percentage of agreement was then compared against the agreement criteria to determine the level of agreement on the alignment between learning activities and both the PBL syntax and scientific literacy competence in the e-module. According to Borich (2003), the results of validation by multiple validators are considered consistent or in agreement if the percentage of agreement obtained reaches or exceeds 75% (Ratnasari et al., 2022).

4. RESULT AND DISCUSSION

Teacher and Student Needs Analysis

The results of the needs analysis conducted with science teachers showed that learning remains dominated by conventional methods, such as lectures followed by note-taking from PowerPoint slides, assignments, textbook-based discussion questions, practical activities, and presentations. The topic of excretory system disorders is still taught only to a limited extent, as it is not yet covered in the school's science textbook. In addition, scientific literacy has not been specifically trained and has only been introduced through student worksheets. Teachers also reported that no technology-based teaching material is yet available to support the development of students' scientific literacy. These findings indicate the need to develop a Problem Based Learning (PBL)-based e-module to facilitate students' scientific literacy on the topic of excretory system disorders due to imbalanced nutritional intake.

The questionnaire results from 33 students in class VIII-F reinforced these findings. As many as 42% of students reported never having received material specifically addressing excretory system disorders, 76% identified lectures as the most frequently used teaching method, and 58% considered this method to be unengaging. On the other hand, 52% of students agreed that technology should be utilized more optimally in learning, and 76% supported the development of a PBL-based e-module on the topic of excretory system disorders.

These findings are consistent with (Hafeez, 2021) who stated that lecture-based methods tend to be less engaging because they fail to optimally encourage active student participation. The use of technology through digital teaching materials, such as e-modules, may serve as an alternative for increasing student interaction in learning. In addition, (Fauziyah et al., 2021) argued that scientific literacy that has not been optimally trained leaves students less accustomed to handling discourse-based and scientifically contextualized questions, contributing to students' low scientific literacy competence.

E-Module and Scientific Literacy-Based Evaluation Question Validation Results

Table 7. E-Module Validation Results

E-Module Validation Aspect	Validator 1 Average (%)	Validator 2 Average (%)	Average (%)	Assessment Criterion
Conceptual Accuracy	100	100	100	Highly Feasible
Content Feasibility	100	90	95	Highly Feasible
Presentation Feasibility	97,22	91,67	94,44	Highly Feasible
Language Feasibility	100	83,33	91,66	Highly Feasible
Graphic Feasibility	98,21	89,28	93,74	Highly Feasible
Software Engineering	100	75	87,5	Highly Feasible
Scientific Literacy Evaluation Questions	90,73	91,66	91,19	Highly Feasible
Overall Average			**93,36**	**Highly Feasible**

The e-module validation results from the two validators show an overall average percentage of 93.36%, which falls into the highly feasible category. These results indicate that the developed e-module has met the feasibility criteria across all assessed aspects. The high score on the conceptual accuracy aspect (100%) suggests that the material presented aligns with established scientific concepts, thereby minimizing the potential for student misconceptions (Endris et al., 2025). The high scores on the content feasibility (95%) and presentation (94.44%) aspects further indicate that the material was systematically organized and supports the implementation of PBL syntax (Fadhillah et al., 2025). These results align with the theory of teaching material development, which states that expert validation aims to ensure the alignment of content, presentation, and media quality before classroom use (Chanifah et al., 2019). This finding is also consistent with (Firdaus & Pahlevi, 2022) who reported that a designed PBL-based e-module achieved a percentage score of 90% and was considered highly feasible for application.

Beyond providing scores, Validator 1 commented that the solutions presented in the e-module were positioned in accordance with the order of the PBL syntax, and that the scientific literacy sub-indicators were integrated into every learning activity. Validator 2, meanwhile, offered suggestions for improving visual aspects, such as increasing the color contrast of diagrams, adding borders to diagrams, adjusting font size, improving the consistency of the reference list formatting, and adding a reflection activity at the final PBL syntax stage. Based on the comments from both validators, the researcher made revisions to the relevant aspects of the e-module accordingly.

Table 8. Scientific Literacy Evaluation Question Validation Results

Sub-Indicator	Validator 1 Average (%)	Validator 2 Average (%)	Assessment Criterion
Recalling and applying relevant scientific knowledge	100	88,88	Highly Feasible
Explaining the potential implications of scientific knowledge for society	94,44	100	Highly Feasible
Identifying questions in a given scientific study	94,44	77,77	Highly Feasible
Interpreting data presented in different representations, drawing appropriate conclusions from the data, and evaluating its relative usefulness	88,88	100	Highly Feasible
Distinguishing claims based on strong scientific evidence, expert vs. non-expert opinion, and opinion, and providing reasons for the distinction	77,77	83,33	Feasible
Constructing arguments to support an appropriate scientific conclusion from a set of data	88,88	100	Highly Feasible
Average (%)	**90,73**	**91,66**	**Highly Feasible**
Overall Average (%)	**91,19**		**Highly Feasible**

The validation results for the evaluation questions from the two validators show an overall average percentage of 91.19% across all indicator aspects, which falls into the highly feasible category. Validator 1

commented that sub-indicator 4 did not yet present data in different representational formats, that sub-indicator 5's answer options were considered insufficiently appropriate because they contained only expert and non-expert claims, and that sub-indicator 6 did not yet include an argumentative element among the answer options. Validator 2, meanwhile, noted a wording inaccuracy in sub-indicator 1, suggested removing the word "previously" from sub-indicator 2 so that it simply reads "packaging," and identified further wording and answer-option inaccuracies in sub-indicators 5 and 6. Based on the feedback from both validators, the researcher revised the scientific literacy-based evaluation questions accordingly.

Practicality Test Results from Science Teachers

Table 9. Teacher Practicality Test Results

Teacher Practicality Test Aspect	Average (%)	Assessment Criterion
Content Suitability	100	Highly Feasible
Presentation and Appearance	99,4	Highly Feasible
Language Quality	100	Highly Feasible
Usefulness	97,91	Highly Feasible
Overall Average	**99,8**	**Highly Feasible**

The practicality test results from the four teachers show an overall average percentage of 99.8%, which falls into the highly feasible category. These results indicate that the developed e-module is easy to use and aligned with the needs of science instruction. The high score on the content suitability aspect (100%) suggests that the e-module's content aligns with the intended learning outcomes and objectives (Pramesti et al., 2025). In addition, the high score on the language aspect (100%) indicates that the language used is easy to understand and appropriate for students' characteristics (Jannah et al., 2025).

These findings align with (Pitorini et al., 2024) who stated that practicality testing aims to obtain user feedback on the ease of use and usefulness of a developed product. The results are also consistent with (Ibrahim et al., 2023) who found that a PBL-based e-module achieving a practicality level above 80% falls into the highly practical category.

Teachers gave positive feedback on the developed e-module overall. It was considered aligned with the learning outcomes, easy to understand, and supported by various features such as videos, QR Codes, formative tests, and scientific literacy-based evaluations. The e-module was further regarded as attractive, interactive, relevant to learning needs in the digital era, and well aligned with both PBL syntax and scientific literacy competence. Nevertheless, two of the four teachers commented that one learning activity had not yet fully facilitated the ability to distinguish claims based on strong scientific evidence, expert versus non-expert opinion, and opinion, since the questions presented were still limited to expert and non-expert claims. The remaining teachers considered the content, language, presentation, and usefulness aspects of the e-module to already meet expectations. Based on this feedback, the researcher revised the learning activity addressing this scientific literacy sub-indicator to better align with the competence being measured.

Readability Test Results from Students

Table 10. Student Readability Test Results

Student Readability Test Aspect	Average (%)	Assessment Criterion
Content Suitability	86,54	Highly Feasible
Presentation and Appearance	88,39	Highly Feasible
Language Quality	89,64	Highly Feasible
Usefulness	90,47	Highly Feasible
Overall Average	**88,76**	**Highly Feasible**

The readability test results from the 35 eighth-grade students show an overall average percentage of 88.76%, which falls into the highly feasible category. These results indicate that the developed e-module is well understood by students and is supported by an appearance and set of features that facilitate the learning process. The high score on the language aspect (89.64%) shows that the language used in the e-module is easy to understand and appropriate for junior secondary students (Rahmatullah et al., 2021). In addition, the high score on the usefulness aspect (90.47%) indicates that the e-module helps students understand the material on excretory system disorders while providing flexibility in learning without time or place constraints (Manggala et al., 2024). The highly feasible category obtained for the presentation and appearance aspect (88.39%) likewise

shows that the use of multimedia elements, such as images, videos, and audio, can increase students' interest and learning motivation (Kusumawati et al., 2021).

This finding aligns with (Asminar et al., 2021) who stated that readability testing aims to assess the extent to which the language, sentences, and instructions in a learning medium can be understood by students. These results are further supported by (Leny et al., 2021) who found that an attractive yet simple e-module design can increase student engagement in learning. In addition, the readability percentage obtained exceeds the feasibility threshold of 80% set by (Siburian et al., 2022), indicating that the developed e-module is highly feasible for use.

Overall, students gave positive feedback on the developed e-module. They considered the material complete, easy to understand, relevant to daily life, and useful for understanding the importance of maintaining excretory system health. The e-module's appearance was considered attractive, its features easy to use, and its multimedia presentation helpful for understanding the material. Nevertheless, some students suggested that the reading text in certain sections be made more concise to improve reading comfort. Based on these comments and suggestions, the researcher made revisions to the relevant aspects of the e-module.

Inter-Rater Agreement Among Raters

The next stage involved measuring the level of agreement among raters regarding the alignment between learning activities and the PBL syntax in the e-module, using Inter-Rater Agreement (IRA).

Table 11. Agreement Results for the Alignment Between Learning Activities and PBL Syntax

Learning Activity by PBL Syntax	Percentage of Agreement (%)
Orienting students to a problem	100
Organizing students for learning	100
Guiding group investigation	100
Developing and presenting the outcome	100
Analyzing and evaluating the problem-solving process	100
Overall Average Percentage of Agreement	**100**

The assessment results regarding the alignment between learning activities and PBL syntax in the e-module, conducted by six raters consisting of two validators and four science teachers, show that every stage of the PBL syntax achieved a percentage of agreement of 100%. Accordingly, the overall average percentage of agreement also reached 100%, falling into the consistent/agreed category. These results indicate that the learning activities designed in the e-module are aligned with the stages of the PBL syntax and were consistently perceived as such by all raters.

The percentage of agreement is used to measure the level of consistency among raters in evaluating a developed product (Abbott et al., 2025). This finding is consistent with (Widianti et al., 2023) who reported a percentage of agreement of 93% among validators for a developed learning tool, and with (Kudus et al., 2022) who reported a percentage of agreement of 91% among validators for a developed learning medium. Both studies show that a high level of agreement reflects consistent assessments of product quality. However, the level of agreement in the present study exceeds that of both studies, indicating that the alignment between learning activities and PBL syntax in the e-module was judged highly consistent by all raters. This result reinforces the earlier validation findings, showing that the e-module is not only feasible in terms of content and presentation, but has also systematically integrated PBL syntax into every learning activity. The developed e-module thus has the potential to support problem-based learning in a more structured manner on the topic of excretory system disorders due to imbalanced nutritional intake. The next stage involved measuring the level of agreement among raters regarding the alignment between learning activities and scientific literacy competence in the e-module, again using Inter-Rater Agreement (IRA).

Table 12. Agreement Results for the Alignment Between Learning Activities and Scientific Literacy Competence

Scientific Literacy Indicator	Scientific Literacy Sub-Indicator	Percentage of Agreement (%)
Explaining phenomena scientifically	Recalling and applying relevant scientific knowledge	83,33
	Explaining the potential implications of scientific knowledge for society	83,33
	Identifying questions in a given scientific study	100

Scientific Literacy Indicator	Scientific Literacy Sub-Indicator	Percentage of Agreement (%)
Designing and evaluating scientific inquiry and critically interpreting data and scientific evidence	Interpreting data presented in different representations, drawing appropriate conclusions from the data, and evaluating its relative usefulness	100
Researching, evaluating, and using scientific information for decision-making and action	Distinguishing claims based on strong scientific evidence, expert vs. non-expert opinion, and opinion, and providing reasons for the distinction	66,66
	Constructing arguments to support an appropriate scientific conclusion from a set of data	100
Overall Average Percentage of Agreement		**88,88**

The assessment results regarding the alignment between learning activities and scientific literacy competence in the e-module, conducted by two validators and four science teachers, show that each scientific literacy sub-indicator achieved a different level of agreement. Sub-indicators 3, 4, and 6 achieved a percentage of agreement of 100%, falling into the consistent/agreed category. These results indicate that the learning activities designed in the e-module align with the targeted scientific literacy competence for these three sub-indicators. Sub-indicator 5, however, obtained the lowest percentage of agreement at 66.66%, which does not yet meet the consistent/agreed criterion. Several raters noted that the questions in the learning activity did not yet fully represent the ability to distinguish claims based on scientific evidence, expert opinion, non-expert opinion, and opinion, since they presented only claims sourced from experts and non-experts. Based on this feedback, the researcher revised the relevant learning activity to better align with the scientific literacy competence being measured.

Inter-Rater Agreement (IRA) is used when an assessment involves two or more raters, to ensure that their judgments are consistent and to reduce bias, namely subjectivity in assessment (Arum et al., 2022). In media development, even when a large number of validators or respondents are involved, the presence of bias in the assessment process can render the validation results inaccurate (Ismunarti et al., 2020). Ratings provided may be overly generous, overly strict, or inconsistent with the given instructions. Agreement among raters is therefore necessary (Ndaru Rosita & Paramastri, 2017). This finding is consistent with (Paspania et al., 2025) who also applied the Borich method and established that a developed product is considered consistent when the percentage of agreement reaches or exceeds 75%. This indicates that the product developed in this study has met the criteria for a high level of agreement. Conversely, if the percentage of agreement among raters falls below 75%, improvements are needed for the product to meet the expected agreement criteria. This finding is also consistent with the results of the evaluation question validation and the teacher practicality test, which similarly showed that the ability to distinguish claims based on scientific evidence, expert opinion, non-expert opinion, and opinion is an aspect that requires further refinement.

4.1. E-Module Specifications and Characteristics

This e-module was developed using the Canva application. It was then converted from PDF format into a flipbook using Heyzine PDF to Flipbook and published in HTML format. The component specifications of the Problem Based Learning-based e-module developed to facilitate students' scientific literacy on the topic of excretory system disorders due to imbalanced nutritional intake are presented in Figure 1.

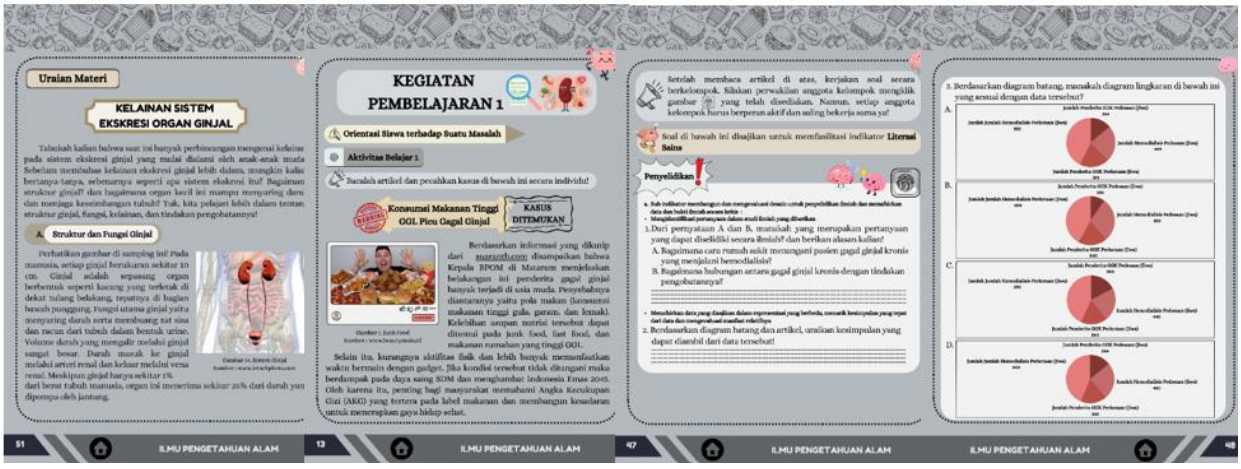

Figure 1. Component specifications of the Problem Based Learning-based e-module

In terms of content, the e-module contains two main materials: the types of kidney disorders due to imbalanced nutritional intake, and the characteristics of kidney disorders along with their treatment. Both materials are presented across two interconnected learning activities. The content is systematically organized and placed after the student learning activities, allowing it to serve as a source of information for confirming the results of the investigation and discussion previously conducted.

The learning activities within the e-module are designed in accordance with the syntax of PBL. Each learning activity begins with the presentation of a different contextual problem: the case "Consumption of Food High in Sugar, Salt, and Fat Triggers Kidney Failure" and the case "A 12-Year-Old Child with Kidney Failure Leading to Dialysis." Both cases were selected for their relevance to students' daily lives and their direct connection to the topic being studied. Each learning stage is accompanied by clear instructions to guide students through the problem-solving process. At the problem orientation stage, for example, students are asked to formulate a hypothesis based on the presented problem statement.

In addition to integrating PBL syntax, the e-module is also designed to facilitate scientific literacy competence. Each activity and question is accompanied by a description of the relevant scientific literacy sub-indicator, allowing students to understand the specific competence being developed. For instance, students are asked to select a question that can be scientifically investigated and to provide reasoning for their choice. In another activity, students are asked to interpret data presented in a diagram and draw conclusions based on the available evidence. These activities are designed to train students' ability to explain phenomena scientifically, evaluate scientific inquiry, and critically interpret data and evidence, in accordance with the scientific literacy competence developed within the PISA framework (OECD, 2023b).

The developed e-module offers several advantages that support flexible and interactive learning. It can be accessed anytime and anywhere through digital devices, and is equipped with QR Codes, interactive links, instructional videos, and questions that can be answered directly within the e-module. Students' work can be monitored by teachers through Google Form, while assignment submission is facilitated through Google Drive. To support ease of navigation, the e-module also includes a Home button, an interactive table of contents, and a list of figures that allow direct access to the corresponding pages. These characteristics align with (Holisoh et al., 2023) who stated that interactive e-modules can support more flexible and effective learning by enabling access without time or place restrictions. The use of multimedia elements, such as images, audio, video, and interactive exercises, also has the potential to increase students' learning interest. In addition, an e-module's appearance that resembles a printed book while being enriched with digital features reflects the use of interactive technology that can support a more adaptive learning process (Gunsri et al., 2023). The integration of Google Form within the e-module further supports interactive learning and assessment through quizzes, surveys, and faster feedback (Sintawati & Margunayasa, 2021). Meanwhile, the embedding of interactive links can facilitate students' access to various learning resources and create a more engaging and varied learning experience (Sidiq et al., 2021).

The topic addressed in this e-module is excretory system disorders due to imbalanced nutritional intake. This topic is relevant to the health context, which is one of the focus areas within the PISA scientific assessment framework at the personal, local, and global levels (OECD, 2023b). Selecting a topic closely related to students' daily lives allows learning to be connected to real-world problems, thereby supporting the development of scientific literacy competence. In addition to the PBL-based learning activities, the evaluation questions presented in this e-module were also designed in line with scientific literacy competence, aiming to develop students' ability to explain phenomena scientifically; design and evaluate scientific inquiry while critically interpreting data and evidence; and research, evaluate, and use scientific information for decision-making and action (OECD, 2023b).

However, the developed e-module still has certain limitations, namely its dependence on internet connectivity to access all interactive features. This condition could pose a constraint in learning environments with limited internet access, as the e-module's interactive features require a stable connection to function optimally (Damayanti & Perdana, 2023). Some students also reported experiencing lag when using the e-module under poor network conditions. This limitation should therefore be taken into consideration by schools with inadequate internet infrastructure. As a direction for further development, the e-module could be equipped with an offline-accessible version, making its use more flexible across different learning conditions.

Implications for Science Education

Overall, the findings of this study offer several important implications for science education. First, the high results of the validation, practicality, and readability tests indicate that integrating Problem Based Learning (PBL) into an e-module can serve as a potential alternative for addressing the limitations of conventional learning still dominated by lectures and note-taking, while simultaneously meeting students' need for more interactive learning. Second, the high level of agreement on the alignment with PBL syntax shows that problem-

based learning can be systematically integrated into digital media without compromising its pedagogical characteristics. Third, the relatively lower percentage found for the scientific literacy sub-indicator concerning the ability to distinguish claims based on scientific evidence, expert opinion, non-expert opinion, and opinion indicates that this sub-indicator requires greater attention in the development of teaching materials. This finding highlights the importance of designing activities and questions that more comprehensively represent the competence being measured, so that all aspects of this scientific literacy sub-indicator can be properly facilitated. For science teachers, these findings show that contextual health topics, such as excretory system disorders due to imbalanced nutritional intake, can be used as a learning context for training scientific literacy. This topic enables students to connect scientific concepts with problems relevant to their daily lives, thereby encouraging the use of data and scientific evidence in decision-making.

5. CONCLUSION

This study successfully developed a Problem Based Learning (PBL)-based e-module to facilitate students' scientific literacy on the topic of excretory system disorders due to imbalanced nutritional intake, and examined its feasibility and practicality for use in eighth-grade junior secondary science instruction. Validation by two experts produced an average percentage of 93.36% (highly feasible), the practicality test by four science teachers yielded 99.8% (highly feasible), and the readability test among 35 students reached 88.76% (highly feasible). The level of agreement among raters regarding the alignment between learning activities and PBL syntax reached 100%, while the alignment with scientific literacy competence reached 88.88%. These results indicate that the developed e-module is feasible and practical for use as science teaching material on the topic of excretory system disorders.

The novelty of this e-module lies in the integration of the excretory system disorder topic with a health issue relevant to students' lives, the explicit integration of PBL syntax with scientific literacy competence, and the use of technology-based interactive features such as QR Codes, Google Form, Google Drive, and active links that allow flexible access anytime and anywhere. Nevertheless, the scientific literacy sub-indicator concerning the ability to "distinguishing claims based on strong scientific evidence, expert vs. non-expert opinion, and opinion, and providing reasons for the distinction" obtained the lowest percentage of agreement among all sub-indicators, at 66.66%. This finding indicates that the activities and questions addressing this sub-indicator still require refinement to more comprehensively represent the competence being measured.

This study is limited by the fact that it was conducted only up to the Develop stage of the 4D model, and therefore does not yet include effectiveness testing for improving students' scientific literacy. Future research is accordingly recommended to: (1) conduct an effectiveness test using an experimental design to measure the improvement in students' scientific literacy competence after direct classroom use of this e-module; (2) refine the activities and questions for the sub-indicator that obtained the lowest percentage of agreement; and (3) develop an offline-accessible version of the e-module to address its dependence on internet connectivity.

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