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Development of an Interactive Multimedia E-Module Based on Everyday-Life Problems to Enhance Science Literacy Competence on the Digestive System

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Abstract: Development of an Interactive Multimedia E-Module Based on Everyday-Life Problems to Enhance Science Literacy Competence on the Digestive System. Objectives: This research is motivated by the low level of scientific literacy among junior high school students and can have an impact on low critical thinking, motivation, and lack of awareness of scientific issues. Scientific literacy is one of the essential 21st-century skills that needs to be enhanced within the Merdeka Curriculum. This study aims to develop an e-module integrated with the Problem-Based Learning (PBL) model that is feasible, practical, and effective in improving students' scientific literacy. **Methods:** This research is an R&D research with ADDIE model. The research subjects involved 65 students who were divided into experimental & control classes, using random sampling techniques. Data collection was carried out through feasibility, practicality, and effectiveness tests, involving two expert lecturers, teachers, and students. Data collection techniques used PG science literacy test questions, and feasibility & practicality questionnaires which were analyzed descriptively, while effectiveness used N-Gain, Manova and effect size tests. **Findings:** The results of the study show that the developed interactive multimedia e-module was deemed feasible based on expert lecturer evaluations and received positive feedback from teachers. In terms of effectiveness, the improvement in students' scientific literacy achieved a high N-Gain score and a MANOVA result with a significance value greater than 0.05, while the effect size was 0.83. **Conclusion:** These findings indicate that the interactive multimedia e-module based on the Problem-Based Learning (PBL) model can effectively enhance students' scientific literacy.

Keywords: problem based learning, e-module, science literacy.

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INTRODUCTION

Education is a crucial factor in determining the success of individuals because it has a positive impact in various fields of life including in shaping individual personalities (Madhakomala et al., 2022; Atstsaniyah & Widagdo, 2024), while also playing an important role in facing contemporary challenges (Gimaletdinova & Khisamutdinov, 2023). Generally, education includes a planned process to create a conducive learning environment (Azizah et al., 2021). Therefore, education must be able to produce quality human resources (HR) that can improve the quality of education in a sustainable manner (Hamidi et al., 2011). This is particularly relevant in a rapidly changing world, where education is required to adapt in order to prepare individuals to face complex challenges (Yelubayeva et al., 2023).

However, based on existing facts, the quality of human resources in Indonesia is still lagging behind compared to other developing countries. Therefore, significant efforts are needed to catch up with the lagging quality of human resources (Muslim & Suci, 2020; Sudianto et al., 2023). Education in Indonesia still faces various challenges, such as low teacher quality, student achievement, interest in reading, and limited facilities and infrastructure (Madhakomala et al., 2022). To address this, the Ministry of Education and Culture continues to improve the quality of education through the development of the Merdeka Curriculum, which focuses on 21st century skills, including science literacy. Various research and observations are also carried out to support the improvement of the quality and level of education (Atstsaniyah & Widagdo, 2024).

In science education, science literacy is the main indicator of successful learning in forming critical and innovative learners. As a 21st century skill, science literacy plays an important role in improving the quality of education and facing future challenges (Pratiwi & Indrayani, 2023; Ramdani et al., 2020; Ding, 2022). The development of science and technology has brought great challenges to science education, affecting various aspects of life, including communication, economy and learning (International Council for Science (ICSU), 2011). Awareness of the importance of science literacy is increasing in various countries, considering that a low understanding of science can have a negative impact on education. Therefore, measuring science literacy is essential in improving the quality of education (International Council for Science (ICSU), 2011; Suwandi & Supriyanti, 2021). However, based on the PISA results by the OECD, Indonesia is still ranked 68 out of 81 countries with a science literacy score of 398, indicating a low level of science literacy (Zohri et al., 2022; Ramdani et al., 2020; Safitri et al., 2024). Surveys from 2018-2022 also showed a significant decline, emphasizing the need for improvement in Indonesia's science education system. The research also revealed that junior high school students' science literacy is still low, with achievements below 60% in all science categories (Fuadah et al., 2017). The contributing factors include unsupportive learning methods, misconceptions in science, lack of mastery of science literacy by educators, and limited facilities and infrastructure (Suroso et al., 2020; Hardianti et al., 2021; Yusmar & Fadilah, 2023). In addition, non-optimal learning activities contribute to low science literacy (Zohri et al., 2022). Therefore, it is important to continuously measure and improve the science literacy of 15-year-olds (Kumar et al., 2023).

Based on the observations, the use of media in learning affects the learning process, as observed at SMPN 12 Mataram. However, the use of media at the school remains limited, with teachers utilizing only the available devices without adapting them to students needs. In addition, the lack of technology integration in learning makes the learning process monotonous and less interactive, which negatively affects students learning outcomes. This condition indicates that the science literacy of students at SMPN 12 Mataram still needs to be improved. Various studies confirm that the use of learning media plays an important role in improving the quality of learning in the classroom (Agustin et al., 2022; Azizah et al., 2023). There are various ways that can be done for science learning, one of which is by implementing problem-based learning. This model encourages students to learn by solving real-world problems encountered in everyday life, thereby enhancing their understanding in a more contextualized manner. As a learner-centered approach, PBL provides students with opportunities to develop knowledge and ideas based on the material learned (Dalila et al., 2022).

In addition, the problem-based learning model makes it easier to solve problems because it presents problems that are contextual to real life (Fareza et al., 2024; Heong et al., 2020).

Improving science literacy is a crucial factor in improving the quality of education. Although Merdeka Curriculum has been implemented, previous research shows that science literacy in some schools, including SMPN 12 Mataram, is still relatively low, as evidenced by interviews with several schools. Research on Problem Based Learning (PBL) based science learning tools that integrate technology is still limited. According to Santoso et al., (2023) Learning technology plays a role in improving the overall quality of education. Educators as learning facilitators need to adapt in a more interactive and interesting way, through more interactive methods and media (Makhroji et al., 2023; Rahmiati et al., 2023). Purba & Saragih, (2023) also highlighted the role of technology in educational transformation, but have not specifically examined its application in the PBL model for science learning. Integration of technology in PBL is believed to increase learning motivation and self-efficacy of students (Supit, 2020; Amalia & Yuliansah, 2024). The application of PBL Learning Model is also effective in improving students' skills and learning outcomes (Widyaningrum et al., 2024; Ratnawati et al., 2020). Therefore, it is necessary to develop a PBL-based e-module that not only improves science literacy, but also supports the implementation of the Merdeka Curriculum.

Based on the problems that have been described, this study aims to develop e-modules based on Problem Based Learning (PBL) integrated with technology to improve the science literacy of students at SMPN 12 Mataram, and provide innovative solutions in science learning to make it more effective, interactive, and in line with the needs of education in the digital era. To achieve these objectives, this study was designed to answer the following questions. How is the feasibility of e-module science learning tools based on Problem Based Learning (PBL) integrated with technology to improve science literacy based on expert assessment. How is the practicality of e-module science learning tools based on Problem Based Learning (PBL) integrated with technology to improve science literacy according to the views of science teachers and students?.

METHOD

Research Design

This research uses the R&D method with the ADDIE model. The ADDIE model is a model developed by Dick and Carry (1996) (Sari, 2018). According to Aldoobie, (2015) The development model through ADDIE includes five stages, namely: (1) analyze, in this case includes the initial needs analysis process through teacher interviews to find out the problems and needs that will be developed in overcoming problems in learning, including learner analysis, curriculum analysis and analysis of science concepts. The results of the analysis can be a reference for researchers to design products that will be developed by overcoming the problems found; (2) design, at this stage the researcher compiled a lattice of e-modules along with the lattice of science literacy question instruments according to the needs and problems found at the initial analysis stage; (3) development, at this stage the researcher made an e-module based on the lattice at the design stage. At this stage, the feasibility test of the developed product was also carried out by involving two expert lecturers. The purpose of doing this is to test the product whether it is feasible or not, through a questionnaire given by the researcher. The results of the improvement of the comments and suggestions given, then obtained the results of revision 1 (draft II); (4) implementation, the application of the product is carried out in limited trials and broad trials. The results of the feasible e-module draft II were

distributed on a limited basis to science teachers and one class VIII E, so as to obtain the results of revision 2 (draft III), finally widely distributed to two classes, namely classes VIII A and B SMPN 12 Mataram; (5) evaluation (evaluate), formative and summative.

At the Implementation stage, a broad trial was conducted using a Quasy exsperiment design, namely Nonequivalent Post-Test Pre-Test Control Group Design. This design involves giving a pre-test before treatment and a post-test after treatment, which is applied to two types of classes, namely experimental and control classes.

Participant

This research was conducted at SMPN 12 Mataram, NTB. The subjects of this study involved 2 expert lecturers for feasibility testing, 1 science teacher, and VIII grade students. The research population was all students of grade VIII of SMPN 12 Mataram with a research sample of 224 students and divided into 8 classes. The research sample at the broad trial stage was 65 students divided into experimental and control classes, and was used to test the effectiveness of the e-module developed. In addition, at the limited trial stage, 32 students were involved to assess the practicality of the e-module. The sample selection technique in the broad trial used the random sampling method from the entire population.

Instrument

The data collection instruments in this study consisted of test instruments and non-test instruments. The test instrument is in the form of multiple choice questions on science literacy focusing on human digestive system material, consisting of 20 items designed based on the synthesis of science literacy syntax. These questions were developed to measure five indicators of science literacy, namely; 1) understanding of science concepts, with a total of 6 items; 2) ability to understand & explain scientific phenomena/issues, with a total of 4 items; 3) ability to solve scientific problems with a total of 5 items; 4) ability to analyze & interpret scientific data/evidence with a total of 3 items, and; 5) integrating science in their daily lives. This instrument is given to students as respondents. While non-test instruments in the form of feasibility and practicality questionnaires. The feasibility questionnaire was filled in by expert lecturers in the field of science education. While the practicality questionnaire was filled in by 1 science teacher and 32 students. The assessment in the questionnaire uses a Likert scale of 1 to 4, with categories of strongly agree (4), agree (3), disagree (2), and strongly disagree (1). All instruments in this study were self-developed by the researcher.

The instrument validation process was carried out by distributing the question instruments that had been made to 4 randomly selected junior high schools in the Lombok region. The distribution of questions is done online through links shared by teachers in their respective class groups.

Data Analysis

The data obtained were then analyzed through the following data analysis techniques. Data on the results of feasibility and practicality are analyzed descriptively by summing up all the scores of statement items that have been selected by students and then analyzed by calculating the average value of the data obtained.

The results obtained show the average assessment score on each aspect of each expert. The average value of the assessment results from the validators is then converted into the assessment category by referring to certain criteria intervals. The category is determined based on the comparison of the average value with the ideal mean value and ideal standard deviation. The ideal mean is obtained from half

the sum between the maximum score and the minimum score, while the ideal standard deviation is calculated from one-sixth of the difference between the maximum score and the minimum score. To determine the quality of the e-module developed is based on 4 category options namely very good, good, sufficient, low and very low.

The effectiveness test was analyzed using N-Gain and MANOVA based on data from pre-test and post-test results to measure the improvement of learning outcomes. This analysis aims to determine the extent to which e-module products have an effect in improving students' science literacy. N-Gain and MANOVA analysis in this study were calculated using the SPSS version 26 program.

■ RESULT AND DISCUSSION

Product development in the form of PBL-based e-module to improve students' science literacy is developed with the ADDIE model, which is achieved through 5 stages. The material presented in the Science learning device in the form of e-modules regarding the digestive system, especially in humans. Development with the ADDIE model includes Analyze, Design, Develop, Implement, & Evaluate stages.

The first stage is analysis. At this stage, an initial needs analysis was conducted by interviewing science teachers at SMPN 12 Mataram, the results of the interview showed that science learning at SMPN 12 Mataram was still dominated by a traditional approach with a greater role of the teacher. Innovative learning models and the use of technology are still limited, while the teaching resources used are general and lack depth. Students tend to be less focused in learning, which has an impact on the low results of practice questions. Therefore, learning methods, models, and media that are more interesting and in accordance with students learning styles are needed. Then the analysis of students, shows that SMPN 12 Mataram students prefer to do assignments rather than listen to teacher explanations. Their motivation is influenced by interesting teaching methods, while monotonous learning often leads to lack of focus. According to (Atstsaniyah & Widagdo, 2024; Resnalia, 2022), individual motivation is one of the factors that have an important role in the learning process, so it is very necessary to increase motivation for students. In addition, most students prefer learning that involves direct observation of a process, plus electronic media in the form of mobile phones. However, in reality teachers rarely use media that shows the process in real time due to media limitations. Almost all learners have a visual learning style, but media limitations make teachers rarely use interactive tools. The use of more varied visual media can increase student understanding and engagement. Effective media use can influence learning motivation (Atstsaniyah & Widagdo, 2024). So in this study, researchers developed media in the form of e-modules that were designed in such a way as to facilitate students and teachers in learning. Furthermore, related to curriculum analysis and analysis of science concepts focused on digestive system material because of its relevance in everyday life. Digestive system material is one of the materials that often experience misconceptions related to basic concepts, so that it can hinder their understanding (Mu'arikha & Qomariyah, 2021). So in this study using digestive system material to measure the level of science literacy of students at SMPN 12 Mataram. Studying digestive system material is very important, aiming to understand health and diseases related to digestion (Harimayati 2021). In this study, the material is systematically organized based on relevant literature with concepts related to facts, concepts, and principles related to the digestive system. Based on the results of the above analysis, it shows that SMPN 12 Mataram school needs learning tools such as e-modules that are specially developed.

The second stage is the design stage. This stage focuses on planning and designing PBL-based e-modules, with reference to the results of learning needs and objectives at the previous analysis stage. This stage starts by designing a description of the PBL-based e-module, with the aim to serve as a reference in developing PBL-based science learning tools. The designed e-module includes several components such as cover, preface, table of contents, list of images, list of videos, usage guide, introduction, competencies, concept map, material presented, e-LKPD, glossary summary, bibliography, and author profile. In addition, evaluation instruments of PBL-based e-modules such as science literacy instruments were also prepared. The preparation of the science literacy instrument lattice is based on 5 indicators of science literacy used such as: understanding of science concepts, ability to understand & explain scientific phenomena/ issues, ability to solve scientific problems, ability to analyze & interpret scientific data/evidence, integrating science in their daily lives. Based on the results of the design, a lattice of e-modules was obtained. Then proceed with the development stage. The e-Module developed with digestive system material is designed based on preliminary analysis tailored to the needs of teachers and students. As an interactive learning tool, this e-module is equipped with illustrative videos and images to support student understanding. Integrated with the Problem-Based Learning (PBL) model, the e-module presents problems as a starting point for learning to encourage students to think critically and find solutions independently.

Third, the development stage. At this stage, researchers developed PBL-based e-modules that referred to the grids that had been designed as well as developing science literacy instruments and questionnaires. In addition, the development steps in this study also include the feasibility of the products developed in the form of e-modules. In line with research Kimianti & Prasetyo, (2019), The development of PBL-based e-modules is one of the science learning tools that can improve students' science literacy skills through learning that involves problems in e-modules. The teacher assessment results also showed the feasibility of the e-module based on the trial results. In this study, the e-module was created using the Canva web application, then downloaded in PDF format and exported to the Heyzine platform. The Heyzine link was shared with learners so that they could access it easily. The e-module display in Heyzine is designed to resemble a flipbook, making it more interactive and enhancing the learning experience. In addition, this e-module contains videos, images, and illustrations relevant to everyday life to strengthen concept understanding. The results of the e-module development process are presented in the following link; https://heyzine.com/flip-book/ed02df514d.html.

The e-module development includes 3 stages of learning activities. Each activity describes the same material, namely the digestive system, but the topic used is different. Each activity is equipped with a student worksheet, integrating students with real problems in everyday life. Based on the results of the development of e-modules and instruments, produce draft 1. The e-module was then validated by expert lecturers to assess the feasibility of the e-module with the correct provisions and criteria including question instruments. Expert lecturer validation involved 2 validators. The results of the e-module product assessment by the two expert validators showed that the developed e-module obtained a feasibility percentage of 100%, including in the "very good" category. All aspects/indicators assessed, starting from the appearance such as cover, content, and cover such as competencies, summary of material and others obtained the maximum score. This shows that the quality of the e-module is at a very good level and is suitable for use in the learning process. Comments and suggestions by experts are used as material for improving the e-module

before use. Based on the results of expert lecturer validation, it has shown that the e-module has been said to be very good, but there are some that need to be added based on input and suggestions from expert lecturers, resulting in improvements from stage I revisions. The results of stage I revision of the e-module were then tested at the implementation stage. Along with the e-module assessment, the science literacy instrument was analyzed. The science literacy instrument developed as many as 20 questions were declared valid with revisions according to expert lecturers. The science literacy instrument was then distributed to 4 junior high schools, especially grade IX students who had studied digestive system material, to test validity and reliability. There were 180 students involved. The validity test results are presented in Figure 2 based on QUEST out analysis, including reliability results.

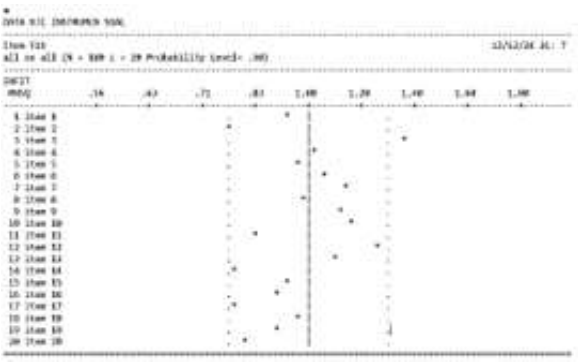

Figure 1. Result of validity test

Figure 1 shows that based on the 20 items developed, there are 19 items declared valid with the Infit MNQS value in the range of 0.77 to 1.30. While the reliability value obtained a value of 0.98 on the Summary of Item Case with a very high acquisition category. The average item estimate is 0.00 with a standard deviation of 1.34, indicating an even distribution of the difficulty level of the questions. The Infit Mean Square value of 0.99 and Outfit Mean Square of 1.17 are within the acceptable range, so the items can be said to fit the model. There are no items with a score of zero or a perfect score, so all items are able to effectively differentiate the ability of students. This data indicates that the instrument has good reliability and internal validity. The implementation stage, in this research, is carried out by testing the device that is feasible and valid based on the expert lecturer's assessment. The trial was carried out including two stages, namely limited trials and extensive trials. The limited trial was applied to one science teacher for the practicality questionnaire and one class at SMPN 12 Mataram involving 32 students, for the readability questionnaire.

The results of the practicality test by teachers on the e-module device showed that the e-module received a score of 100%. In line with the opinion (Kimianti & Prasetyo, 2019) Learning using e-modules integrated with PBL is declared feasible for use in the learning process based on teacher assessment. Meanwhile, the readability test showed that the e-module obtained an average score of 9.51, with a very good category. The acquisition of this value indicates that the developed e-module has a high level of readability, so that the content of the material can be understood well by learners. This also indicates that the language, layout and presentation of information in the e-module have been effectively designed to support an interactive and engaging learning process. Both test results, both in the practicality test for teachers and readability for students have shown that the e-module is feasible/ effective to use in learning. This e-module has met the requirements of good readability and practicality criteria, so it can be applied in a wide-scale trial. However, to improve the quality of the product, some improvements and refinements are needed based on input and suggestions from the results of both tests. Furthermore, the implementation of the broad trial be carried out.

Assessment of the PBL-based e-module on a broad trial was carried out by providing a valid science literacy instrument. The assessment was carried out on students of classes VIII A and VIII B of SMPN 12 Mataram, which were

randomly grouped into experimental and control classes. Class VIII A (experimental) used PBL-based science learning tools, while class VIII (control) used learning tools from the teacher in the form of learning tools (Discovery Learning). Learning activities were carried out 3 times a meeting with 4x45 minutes. Each meeting was interspersed with e-LKPD activities contained in the e-module, with different material coverage at each meeting but still related, which was provided through the link. At the end of the meeting a post-test and questionnaire were given. During the learning process, the observer made observations related to the achievement of learning implementation using the observation sheet questionnaire. The science literacy data was used to measure the effectiveness of the PBL-based science learning tools. Data analysis was conducted using the N-Gain test, MANOVA test, and effect size test. The following is a description of the results from the tests performed.

The improvement of pre-test and post-test results of science literacy with N-Gain analysis is presented as Table 1.

No	Science Literacy Indicators	Pre-test		Post-test		N-Gain Eks	N-Gain Control
		(E)	(K)	(E)	(K)		
1	Understanding of science concepts	88	90	171	158	6.92	6.80
2	Ability to understand & explain phenomena/issues scientifically	46	51	110	98	1.19	0.96
3	Scientific problem-solving skills	43	47	132	115	1.56	1.28
4	Ability to analyze & interpret data/scientific evidence	36	36	84	75	0.75	0.61
5	Integrating science in daily life	9	9	28	24	0.21	14.91

Table 1 shows the improvement of science literacy in all indicators in both experimental and control classes. The experimental class generally had a higher N-Gain, especially in understanding science concepts and solving scientific problems. However, on the indicator of science integration in daily life, there is a data anomaly in the control class. Overall, learning in the experimental class was more effective in improving science literacy.

The difference in N-Gain values shows that although there was an increase in both classes, learning in the control class was not as effective as the experimental class. The difference in scores between PBL and DL classes is influenced by the systematic guidance in PBL which helps students focus more on understanding concepts, while DL demands independent exploration which risks causing misconceptions (E & Silver, 2004; Elshama, 2020). PBL excels in 21st century skills, while DL is stronger in conceptual understanding. Research shows PBL is more effective with an N-Gain of 0.57 (Anggelina & Harjono, 2022), but another study found DL to be superior (Anggelina & Harjono, 2022). Their effectiveness depends on factors such as student characteristics, the role of the teacher, and the complexity of the material.

The effectiveness of the e-module was analyzed by comparing learning outcomes between experimental and control classes using the MANOVA test through SPSS. Before conducting the MANOVA test, the prerequisite assumption test, namely normality and homogeneity test, was first conducted. The results of the normality test showed that the data were normally distributed (sig> 0.05), while the results of the variance homogeneity test showed a significance value (sig> 0.05) in both classes,

which means that the data met the assumption of homogeneity. Thus, the data meet the basic assumptions for further analysis.

Furthermore, ANCOVA test was conducted to control the effect of pre-test scores on students' post-test results. Based on the ANCOVA test results, the significance value in the experimental group was 0.036 ($p < 0.05$) with F (1.62) = 4.575, and Partial Eta Squared of 0.069. This indicates that there is a significant effect of the treatment on science literacy learning outcomes after controlling for students' initial ability. While in the control group, a significance value of 0.000 ($p < 0.05$) was obtained with F (1.62) = 19.344 and Partial Eta Squared of 0.238, indicating a greater influence. Thus, it can be concluded that the linearity assumption is fulfilled and the treatment given is effective in improving students' science literacy. After ensuring that the difference in post-test results was not caused by the difference in pre-test scores through ANCOVA analysis, the analysis continued with the MANOVA test. MANOVA test was conducted to determine the effect of variables, namely the use of PBL-based interactive multimedia e-module (experimental class) and Discovery Learning-based e-module (control class) on various aspects of science literacy multivariate. The results of the MANOVA analysis are presented in Table 2.

Table 2. MANOVA test results

Effect	Value	F	Sig
Intercept Hotelling's Trace	255.0	7779.5[b]	.000
Variabel Hotelling's Trace	0.295	8.987[b]	.000

Based on the results of the MANOVA multivariate test using Hotelling Trace with the experimental class and control class variables, a significance value of 0.000 ($p < 0.05$) was obtained. Karena nilai sig <0.05, then the hypothesis H is accepted and H€ is rejected. This indicates that there is a significant influence of the treatment given to the experimental class on improving students' scientific literacy. MANOVA test with Hotelling's Trace (sig = 0.000 <0.05) further confirmed the existence of significant influence or difference in science literacy skills between experimental and control classes. This finding reinforces that PBL-based e-modules have a positive impact on learning outcomes, especially on aspects of science literacy.

The results of this study are supported by previous studies which state that e-modules can improve students' problem solving skills (Kaniyah et al., 2022; Putra & Nurlaily, 2021; Suciati et al., 2014). Theoretically, the PBL model emphasizes the active involvement of learners in building their own understanding and developing critical thinking skills (Lidyawati et al., 2017), which is then combined with a digital-based e-module to support the improvement of science literacy (Kimianti & Prasetyo, 2019; Rati & Astawan, 2022).

In addition to learning models, media utilization also plays a role in learning effectiveness. Interactive media and multimedia can improve learning motivation and learning outcomes (Permatasari et al., 2024; Yuliansih et al., 2021). The use of Android-based applications in PBL is proven to improve critical thinking skills and student motivation (Fitriyani et al., 2023). In addition, PBL-based e-modules with animations and videos strengthen student interaction and understanding (Putri & Hardeli, 2021). The development of innovative media in accordance with the character of students is a key factor in the success of PBL (Ganefri et al., 2020), especially with technology such as mini servers to overcome internet network limitations. Therefore, teachers need to choose effective and accessible learning media to improve the affordability and effectiveness of student learning.

After it was known that the treatment had a significant effect on science literacy through MANOVA analysis, the analysis was continued

by calculating the effect size to provide a quantitative picture of how much impact the intervention provided. The effect size test was conducted to determine the effect of using PBL-based interactive multimedia e-module science learning tools in improving science literacy. The value analyzed is the Partial Eta Squared value. Based on the results of the SPSS output effect size test, science literacy obtained a value of 0.831. The value is included in the large category, which indicates that the treatment or intervention provided in the form of PBL-based interactive multimedia e-modules has a strong influence on improving students scientific literacy. Thus, it can be concluded that the use of PBL-based e-modules is able to provide significant and substantial changes to students' learning outcomes.

The last stage is the evaluation stage. This stage is carried out to determine the effectiveness of the PBL-based e-module developed in improving students science literacy. This evaluation includes formative and summative evaluation. Formative evaluation was conducted during the development process to collect data to improve and refine the e-module. This process includes validation by experts, readability tests by learners, and practicality assessment by teachers. The results of the formative evaluation showed that the e-module was in accordance with the learning needs and characteristics of the learners (Arianti et al., 2023; Nurrahmah et al., 2023). Summative evaluation was conducted after the e-module was fully implemented in learning to assess its effectiveness in improving science literacy. This evaluation uses an experimental design with pre-test and post-test in the experimental and control classes. Data were analyzed using N-Gain to see the improvement of learning outcomes as well as MANOVA to test significant differences between groups using PBL-based e-modules and groups with other learning models. The analysis showed a significant increase in science literacy in the experimental class compared to the control class (Dermawan et al., 2024). These findings confirm that PBL-based e-modules are effective in improving students' understanding of science concepts and scientific thinking skills. Some of the above opinions are consistent with the results obtained at SMPN 12 Mataram.

There are several uniquenesses in the context of this study. One of them is the use of mini-server-based e-modules to overcome the constraints of limited internet access, something that has not been widely discussed in similar studies. This innovation shows the adaptation of technology that is contextual to the infrastructure conditions at SMPN 12 Mataram, thus strengthening the effectiveness of learning. In addition, the application of the PBL model through digital e-modules in a public school environment with heterogeneous conditions such as SMPN 12 Mataram proves that this approach is effective not only in superior schools, but also in schools with limited facilities. Thus, the findings of this study are not only consistent with previous research results, but also enrich the literature with innovative approaches that are relevant to local needs.

Based on the results of the description above, it can be concluded that the Problem-Based Learning (PBL)-based e-module developed in this study proved to be feasible and effective for improving students science literacy. This e-module was designed by considering the needs of teachers and students, and validated by experts and practitioners before implementation. Expert validation and readability test showed excellent quality, supporting interactive and interesting learning. PBL is more effective than discovery learning in improving concept understanding, supported by interactive features such as flipbooks and videos. The limitation of the study lies in the limited sample coverage, so it needs to be tested further. The implications of this study indicate that PBL-based e-modules can be an alternative solution to improve the quality of science learning, motivate students, and assist teachers in the teaching process.

In addition, qualitative data from interviews with teachers also reinforced the quantitative findings. Science teacher of SMPN 12 Mataram stated that the use of PBL-based e-module is effective in improving learning outcomes of digestive system material, accompanied by positive responses from students who are more active and enthusiastic during learning. This e-module has also been implemented in other classes with similar results, so it was established as a permanent digital teaching material in the school. Qualitative analysis shows that this e-module facilitates understanding of the material, increases student activeness in problem-based discussions, and encourages an increase in academic grades. This finding confirms that PBL-based e-modules not only significantly improve science literacy, but also strengthen students' motivation and learning participation.

CONCLUSION

The PBL-based interactive multimedia e-module developed in this study proved effective as a learning media in improving science literacy as well as students' learning motivation. The integration of the PBL approach in the e-module encourages learners to think critically, solve problems, and connect science concepts to everyday life. In addition, interactive features such as flipbooks, videos and illustrations enrich learners' learning experience. Thus, this e-module contributes to technology-based learning innovation and can be an effective alternative in science learning. Further development can be done by customizing e-modules for various levels of education and other learning materials.

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