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Development of a Science E-Module Based on Problem Based Learning Using Moodle to Improve Students' Science Literacy and Critical Thinking Abilities

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ABSTRACT
The purpose of this research is to produce a problem-based learning science e-module using Moodle that is (1) suitable for improving scientific literacy and critical thinking skills; (2) practical for teachers and students to use in enhancing scientific literacy and critical thinking skills; and (3) effective in improving students' scientific literacy and critical thinking abilities. This research employs Research and Development with the 4D development model (define, design, develop, and disseminate). The study was conducted at Abu Bakar Integrated Islamic Junior High School, Yogyakarta, during the 2024/2025 academic year. Prior to the research, the developed product and learning tools were tested for feasibility by two experts and for practicality by teachers and students in a limited trial. The results of the study indicate that the problem-based learning science e-module using Moodle to improve students' scientific literacy and critical thinking skills: (1) is feasible for use, based on very high content validity, empirical evidence of validity that fits the Rasch model (mean INFIT MSNQ value = 1), and reliability categorized as sufficient; (2) very practical to use, based on teacher assessments, and categorized as practical based on student readability responses; and (3) effective to use, as shown by a significant increase in students' scientific literacy and critical thinking skills according to MANOVA test results, with the effect size value of the treatment categorized as medium.

Keyword: *e-Module, Problem Based Learning, Moodle, Scientific Literacy, Critical Thinking*

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INTRODUCTION

Natural Science is a branch of science that involves ways of thinking related to natural phenomena, exploration of the natural world, accumulation of knowledge, and the interaction between technology and society (Ariska & Rosana, 2020). Science learning focuses more on providing direct experience to students in developing competence, enabling students to better understand the environment because they are actively involved in discovery and action processes. This approach allows students to gain more knowledge than simply following a learning process without direct involvement (Ananda & Abdillah, 2018). Education in the 21st century—also known as the Industrial Revolution 4.0—is characterized by the rapid development of science and technology. Education in this era aims to encourage students to develop skills that enable them to respond to changes accompanying the progress of the times. Wijaya et al. (2016) stated that a change in the mindset of humans or students is needed. The competencies that must be developed in 21st-century education are known as the 7Cs: critical thinking, communication, collaboration, creativity, character building, citizenship, and technological literacy. Nowadays, students are challenged and required to develop scientific literacy skills, think critically, communicate effectively, work collaboratively, be creative, be independently innovative, and be aware of technology.

Science learning also aims to develop scientific literacy skills (NGSS Lead States, 2013; Lederman & Bartels, 2018; Fortus, Neumann & Sadler, 2022). Scientific literacy skills are key to lifelong learning, both to face challenges in daily life and to pursue careers (Nurmazia et al., 2025). According to Toharuddin (2011), scientific literacy is important for students to master, as it relates to how students can understand the environment, economic health, and the problems faced by modern societies that depend on scientific progress and technology. The importance of scientific literacy is underscored by its role in enabling students to apply their knowledge to solve problems in everyday life, whether in personal, social, or global contexts (Yuriza, 2018). Ultimately, scientific literacy skills are expected to guide individuals to become wiser and more responsible in making decisions related to the problems they encounter.

According to the Organization for Economic Cooperation and Development (OECD), scientific literacy is defined as the capacity to use scientific knowledge, identify questions, and draw conclusions based on facts to understand nature and make decisions regarding changes in nature caused by human activities (OECD, 2015). Furthermore, Choerunnisa, Wardani, and Sumarti (2017) add that every individual in society is required to have scientific insight and literacy to tackle increasingly complex everyday problems arising from advances in science and technology, including environmental issues.

The scientific literacy abilities of Indonesian students, based on PISA results, remain below the international average (Toharudin, Hendrawati, & Rustaman, 2011). This is reinforced by Naruto and Supardi (2019), who described a tendency for the ranking of Indonesian students' science literacy to decline based on PISA assessments from 2000 to 2018. The 2022 PISA results showed Indonesia's ranking in literacy learning outcomes improved by 5 to 6 positions compared to 2018, marking the highest achievement in the country's PISA history. Although Indonesia’s scientific literacy score rose to 383, this is still below the OECD average score of 485 (OECD, 2023). These results indicate that the Indonesian education system has yet to effectively facilitate the enhancement of students' scientific literacy. Several studies have concluded that junior high school students in Indonesia still display low literacy skills (Afina et al., 2021; Hidayah & Susilowati, 2019; Sujudi et al., 2020; Widyastuti & Widodo, 2018). According to Widowati et al. (2019), the low science literacy profile of junior high students in Yogyakarta City is particularly evident in the competency aspect, caused by insufficient regular science-based learning geared toward scientific literacy and inadequate training in problem-solving based on scientific literacy principles.

Several factors contribute to the low scientific literacy and critical thinking abilities of students in Indonesia, including the implementation of a curriculum and education system that are less supportive, limited variety in teaching methods and learning modes used by teachers, suboptimal learning tools and facilities, and the use of less engaging learning resources (Kurnia, Zulhermman, & Fathurohman, 2014; Ashri & Hasanah, 2015). According to Fitriyah et al. (2020), students' abilities and understanding of scientific literacy and critical thinking can be enhanced with appropriate learning models and supporting technology.

Science learning is also expected to address global challenges by improving critical thinking and technological skills in society. One of the essential skills that students must possess to compete in the 21st century is critical thinking (World Economic Forum, 2015). According to Aprina et al. (2024), critical thinking is an intellectual skill that serves as valuable intellectual capital for students and is a crucial aspect of thinking maturity. The purpose of teaching critical thinking is to help students learn how to solve problems in a structured and creative way, enabling them to identify various alternative solutions. Norris (Sani, 2019) stated that a critical thinker seeks reasons for thinking, gathers sufficient information, uses trustworthy sources, openly cites these sources, considers alternatives, seriously evaluates the views of others and oneself, withholds judgment when evidence is insufficient, and seeks as much accurate information as possible. The ability to think critically is vital in education because it constitutes a key scientific attitude that students must possess when learning science. Students lacking critical thinking skills struggle to solve problems or issues encountered in science learning (Mareti & Handayani, 2021).

The learning process at Abu Bakar Yogyakarta Integrated Islamic Middle School is generally still based on rote memorization, forcing students to remember information without understanding its context or real-life application. This hampers the development of their learning independence and critical thinking abilities. This condition, often observed in science learning, negatively impacts student learning outcomes, especially given the importance of critical thinking for deeper understanding and increased academic achievement. Prihanti (2015) reinforces this by noting that critical thinking ability in the learning process leads to greater learning resilience, more active engagement, broader knowledge acquisition, and the ability to select appropriate information or learning resources. Therefore, teachers must select learning strategies that can enhance students' thinking abilities. In science instruction, teachers should provide direct experiences that facilitate genuine understanding. Students should also learn through encountering and solving problems in their surroundings.

Critical thinking is particularly important in science learning because it is a fundamental scientific attitude students must master. Deficiencies in critical thinking skills impede students' problem-solving abilities and the understanding of scientific concepts, prevent knowledge development, and result in poor learning outcomes. Mareti (2021) confirms this by stating that students with weak critical thinking abilities tend to be passive, simply receiving information without filtering or expressing opinions, leading to a poor grasp of material. Low critical thinking skills usually correlate with low academic performance. Thus, stimulating and improving students' critical thinking skills is crucial for achieving optimal learning outcomes.

The success of the learning process is also influenced by the curriculum implemented. Transitioning from the 2013 Curriculum to the Merdeka Curriculum brings changes in strategic approaches, teaching materials, methods, media, and learning modes. The concept of "being free to learn" centers on freedom and creativity in the thinking process (Rahayu et al., 2022). According to Risdianto (2019), the Merdeka curriculum was introduced as a solution designed to provide students with opportunities to learn more flexibly and without pressure, supporting

the development of natural talents to meet the educational challenges of the 21st century and the Industrial Revolution 4.0. Learning must support skills in critical thinking and literacy to solve problems, be creative and innovative, as well as proficient in communication and collaboration. The curriculum also focuses on improving teacher quality and integrating required reading materials into teaching (Kristiawati & Purwanto, 2019). Therefore, educators are encouraged to implement learning modes that allow students to actively participate in the learning process, such as problem-based learning modes. Government Regulation on Education and Culture Number 65 of 2013 concerning Process Standards recommends innovative learning modes suitable for use in education, among which is problem-based learning (Permendikbud, 2013).

Problem-Based Learning (PBL) is an innovative, student-centered learning model that can improve critical thinking skills and scientific literacy. As stated by Wulandari & Sholihin (2015), the learning model that can significantly improve problem-solving skills and scientific literacy is problem-based learning. Lastri (2023) explains that PBL is designed to develop problem-solving and critical thinking skills through the exploration of authentic problems. In the PBL mode, the teacher acts as a facilitator, while students work in groups, conduct independent studies, and collaborate to find solutions. This approach encourages integrated learning based on four core principles: real-world problems, collaborative independent study, inquiry-based solutions, and fostering creativity and self-assessment (Sulfiana, 2024). Applying this mode can stimulate students' interest in scientific issues, increase scientific inquiry, and foster a sense of responsibility toward the environment. To maximize the use of problem-based learning, the learning process must not rely solely on a single textbook but should include diverse teaching materials that support mastery of learning competencies, facilitate critical thinking, and enhance scientific literacy.

Various studies support the effectiveness of PBL in increasing scientific literacy and critical thinking. Research shows a significant improvement in students' scientific literacy when taught using PBL compared to conventional methods. PBL has also proven effective in enhancing students' critical thinking across various contexts, including by accelerating differentiated learning approaches (Smith et al., 2023). This model strategically addresses the shortcomings of conventional science teaching in Indonesia, such as rote memorization and lack of contextual relevance, by shifting the focus to active student involvement, independent investigation, and collaboration. Thus, PBL stands as an empirically validated pedagogical solution to improve science education quality.

The learning process, as the interaction between students and various learning resources within the learning environment, plays an important role in achieving educational goals. Learning resources—including data, people, or objects—are crucial for helping students achieve their learning objectives independently and collaboratively (Daryanto, 2010). Teaching materials, an important class of learning resources, remain indispensable in the learning process. Although books continue to be the main source of learning, Indonesia faces challenges with insufficient adequate teaching materials. Hence, the e-Module emerges as an

effective and efficient solution—an interactive digital book that makes learning more enjoyable and optimal through the integration of text, images, and videos, accessible anytime, while minimizing paper use (Wijayanti et al., 2024).

According to Kimianti (2019), Moodle can serve as an alternative platform for developing a science e-Module due to its accessibility anytime and anywhere, as well as its ability to present concrete, engaging, and up-to-date information, thus reducing teacher workload (Fujiarti et al., 2024). The implementation of this e-Module is strongly supported by Moodle, an open-source Learning Management System (LMS) with built-in features that support Problem-Based Learning, enabling flexible group formation and assessment (Guorui Liu, 2021). Additionally, Moodle provides various collaboration tools such as discussion forums and web integration tools for active student interaction (Buus, 2016). An e-Module is defined as an interactive digital book that offers effective and efficient accessibility (Herawati & Muhtadi, 2014) and helps minimize paper use, making learning more enjoyable and optimized (Tosun, 2014).

Based on observations, interviews, and analyses conducted, researchers plan to develop teaching materials in the form of learning modules. The module to be developed will be an electronic module. This electronic format was chosen to align with current developments. The e-Module will be developed based on an innovative learning mode recommended by policy, namely problem-based learning. The problem-based learning mode was selected because it engages students in problem-solving, application of scientific concepts in real life, and critical thinking (Asnidar et al., 2024). Problem-Based Learning can effectively train students' scientific literacy and critical thinking through the use of appropriate media, assist teachers in delivering material, save preparation time, and reduce misconceptions (Arsyad, 2011). Applying this mode in lessons will stimulate students to think critically, as they actively solve problems, while also enhancing their scientific literacy skills through the stimuli presented. The Moodle platform was chosen to implement the e-Module because its features facilitate the stages of problem-based learning, including discussion forums, evaluations, and integrations for active interaction among students.

METHOD

The model used is 4-D. The 4-D development mode which consists of the stages define, design, develop, and disseminate is a structured approach that is widely used in research development. Peneliti seperti Luthfi et al., (2021), Fatahillah et al., (2020), and Yusra et al., (2023) have applied this model in various domains such as education. The aim of this research, namely to develop a science e-Module using Moodle with the application of Problem-Base Learning (PBL) mode, was developed for learning to sharpen the scientific literacy and critical thinking skills of junior high school students.

The development procedure uses R&D research (Research and Development) proposed (Thiagarajan & Sivasailam, 1974), the mode is descriptive in nature through the steps followed to produce a product. Model consists of four stages of development, namely Define, Design,

Develop, and Disseminate. The steps taken in the R&D development mode (Research and Development) are as follows (Syam & Furwana, 2022).

RESULTS AND DISCUSSION

E-Module IPA based on Problem-Based Learning (PBL) using Moodle is the initial result of the development process carried out in this research. The product in the form of an e-Module is designed to support learning activities on the topic of environmental pollution for class VII students in primary secondary schools. The development of this product was carried out using a 4-D model approach (Define, Design, Develop, and Disseminate) where each stage of the development process is explained in detail in the following section.

Define Stage

The Define stage aims to identify the main needs in the learning process which is the basis for product development. At this stage, an in-depth analysis is carried out to determine the important elemen-elemen that must be present in the PBL-based science e-Module using moodle. This process involves assessing the curriculum, student needs, and the characteristics of environmental protection materials. In this way, the results of this stage become an important starting point for developing relevant and effective product designs.

a. Preliminary Analysis

Preliminary analysis is carried out with the aim of identifying needs in developing teaching materials. The results of the observations show that the school has implemented the Independent Curriculum for all levels, both grades VII, VIII and IX. Even though the New Curriculum provides opportunities for teachers to innovate, the application of modes of learning in the classroom is still dominated by friendly methods and cooperative learning. Teachers admit that this method is not yet fully effective in increasing student engagement as a whole, especially because there are students who tend to be passive in the group learning process. This challenge shows the need to integrate learning approaches that are more active and student-centered, such as Problem-Base Learning (PBL).

b. Student Analysis

The evaluation results show several obstacles faced by students in science learning, especially in scientific literacy and critical thinking skills. (1) Students' scientific literacy skills still need to be improved. Scientific literacy is not only about memorizing formulas or theories, but about the ability to understand the world around us scientifically, think critically, and make decisions based on evidence. Teachers said that students often only memorize material without being able to connect it to real contexts or applications. (2) Students' critical thinking is also not optimal. The current learning pattern tends to be dominated by a one-way method, where students receive more information than analyze and process it independently. Lack of opportunity to discuss, or solve complex problems collaboratively makes students less accustomed to formulating questions, evaluating

evidence, and providing solutions to various problems, so that students tend to focus on memorization rather than conceptual understanding that triggers critical thinking.

Based on the results of this analysis, teaching materials are needed that are able to support increasing students' scientific literacy and critical thinking abilities. PBL-based science e-Module using Moodle is an innovative alternative that can present interactive learning. With visualization, animation and video features, this e-Module is expected to help students understand the material in more depth, increase their involvement in learning, and at the same time encourage their ability to understand the world around us scientifically and think critically.

c. Curriculum Analysis

Curriculum analysis includes analysis of Learning Outcomes (CP) as well as material analysis which is important. CP analysis ensures that learning objectives related to environmental pollution, such as understanding environmental pollution, types of pollution, impacts and efforts to overcome environmental pollution can be achieved effectively. Meanwhile, material analysis assesses the adequacy and relevance of the learning content presented in the textbooks or teaching materials used, thus ensuring that the information presented is in accordance with the competency standards and needs of class VII students in understanding environmental pollution in a comprehensive manner. The following is a detailed explanation of the results of the curriculum analysis and how the e-Module product developed is in line with the demands of science learning in class VII.

d. Concept Analysis

Consequence analysis is carried out to provide a comprehensive picture of the content of the materials that will be included in the product. This analysis aims to ensure that the material presented has been prepared systematically, is relevant, and supports the learning objectives to be achieved. The material developed is focused on the concept of environmental pollution, covering types of pollution, impact of pollution, efforts to overcome and prevent environmental pollution. Through this analysis, the material is prepared to be able to help students understand the topic in depth which is designed in a PBL-based e-Module using Moodle. Figure 7 provides a comprehensive picture of the concept of environmental pollution.

Design Stage

In this phase, planning or e-Module design is carried out which is developed including:

a. Outline e-Module IPA based on Problemm-Based Learning

Preparation of Outline of e-Module IPA based on Problem-Based Learning with "Environmental Protection" material created using Moodle software which is operated online, accessed by website url address.

Develop Stage

a. Initial Product Development

The initial product preparation was carried out to develop a science e-module based on Problem Base Learning using Moodle with the aim of improving students' scientific literacy and critical thinking skills. The product development process involves several stages as follows:

1) Selection or Medevelopment
   This stage is carried out based on context, resources, work conditions, culture, and practicality. E-module combines several electronic contents such as YouTube to provide videos related to the problems presented and links to articles related to environmental protection.
2) Platform for Media Implementation
   This stage includes the development of the system used to build the e-module. In the module development stage, the design is carried out using Microsoft Word and Corel Draw. Then, the content is entered into Moodle, which has been installed on a website hosting platform. Moodle was chosen as the primary platform because it offers flexibility in the features it provides and is interactive.
3) Visualization
   This section develops elements based on a display that is easy for new users to understand. This visualization can be refined through expert validation and limited testing. Visualization development is carried out to organize interactive features and ensure the display is easy to understand.

b. Content Validation

Content Validation is carried out at the next stage, which involves analysis and validation of the IPA e-module based on Problem Base Learning using Moodle, teaching modules, as well as instruments for assessing scientific literacy skills and critical thinking on environmental protection materials. This process is carried out by the lecturer and supervisor which then leads to revision. After being revised by lecturers, the e-module was submitted to expert validators, consisting of two lecturers, media experts and materials from Yogyakarta National University. The science e-module and instrument for assessing scientific literacy and critical thinking abilities is verified by subject matter experts and mehers to ensure its accuracy.

c. Limited Trial

After product improvements were made based on input from expert validators, teachers, and students, a limited trial was conducted. This trial aimed to evaluate the extent to which the e-Module could be understood and accepted by students, as well as to gather additional input. Based on the results of the trial, further revisions were made, which were used in field trials in experimental classes. The final product of this development is an e-Module based on Problem Based Learning using Moodle that is ready to be used to support science learning.

Disseminate Stage (Spreading)

This stage is the final part of the research development mode with the 4-D approach. The product in the form of a Science e-Module based on Problem Base Learning using Moodle is disseminated at the research location, namely Abu Bakar Integrated Islamic Middle School, Yogyakarta. The results of this development will also be published through research journals to expand the reach of audiences and users. In addition, it is hoped that this dissemination can support the implementation of technology-based learning in various other schools.

CONCLUSION

The Science e-Module based on Problem Based Learning (PBL) using Moodle has been validated by material and media experts as highly suitable in terms of content, language, and presentation, achieving a very good rating. It is also deemed very practical and user-friendly based on positive feedback from science teachers and students during implementation. Furthermore, effectiveness tests using MANOVA demonstrated a significant improvement in students' scientific literacy and critical thinking skills ($p < 0.05$), with effect sizes indicating a moderate positive impact on both scientific literacy (0.59) and critical thinking (0.58). For future research, it is recommended to explore the long-term effects of this e-Module on students' learning outcomes across diverse educational contexts and to investigate how integration with other digital tools or pedagogical approaches might further enhance its effectiveness.

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