



Development of E-Module based on Education for Sustainable Development to Train High School Students' Scientific Literacy on the Topic of Biogas Purification

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Abstract: Development of E-Module based on Education for Sustainable Development to Train High School Students' Scientific Literacy on the Topic of Biogas Purification. This study aims to develop a product in the form of an ESD based e-module on the topic of biogas purification to train students' scientific literacy. The research method used is DDR type 1 with a focus on specific project phases that include the analysis, design, development, and evaluation stages. This study involved seven chemistry teachers in the initial needs analysis stage, three validators consisting of two expert lecturers and one chemistry teacher, and nine 11th grade students at a high school in Bandung for a pilot test during the evaluation phase. Data collection were carried out using e-module validation sheets, e-module questions, and analysis of student answers. The validation results showed that the developed e-module met the e-module eligibility criteria with several suggestions and improvements from the validators. In addition, the results of the analysis of the pilot study on students' science literacy profiles indicate a high level of achievement in various aspects of science literacy, suggesting that the e-module has the potential to train students' science literacy.

Keywords: *Biogas Purification, E-Module, Education for Sustainable Development, Science Literacy.*

Abstrak: Pengembangan E-Modul Berbasis Education for Sustainable Development pada topik Pemurnian Biogas untuk Melatih Literasi Sains Murid SMA. Penelitian ini bertujuan mengembangkan produk berupa e-modul berbasis ESD pada topik pemurnian biogas dari limbah organik untuk melatih literasi sains murid. Metode penelitian yang digunakan adalah DDR tipe 1 dengan berfokus pada tahapan specific project phases yang meliputi tahap analisis, perancangan, pengembangan, dan evaluasi. Penelitian ini melibatkan tujuh orang guru kimia pada tahap analisis kebutuhan awal, tiga orang validator yang terdiri dari dua dosen ahli dan satu guru kimia, serta sembilan murid kelas XI di salah satu SMA di Kota Bandung untuk uji coba terbatas pada tahap evaluasi. Instrumen menggunakan lembar validasi e-modul, soal-soal e-modul, dan analisis jawaban murid. Hasil validasi menunjukkan bahwa e-modul yang dikembangkan memenuhi kriteria kelayakan e-modul dengan beberapa saran dan perbaikan validator. Selain itu, hasil analisis uji coba terbatas pada profil literasi sains murid menunjukkan tingkat capaian baik dalam mencapai kemampuan pada aspek-aspek literasi sains, sehingga e-modul berpotensi untuk melatih literasi sains murid.

Kata kunci: *E-Modul, Literasi Sains, Pemurnian Biogas, Pendidikan untuk Pembangunan Berkelanjutan.*



▪ INTRODUCTION

Scientific literacy is essentially focused on four interrelated aspects: knowledge, context, competence, and scientific identity. This aligns with the Organization for Economic Co-operation and Development (OECD) definition of scientific literacy as a person's ability to engage with science-related issues and ideas as a reflective citizen. This requires the ability to explain phenomena scientifically, design and evaluate scientific investigations, and interpret data and evidence scientifically, enabling them to participate in addressing issues and ideas about science (OECD, 2023). Science competencies can be used to develop the scientific literacy that students need to tackle problems in their daily lives, making them relevant for use in science education.

The OECD periodically measures scientific literacy through the Programme for International Student Assessment (PISA) every three years. The 2018 PISA results showed that Indonesian students' scientific literacy skills were still very low internationally. In 2018, Indonesian students' scientific literacy ranked 70th out of 79 countries with a score of 396 (OECD, 2018). Kemendikbudristek (2023) released the results of the 2022 PISA results, which showed that Indonesia's literacy learning outcomes ranking rose by 5 to 6 positions compared to the 2018 PISA. Although Indonesia's ranking improved compared to the previous year, according to the OECD, Indonesian students scored below the OECD average in mathematics, reading, and scientific literacy. Overall, the average results for 2022 decreased compared to 2018 in each of the assessment subjects of reading, mathematics, and scientific literacy. The low achievement of students' scientific literacy in Indonesia is caused by several problematic factors in the learning process.

Several factors contribute to the low scientific literacy skills of students in Indonesia. According to Fuadi et al (2020) factors contributing to low scientific literacy include inappropriate textbook selection, misconceptions in understanding the material, and a non-contextual learning process. This is due to the fact that teaching materials commonly used by teachers often only present content without connecting it to everyday life examples (context). As a result, students simply read without understanding how to apply the concepts they have learned in real life (Raharjo et al., 2017). In fact, contextual learning can help students understand and apply the knowledge they have learned in various situations, so they are better prepared to face the complexities and challenges that exist (Fatihah & Wiji, 2025).

Contextuality can be applied in several learning approaches, one of which is ESD-based learning, which connects scientific concepts with everyday life issues. The ESD concept is based on three main pillars: environmental sustainability, economic growth, and socio-cultural dimensions. These three pillars are the main factors that arise from global issues facing humanity (Ruswendi et al., 2024). ESD can be incorporated into both intracurricular and extracurricular activities. ESD is not merely viewed as a supplement to education but as an integral part of the formal education curriculum (Imran et al., 2024). In line with this statement, the education policy currently implemented by the Indonesian government is stipulated in Ministry of Education, Culture, Research, and Technology Decree No. 56/M/2022, which regulates the national curriculum guidelines. This policy emphasizes the importance of lifelong education and focuses on a sustainable future. In this curriculum, teachers are required to collaborate relevant values, knowledge, and skills in sustainable development efforts (Kemendikbudristek, 2022).

Students' low scientific literacy skills in learning can be trained with good learning media (Shofia et al., 2024). Therefore, teachers need to design interactive, contextual learning media that can train students in interpreting scientific data, thereby encouraging students to be actively involved in observing, interpreting, and communicating natural phenomena, which are competencies that must be possessed in understanding scientific literacy (Resvania et al., 2025). One learning media that can be developed is teaching materials in the form of ESD-based electronic modules so that they can be used independently and can train students' scientific literacy. This is supported by research by Hanifah et al (2025) who stated that ESD-based e-modules with the topic of low-carbon energy can be used to train students' scientific literacy. In addition, research by Musyarofah & Fitrihidajati (2025) stated that E-Modules with contextual material are proven valid and practical based on aspects of presentation feasibility, content feasibility, and can be used to train students' scientific literacy skills.

Biogas purification can serve as a relevant topic in chemistry education that can be implemented in e-modules based on Education for Sustainable Development (ESD). Biogas is a flammable gas produced from the decomposition of organic compounds, such as livestock manure or food waste, through anaerobic fermentation. Biogas contains, among other things, methane (CH_4) 55-75%, carbon dioxide (CO_2) 25-45%, and hydrogen sulfide (H_2S) 1–5%. Biogas can be utilized for cooking (Elizabeth, 2021). Biogas contains impurities namely CO_2 and H_2S that can reduce its quality. One way to improve biogas quality is through the biogas purification process (Ritonga et al., 2020). Biogas purification can be performed by passing the biogas through a NaOH solution, thereby facilitating an absorption process accompanied by an acid-base reaction (Isya & Purba, 2023).

This context aligns with the 2025 Learning Outcomes, which state that acid-base balance can be applied in various fields, one of which is the energy sector, such as biogas (Kemendikdasmen, 2025). Therefore, the use of the biogas purification topic in chemistry instruction can be employed to develop students' scientific literacy and foster their awareness of environmental issues and sustainability. This is supported by Gurusinga (2024) research, which found that the application of PjBL-based STEM e-modules on chemical equilibrium demonstrated that the developed e-modules were categorized as "highly practical". Suhandi (2026) research on an ESD-based e-module on acid-base equilibrium concepts with a biochar topic found it to be valid and having the potential to develop students' science literacy.

This study aims to develop an ESD-based e-module on biogas purification to enhance students' science literacy. This is because no previous research has specifically developed an ESD-based e-module on biogas purification—which relates to the concept of acid-base equilibrium—to enhance students' science literacy. Therefore, this study is expected to develop teaching materials in the form of e-modules that can foster science literacy, thereby incorporating questions that address the key aspects of science literacy: scientific competence, scientific knowledge, and scientific identity (OECD, 2023b). Additionally, the e-module is also developed based on ESD to foster students' awareness of environmental, economic, and social aspects in line with the components of ESD.

■ METHOD

This study employs a quantitative descriptive approach using the DDR (Design and Development Research) model to develop an ESD-based e-module on biogas purification designed to foster science literacy. The development model used is DDR according to

Richey & Klein (2007) explaining that DDR type 1 consists of four stages: analysis, design, development, and evaluation. This study is limited to the evaluation stage consisting of a limited trial involving nine students. This trial aims to determine the achievement of students' scientific literacy profiles. The DDR model is implemented through a series of stages arranged as follows:

1. Analysis

The design phase involved a literature review on science literacy and ESD, an analysis of the learning outcomes for chemistry in the national curriculum, an analysis of content and context, and a preliminary survey to determine whether an e-module needed to be developed. Needs analysis was conducted through a literature review of various journals and a questionnaire distributed via Google Forms to high school chemistry teachers. A questionnaire is a data collection technique involving questions that have been systematically formulated (Ardiansyah et al., 2023).

2. Design

The design phase involved several stages of developing the e-module, including the formulation of learning objectives based on an analysis of the national curriculum, the PISA 2025 literacy framework, and ESD principles. After formulating the learning objectives, the researchers grouped them based on the context and content of chemistry material on the topic of biogas purification found in credible and relevant sources such as journal articles, books, and general chemistry textbooks. An outline of the e-module was then created using a structured framework in accordance with the guidelines for e-module development from Kemendikbud (2017)

3. Development

At this stage, the e-modules are developed based on the outline created during the design phase. This involves rewriting the original text to align with the students' developmental level, adding learning media (such as images, videos, and graphics), and compiling the modules into an electronic format. Subsequently, the e-modules are validated by experts to determine their suitability. The evaluation rubric used for validating the text within the e-modules includes the following criteria: 1) Alignment of the material with learning objectives; 2) Accuracy of content and context; 3) Alignment of illustrations, images, symbols, and sketches with the text; 4) Linguistic appropriateness for students' developmental level. Meanwhile, the assessment rubric for validating questions in the e-module includes: 1) Alignment of questions with learning objectives; 2) Alignment of questions with aspects of science literacy; 3) Accuracy of the answer rubric. Analysis results are calculated using the Guttman scale, with a score of 1 for "Yes" and a score of 0 for "No" (Aprilia & Mahardika, 2024).

4. Evaluation

This evaluation phase was used to review the e-module developed based on a pilot test of the practice questions included in the e-module. The pilot test involved a limited number of students, with three students each representing the high, medium, and low ability groups. The purpose of this limited pilot test is to determine the science literacy profile based on an analysis of students' answers after using the developed e-module as learning material. The assessment rubric used in this study is a holistic rubric adapted and modified from the rubric developed by Allen & Tanner (2006). These holistic assessment

guidelines use a three-point scale to evaluate student responses with the following criteria: 1) a score of 2 for students who demonstrate understanding by answering the questions completely; 2) a score of 1 for students who are able to answer the questions, but not completely; 3) a score of 0 for students who are unable to answer the questions in the e-module

Participants and Research Site

This study involved seven chemistry teachers during the initial needs analysis phase of the e-module. The e-module development and validation phase involved two expert lecturers and one chemistry teacher as validators, as well as nine 11th grade students from a high school in Bandung as participants in a pilot test. The nine students were categorized into three groups high, medium, and low based on assessments by the chemistry teachers at the school.

A total of 12 science literacy questions were developed in the form of open-ended questions aligned with the learning objectives, aspects of science literacy (science competencies, science knowledge, and science identity), and ESD aspects (environmental, economic, and social) that students must achieve. The question indicators are structured based on the aspects of science literacy within the PISA 2025 framework to develop the ability to explain phenomena scientifically, design and evaluate scientific investigations, and interpret data and evidence scientifically, thereby enabling students to participate in addressing issues and ideas related to science (OECD, 2023a). In addition, students are also expected to demonstrate awareness of and contribute to addressing environmental issues and the energy crisis covered in the e-module.

Data Analysis Techniques

The data analysis technique employs a quantitative descriptive approach. This approach is used to analyze the data from the textbook feasibility validation by calculating the average scores of the validators, which are then described qualitatively according to the evaluation criteria (Sumbawati et al., 2024).

The data collected from several validators consists of qualitative data. Therefore, the next step for the researcher is to analyze the data using the validity formula for the e-module and the questions developed. According to Aprilia & Mahardika (2024), the validity of the developed e-module can be measured using the following formula:

$$TV = \frac{\sum x}{n} \times 100\%$$

Description:

TV : Level of validity

$\sum x$: Number of “yes” responses from validators

n : Maximum score

The validity levels, adapted from Sumbawati et al (2024), are assessed based on the percentages obtained and divided into five categories in Table 1.

Table 1. Validity Level Categories for E-Modules and Questions

No	Achievement Level	Validity Categories	Description
1	81-100%	High Validity	Acceptable with minor revisions
2	61-80%	Valid	Acceptable with minor revisions
3	41-60%	Quite Valid	Acceptable with major revisions
4	21-40%	Low validity	Not suitable for use

5	< 20%	Not valid	Not suitable for use
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The level of achievement in students' science literacy profiles is measured mathematically using a formula developed by Jakiah et al (2024), as follows:

$$S = \frac{R}{N} \times 100\%$$

Description:

S : Level of science literacy
R : Total score for correct answers
N : Skor maksimum

The achievement value of scientific literacy skills can be interpreted descriptively through the percentage interpretation developed by Randan et al (2022) in the following table 2.

Table 2. Student science literacy achievement categories

Scientific Literacy Ability	Category
86-100%	Very good
76-85%	Good
60-75%	enough
55-59%	less
≤ 54%	very less

■ RESULT AND DISCUSSION

The development of an ESD-based electronic module on the topic of biogas was carried out using the DDR model, which focuses on training students' scientific literacy through four systematic stages: analysis, design, development, and evaluation.

Analysis phase

The needs analysis stage is an important initial step in developing an e-module. The purpose of this stage is to identify the needs and constraints in schools by collecting information through questionnaires from chemistry teachers (Adrianus et al., 2023). This questionnaire was distributed as a preliminary survey to 7 chemistry teachers in Bandung City and Regency. The results of the preliminary survey showed that all 7 teachers stated that an ESD-based e-module and scientific literacy needed to be developed. Respondents gave the following reasons: 1) ESD-based e-modules and scientific literacy need to be developed so that students become accustomed to and can practice their scientific literacy skills, 2) The development of e-modules can be a means for students to connect chemical concepts with everyday phenomena, so that students can solve problems in everyday life, 3) Chemistry learning becomes more meaningful for students because it is relevant and applicable to real life, so students can be more creative in applying their knowledge. The topics presented in the e-module include contexts that are new to learning for high school students, making this material more interesting for students.

Design phase

The e-module development was carried out by compiling an e-module outline that refers to the practical guidelines for compiling e-modules according to Kemendikbud (2017). This e-module is structured in three learning activities as follows: 1) Learning activity 1 begins with problems regarding organic waste and the energy crisis that

occurred in Indonesia, this aims to attract students' attention to the phenomena occurring around them, 2) Learning activity 2 focuses on the context of making biogas from cow dung waste. In this learning activity, chemical content is discussed regarding acid-base equilibrium during the anaerobic decomposition process stages, 3) Learning activity 3 focuses more on the context of biogas purification using the concept of chemical absorption. In this learning activity, chemical content is discussed regarding acid-base equilibrium during the chemical adsorption stage. An example of the outline structure in the developed e-module is shown in table 3.

Table 3. Outline E-Modul

Components	E-Module Contents
E-Module Components	Front cover Foreword Table of Contents List of Figures List of Tables
Introduction	E-module Description Learning Objectives E-module Usage Instructions Concept Map
Learning activities 1 to learning activities 3	Learning Activity Title Learning Objectives “Ayo pikirkan!” Feature “Ayo pelajari!” Feature “Ayo berlatih!” Feature Summary Evaluation
Conclusion	Glossary Bibliography Author Profile

Development phase

The development of an e-module product consists of several stages: combining original texts, creating basic texts, formulating scientific literacy questions, and compiling the e-module in digital format using the Canva application. Canva is a graphic design application that can be accessed online on electronic devices such as personal computers or Android devices. Currently, Canva is often used in various fields, one of which is education. Canva has various features that make it easier for teachers to design e-modules. The features in Canva can make e-modules more attractive (Nugroho et al., 2024). Next, the draft e-module that has been created will be validated by two expert lecturers and one chemistry teacher.

At this stage, validation of the developed e-module and questions was conducted through a triangulation process between researchers (investigator triangulation). All text and questions in the e-module were validated by three validators, consisting of two expert lecturers in the fields of chemistry and scientific literacy, and a chemistry teacher at the school. This process was carried out to ensure the accuracy of the material and questions contained in the e-module based on predetermined indicators, and to minimize interpretive bias because the influence of social interactions in the world of education

creates a higher tendency for researchers to interpret data based on personal beliefs (Muhtadi, 2025). The results of the text validation in the e-module by the three validators are presented in Table 4.

Table 4. Analysis of E-Modul Validation Results

Validator	Score	Maximum Score	Percentage for Each Validator	Validity Category
Validator 1	48	48	100%	High Validity
Validator 2	48	48	100%	High Validity
Validator 3	48	48	100%	High Validity
Average Validity Percentage			100%	High Validity

In Table 4, the validation results indicate that the ESD-based e-module on the topic of biogas purification from organic waste is suitable for use, with a 100% validity rating categorized as “High Validity.” This means the e-module can be used with minor revisions, as there are several notes and suggestions for improvement from the validators regarding certain sections of the e-module. The text in the e-module is found in the “Ayo Pikirkan” feature, which contains prompt questions, and the “Ayo Pelajari” feature, which contains contextual learning materials. Contextual material regarding the energy crisis and biogas purification is used so that students can practice their science literacy skills. This is in line with the research by Muhlis et al (2024), which states that the use of contextual teaching materials enables students to interpret data and evidence scientifically, evaluate and design scientific investigations, and explain phenomena scientifically.

The results of the validation of science literacy questions in the e-module by the three validators are presented in Table 5.

Table 5. Analysis of Question Validation Results

Validator	Score	Maximum Score	Percentage for Each Validator	Validity Category
Validator 1	34	36	94%	High Validity
Validator 2	36	36	100%	High Validity
Validator 3	36	36	100%	High Validity
Average Validity Percentage			98%	High Validity

Based on Table 5, the validation results indicate that the science literacy questions in the e-module are deemed suitable for use, with an average percentage of 98%, which is categorized as “High Validity.” These results mean that the questions in the e-module can be used with some revisions or minor improvements so that the questions in the e-module align with the aspects of science literacy and the learning objectives that were previously developed.

Evaluation phase

Student responses were analyzed based on their alignment with the scoring rubric that had been developed. The assessment uses a scoring range adapted from the scale developed by Allen & Tanner (2006), namely a 0–2 scale. This stage involves cross-verification among three researchers (investigator triangulation), where the results of the analysis of student responses by the first researcher are validated by the second and third researchers, who are expert lecturers in the fields of chemistry education and science literacy. This is done to maintain the objectivity of the analysis of student responses by

reducing the influence of the researchers' personal views (Muhtadi, 2025). The results of the analysis of student responses for each question are presented in Table 6

Table 6. Analysis of Each Student's Answers

Question	Scientific Literacy Aspect		Student Category								
			High			Moderate			Low		
			S1	S2	S3	S1	S2	S3	S1	S2	S3
1	C1	S2	1	2	2	2	2	1	1	2	0
2	C1	EK	1	2	2	2	1	2	1	2	1
3	C1	EK	2	2	2	2	2	1	2	2	1
4	C3	S1	2	2	2	1	2	2	2	1	2
5	C2	CK	1	1	1	0	1	1	1	2	0
6	C1	CK	2	1	2	1	2	1	2	1	2
7	C1	CK	2	2	2	2	2	0	2	1	2
8	C3	CK	2	1	2	2	2	2	2	1	1
9	C3	CK	1	2	2	2	2	1	2	1	2
10	C1	CK	1	2	2	2	1	2	2	2	1
11	C3	CK	2	2	1	2	2	1	1	2	1
12	C1	S3	2	2	2	2	1	2	2	2	2
Total Score			19	21	22	20	20	16	20	19	15
Overall Achievement Rate			79,63%								

Description:

- 2 : Achieving all aspects of scientific literacy
- 1 : Achieving some aspects of scientific literacy
- 0 : Not achieving the scientific literacy aspect
- S1 : Science Identity dimension 1: Valuing Scientific Perspectives and Scientific Approaches to Research
- S2 : Science Identity Dimension 2: Affective Elements of Science Identity
- S3 : Science Identity dimension 3: Environmental awareness, beliefs and agency
- CK : Content Knowledge
- PK : Procedural Knowledge
- EK : Epistemic Knowledge
- C1 : Science Competence Dimension 1: Explaining phenomena scientifically
- C2 : Science Competency Dimension 2: Developing and evaluating designs for scientific investigations and critically interpreting data and evidence
- C3 : Science Competence dimension 3: Researching, evaluating, and using scientific information for decision making and action

The overall scientific literacy achievement of the nine students who participated in the limited trial showed an average score of 79.63%. This score indicates that, in general, students who participated in the limited trial using e-modules in their learning had good scientific literacy skills. This is supported by research by Faridah et al. (2022) which found that learning using e-modules was effective in developing students' scientific literacy skills because e-modules can combine the presentation of material in the form of text, images, graphics, and learning videos.

The results of the analysis of students' answers can be used to measure the level of scientific literacy achievement based on the average value for each group of high, medium, and low student categories presented in Figure 1.

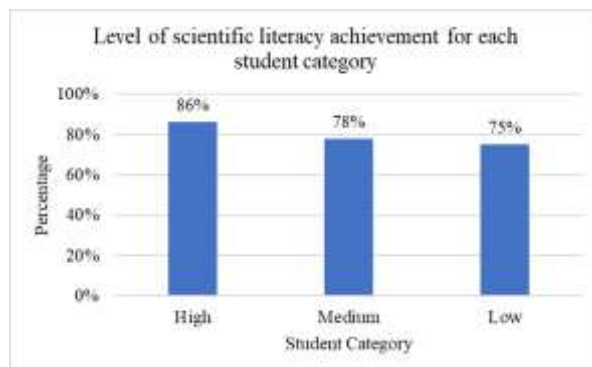


Figure 1. Level of Scientific Literacy Achievement for Each Student Category

Based on Figure 1, the scientific literacy achievement for each group of students in the high, medium, and low categories was 86%, 78%, and 75%, respectively. Students in the high and medium categories achieved scientific literacy skills in the very good to good categories. Differences in students' scientific literacy achievement results are influenced by several factors, one of which is differences in students' academic abilities. This is consistent with research by Purba et al (2026) which states that there is an indication of a positive and significant relationship between scientific literacy skills and students' academic achievement in learning. According to Wibowo & Ariyatun (2020), students' ability to identify scientific issues is greatly influenced by the quality of their prior knowledge. This is in accordance with constructivism theory, where students' prior knowledge is crucial in the learning process. Prior understanding serves as a foundation for students to receive or learn new information (Panggabean & Tamba, 2020). Therefore, students with high academic abilities will have the ability to solve problems in questions containing scientific data presented. Meanwhile, one of the reasons why students still have lower achievement in the scientific literacy aspect is because students do not have experience in solving questions of high complexity, so that students who are not used to solving contextual problems related to science will face difficulties when solving these questions (Kurniawan et al., 2024).

The results of the analysis of the level of scientific literacy acquisition in each aspect, which includes scientific competence, scientific knowledge, and scientific identity, are presented in Figure 2.

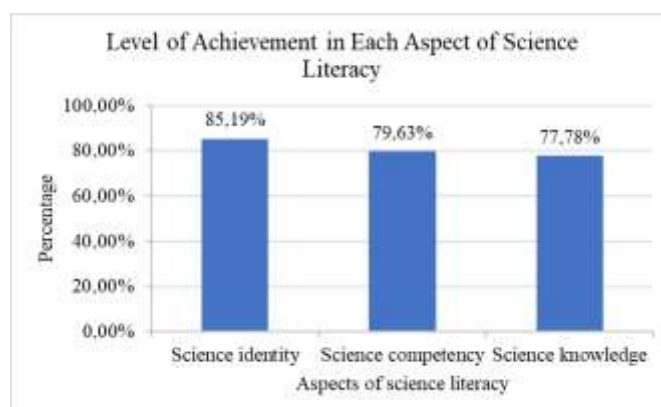


Figure 2. Level of Achievement in Each Aspect of Science Literacy

Based on Figure 2, it shows the data from the analysis of the achievement of scientific literacy aspects including science identity, science competency, and science

knowledge. The level of student achievement in the science identity aspect obtained a score of 85.19% with a good category. The good category indicates that the e-module has the potential to be used to train the science identity aspect, because the e-module contains contextual material that can train students' awareness of the surrounding environment, including regarding the energy crisis, livestock waste problems, and biogas purification which is used as an environmentally friendly alternative energy. This is in line with research by Muhlis et al (2024) which states that the use of contextuality-based teaching materials can train students' science literacy skills. This learning is also in accordance with the deep learning approach in the national curriculum in Indonesia. This approach emphasizes a more in-depth and relevant learning experience, so that students can connect the knowledge gained with real experiences around them. This approach aims to produce a more meaningful learning process (Suwandi et al., 2024).

In science competency, there are three main science competencies that students need to achieve this ability, namely explaining phenomena scientifically; developing and evaluating designs for scientific investigations and interpreting data and evidence critically; and researching, evaluating, and using scientific information for decision-making and action (OECD, 2023b). The results of the analysis of the achievement of the science competency aspect showed a value of 79.63% which is included in the good category. A good science competency aspect means that students can demonstrate the ability to apply previously understood scientific knowledge in solving problems contained in scientific literacy questions (Wibowo & Ariyatun, 2020). This shows that learning using e-modules that connect the context of the energy crisis and biogas purification as an alternative energy can encourage students to connect chemical concepts with phenomena in everyday life, so that students are trained to make decisions or actions by producing alternative energy due to scientific information regarding the energy crisis problem. The results of this study are supported by Sari et al (2022) who stated that students' scientific literacy abilities in the science competency aspect increased after going through a contextual learning process.

The students' scientific knowledge aspect was achieved at 77.78%, categorized as good. The good achievement of the scientific knowledge aspect indicates that the developed e-module makes it easier for students to understand the material because it is more interactive. In addition, the learning material that not only presents concepts but also allows students to construct scientific knowledge from surrounding phenomena. This is supported by research by Jannah & Utami (2024) that constructivist learning activities that direct students to construct their own knowledge about phenomena and problems integrated with a scientific context can improve students' scientific literacy in the scientific knowledge aspect. Then Faridah et al. (2022) stated that e-modules can present more interactive learning materials for students to use independently.

■ CONCLUSION

The results of expert validation of the developed e-module and scientific literacy questions show that the e-module and questions are categorized as "High Validity" with minor revisions, so that the developed e-module and questions have met the criteria that have been set for e-modules. These criteria include the suitability of the material to the learning objectives; the accuracy of the content and context; the accuracy of the illustrations of images, symbols, and sketches with the text; and the appropriateness of the language with student development, while for questions, the criteria include the suitability of the questions to the learning objectives; the suitability of the questions to

the aspects of scientific literacy; and the accuracy of the answer rubric. Several questions have been revised according to input from the validator. Although the developed e-module and questions meet the criteria, there are still several parts that need to be improved based on the findings and input from the validator.

The students' scientific literacy profile is demonstrated through the results of a limited trial of the use of the e-module by three students from each of the high, medium, and low groups. Based on the results of the analysis of students' answers, it can be concluded that the average achievement score of the scientific literacy aspects of all students is categorized as good, so that students in the limited trial have been able to achieve aspects of scientific literacy (science skills, science knowledge, and science identity). This indicates that the developed e-module contributes to training students' scientific literacy. Students' scientific literacy abilities have a positive relationship with students' initial academic abilities.

Suggestions for future researchers include developing e-modules that reinforce the content and context of other chemistry materials related to issues surrounding students and aligned with the chemistry material in the applicable national curriculum.

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