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Implementation of STEM E-Module with SDGs Principle to Improve Science Literacy and Environment-friendly Attitudes in Terms of Gender

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Abstract

Scientific literacy plays an important role in developing education in the 21st century. However, the current student's scientific literacy ability is relatively low. The millennial generation has been named as a generation that has an environment-friendly attitude. In cases that occur in the field, many students still litter and are not friendly to the environment. There are no teaching materials that develop scientific literacy and environment-friendly attitudes in implementing STEM (Science, Technology, Engineering, and Mathematics) with the principles of Sustainable Development Goals (SDGs). This research aims to produce a STEM e-module with the principles of SDGs to improve scientific literacy and environment-friendly attitudes of 11th grade students regarding gender that is valid, practical, and effective. This research is development research (R&D) with the Plomp model. The data analysis results show that the STEM e-module with SDGs principle has a good impact on students' scientific literacy skills and environment-friendly attitudes. The developed e-module can also help students practice scientific literacy and improve a better environment-friendly attitude.

Keywords: e-module, environment-friendly attitude, gender, scientific literacy

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1. Introduction

Sustainable development goals (SDGs) or also called sustainable development are on the agenda of the United Nations (UN). Its main objectives are socio-economic development of the environment and overcoming global challenges such as climate change and the loss of biodiversity (Sebestyén et al., 2020; Coscieme et al., 2020).

Physics learning as a part of STEM education that has a reciprocal relationship with the environment is thermodynamics (Rizal, 2017). Thermodynamics in the principles of sustainable development can be a strong driver to foster curiosity, control towards new ideas and habits of quantitative analytical thinking (Aswirna et al., 2020). Thermodynamics can also understand natural resources well (Rizal, 2017). One way to understand resources is to understand the environment around us.

The environment gives positive and negative feelings towards people, objects or problems related to the environment, then the individual will raise the intention to perform behaviors that reflect love for the environment by protecting and preserving the environment. The fact that is happening now, human interaction with the environment has caused a lot of environmental damage such as higher waste production, air pollution, and deforestation, causing flooding (Septian et al., 2016). One of the efforts made to improve the quality of the environment is to use

environment-friendly attitudes as part of the learning process.

Environment-friendly attitude is a theory but is a cognitive assessment of beliefs and feelings about an attitude object (Heberlein, 2012). This behavior is exemplified by a student who prefers cycling when going to school, this motive is motivated by the desire to reduce air pollution. not only in the field of science and the environment but also in the field of technology because the development of technology and information has revolutionized all aspects of life in the 21st century (McGrath & Fischetti, 2019) to produce human resources capable of mastering 21st century skills (Fahmi et al., 2021).

The progress of science and technology in various countries is increasing rapidly in the 21st century. In the field of education, the education system has grown in the last five decades to meet the demands of higher-quality education (Aswirna & Harahap, 2020). One of the things that are emphasized in the 21st century in the field of education is the literacy that students must have to build the golden generation of 2045. The literacy that students need in the 21st century is scientific literacy (Rifqi, 2021).

Scientific literacy includes knowledge of science, scientific processes, and the development of scientific attitudes that will enable students to make decisions with the knowledge they have. Scientific literacy describes a person's ability to understand laws, theories, phenomena, and scientific matters (Aswirna & Ritonga, 2020). Scientific literacy is a combination of skills, values, attitudes, understanding, competence, and knowledge of science needed for individuals to develop research-investigations, problem-solving, skills and abilities to interpret data and facts scientifically and the ability to understand learning concepts (Klucevsek, 2017).

The results of the 2018 PISA study of scientific literacy of 396 points are ranked 74th out of 79 countries. From these results, it can be seen that Indonesian scientific literacy is very lacking (Salsabila et al., 2021). According to the 2017 Environmental Quality Indeks (*Indeks Kualitas Lingkungan Hidup/ IKLH*) and Indonesian Environmental Status (*Status Lingkungan Hidup Indonesia/ SLHI*) report issued by the Indonesian Ministry of Environment, it was reported that around 30% of Indonesia's water has been polluted. Likewise, the air condition has decreased due to the shrinking green land, polluted air, and more garbage piling up. From these results it can be seen that Indonesia's environment-friendly attitude is very low (Sugiarto & Gabriella, 2020).

One of the causes of the low scientific literacy and environment-friendly attitudes of students is the lack of teaching materials that can shape students' scientific literacy skills and environment-friendly attitudes. Most of the teaching materials found are only focused on the material, lack contextual and monotonous, and have no scientific knowledge in solving problems in teaching materials (Nurhasnah & Sari, 2020). The teaching materials used are still in the form of conventional print media so there is a lack of activeness and creativity among students and there are no teaching materials that form a friendly attitude to the environment (Retnowati et al., 2018).

One of the teaching materials that makes it easier for students to learn the subject matter (Wulansari et al., 2018), by utilizing technological resources in learning is e-module (Aswirna et al., 2020). E-modules are teaching materials that are arranged in sequence with reference to the curriculum and packaged in the form of a certain time unit that can be presented with electronic media such as computers or androids (Garjita et al., 2017). E-modules help in navigation containing images, audio, and video, and are equipped with formative tests or quizzes (Aswirna et al., 2020)

STEM (science, technology, engineering, and mathematics) can be defined as education to increase students' interest and understanding of scientific technology and to develop STEM literacy based on scientific technology and the ability to solve real-world problems. STEM can

increase investment for innovation and sustainable economic development and STEM can improve the welfare of people (Saraç, 2018). STEM is a learning approach that is able to improve skills and prepare human resources with quality that is in accordance with the demands of 21st century skills (Jang, 2016).

STEM with the principle of sustainable development aims to design the improvement of people's abilities in science and innovative technological products so that they can compete globally (Utami et al., 2017). STEM can create human resources (HR) which in addition to being able to overcome environmental problems but can also reduce environmental damage and issues related to sustainable development (Nurkanti & Darta, 2019).

Thermodynamics is an experimental science in which concepts, principles, and laws are obtained through experimentation. In thermodynamics, the elements of science are very prominent and involve a lot of physical variables. These variables are interrelated so that interventions and engineering can be carried out. The results of intervention and engineering of these variables are applied to technology to help humans fulfill their needs and desires. In its application, mathematics is needed as a tool and language in expressing the relationship between thermodynamic variables and in the data processing. Based on this description, the use of the STEM approach in Thermodynamics learning is very suitable to be applied because it has a very close relationship with STEM elements (Egon et al., 2018). The concept of Thermodynamics with scientific literacy can relate to natural phenomena and phenomena so that it is more understandable to students (Nafaida, 2018). Thermodynamics with the use of alternative renewable energy sources, for example, biogas being environment-friendly is an option (Wicaksono & Marzuki, 2015).

Gender differences explain that males develop their left brain more so that he is able to think logically, think abstractly, and think analytically. Females develop their right brain more, so they tend to be artistic, holistic, imaginative, think intuitively, and have some visual abilities (Hodiyanto, 2017). It can be said that male students dominate STEM in mathematics, technology, and engineering because they use the left brain. Meanwhile, female students dominate STEM in biology or science because they use their right brain.

Furthermore, research by Retnowati et al. (2018) regarding the development of a pocketbook model based on local wealth in increasing environment-friendly behavior of SMAN Bogor City students has very high effectiveness in increasing students' environment-friendly behavior. However, not all the material for this pocketbook discusses the environment. Furthermore, research by (Muzijah et al., 2020) on the development of e-modules uses the Exe-Learning application to train scientific literacy. The developed e-module is suitable to be used to train students' scientific literacy. However, it is better to add a model or approach to make scientific literacy more visible. Based on the existing problems, it is necessary to develop teaching materials that can improve scientific literacy and environment-friendly attitudes. Therefore, the authors focused on "Using Thermodynamic E-Module of STEM with SDGs Principle to Improve Science Literacy and Environment-friendly Attitudes in Terms of Gender".

2. Research Method

The method in this research is Research and Development (R&D) using the Plomp model which consists of three phases. In this study, the research procedure was carried out based on the development procedure proposed by Plomp & Nieeven which included three phases.

Figure 1 shows the Plomp development procedure on the development of STEM-based e-modules on scientific literacy and environment-friendly attitudes on thermodynamic materials.

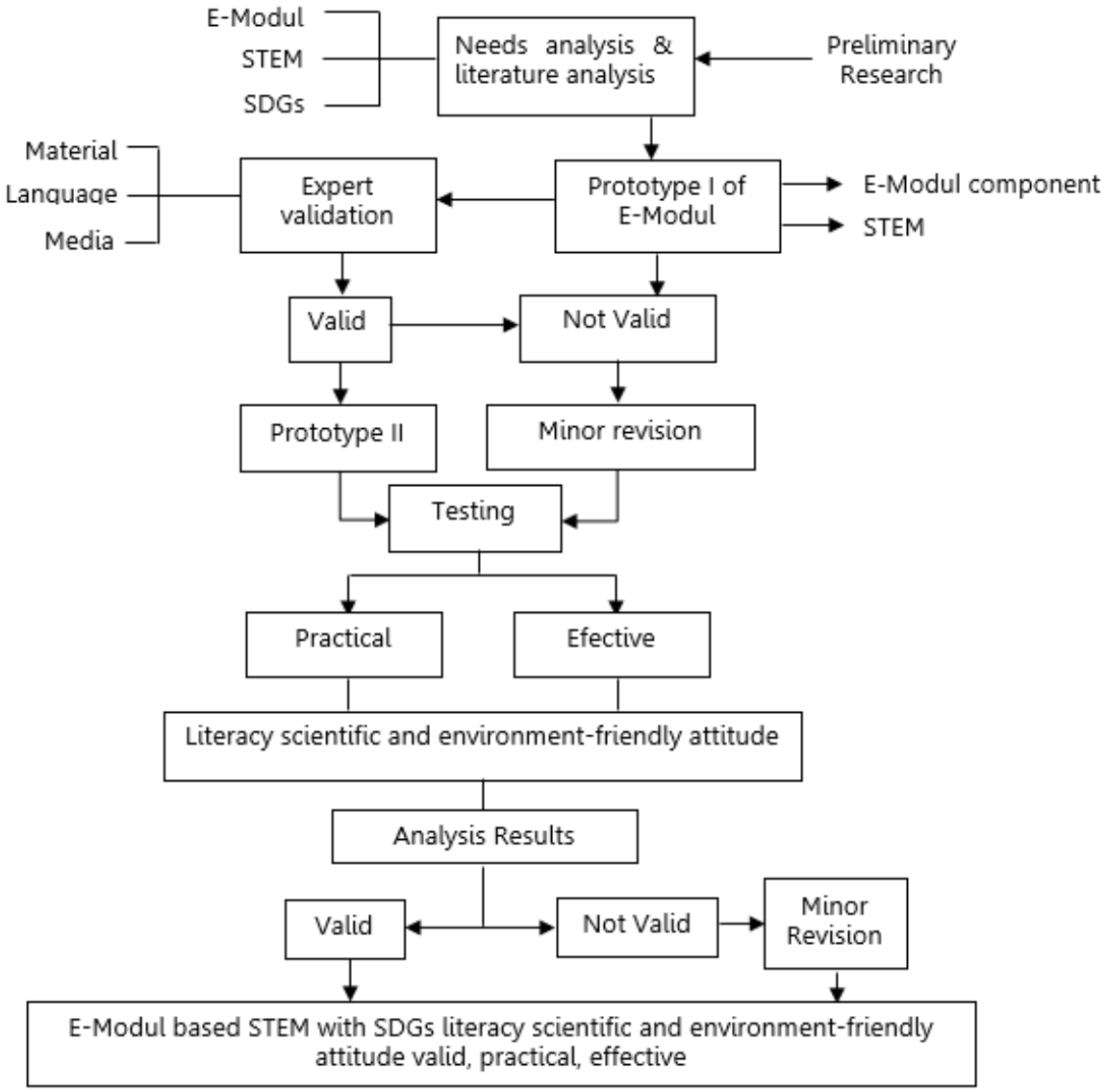

Figure 1. Research Flow

2.1. Preliminary Phase

At this phase, there is a needs analysis that aims to find out what needs are needed to overcome the problems found in the learning process. Needs analysis is carried out by interviewing teachers and students. Literature analysis was conducted to find a theoretical basis that strengthens the development of STEM e-modules. The stages of literature analysis are curriculum analysis, media analysis, material analysis, and concept analysis.

2.2. Prototype Development Phase

This phase is a continuation of the first phase which aims to produce a prototype of a STEM e-module, which consists of three activities: designing a prototype, conducting formative evaluation, and revising the prototype.

2.3. Assessment Phase

At this phase, the goal is to explore the practicality and effectiveness of a STEM e-module prototype. The level of practicality can be seen in the answers to the practicality questionnaire for teachers and students' practicality questionnaires. The effectiveness of STEM e-modules can be seen in students' answers to questionnaires and tests.

The instrument for collecting data in this study was carried out by several techniques which can be seen in Table 1.

Table 1. Data Collection Instruments

No.	Criteria	Instrument
1.	Valid	a. Validation instrument assessment sheet b. Practicality instrument assessment sheet c. Effectiveness instrument assessment sheet d. Questionnaire on the validity of the STEM-based e-module
2.	Practical	a. Practicality Questionnaire by teachers b. Practicality questionnaire by students
3.	Efective	a. Science literacy test questions, in the form of quizzes conducted in class b. Questionnaire for scientific literacy skills and environment-friendly attitudes

There are two types of data in this study, quantitative and qualitative data. Quantitative data was obtained from the results of questionnaire data, while qualitative data was obtained from suggestions and comments from validators and practitioners. Qualitative data processing is processed using qualitative descriptive techniques. This data is the result of an analysis of the assessment/response questionnaire from the product validator. The collected data is analyzed using a Likert scale technique with a positive category, in that positive statements get the highest weight.

3. Result and Discussion

Based on the research objectives and procedures, this research aims to produce STEM-based thermodynamic e-modules with SDGs principles of scientific literacy and environment-friendly attitudes of class XI students in terms of gender. The phases in this research procedure are preliminary, development, and assessment.

3.1. Plomp Development Research Results

3.1.1. Preliminary Research Phase

The preliminary phase consists of need analysis and literature analysis. Needs analysis is the first step that must be done in development activities. The analysis aims to raise and determine the basic problems faced in learning so that the development of learning media is needed. Needs analysis is done by conducting interviews with teachers and students. At this stage, the researcher collects, analyzes information, and defines problems related to the use of learning resources. The researcher has conducted an interview with a teacher at SMAN 3 Solok Selatan. Interviews were conducted with teacher on August 23, 2021, in natural science 11th grade and interviews with students.

While the second is literature analysis, which is an attempt to examine theories and research results that are relevant to the research conducted. This analysis was conducted to find concepts or theoretical foundations that strengthen the STEM-based thermodynamic e-module with the principle of sustainable development of scientific literacy and environment-friendly attitudes of natural science 11th grade students in terms of gender.

3.1.2. Prototype Development Phase

In this development phase, the goal is to produce a STEM e-module with SDGs principle on scientific literacy and environment-friendly attitudes toward thermodynamic material. At this phase, there are repetitions to improve the product. This phase consists of three stages, designing prototypes, formative evaluation, and prototype revision. At the first stage, researcher design a prototype of STEM e-module. The Flip PDF Professional application used by researchers to create STEM e-modules can be seen in Figure 2.

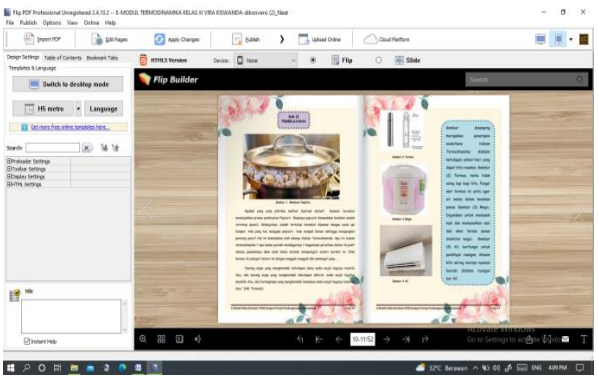

Figure 2. Display of the STEM e-module in Flip PDF Professional Application

The second stage aims to validate a STEM-based thermodynamic e-module of scientific literacy and environment-friendly attitudes by three lecturers at UIN Imam Bonjol who are experts in media, language, and material/content, respectively. In general, the results of the expert validation of the developed STEM-based thermodynamic e-module have a very good category and can be used with little revision. The STEM-based thermodynamic e-module can be seen in Figure 3.

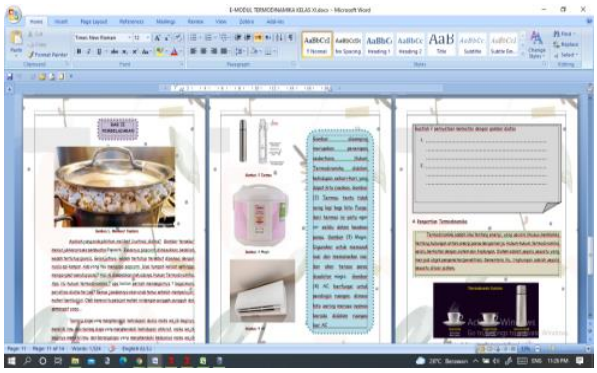

Figure 3. The STEM-based Thermodynamic E-Module

In the third stage, revision of the prototype was carried out based on input and suggestions from the validator on formative evaluation. The prototype can be seen in Figure 4.

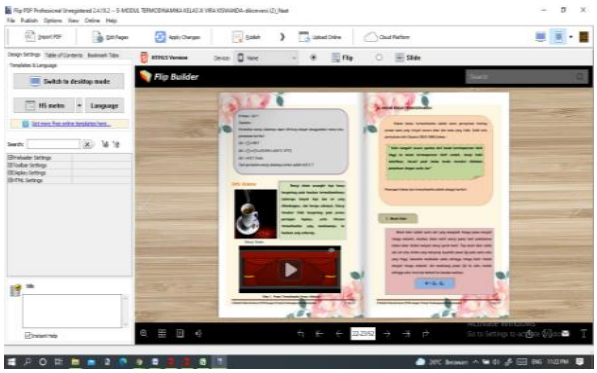

Figure 4. The STEM-based Thermodynamic E-Module Prototype after Revision

3.1.3. Assessment Phase

This phase aims to see the practicality and effectiveness of the developed STEM e-modulewith SDGs principle which was filled in by teachers and students. The level of practicality is seen from a questionnaire assessed by two teachers and a practicality questionnaire for students. Its effectiveness is seen from the questionnaires and test questions filled out by students. Each stage aims to produce a product that is valid, practical, and effective. The assessment phase can be seen in Figure 5.

Figure 5. Students Answer the Questions on the STEM-based Thermodynamic E-Module

3.2. Validity Test

The validity of the data was obtained by filling out a material/content validity questionnaire, a media validity questionnaire, and a language validity questionnaire. The questionnaire was filled out by three professional validators consisting of one material/content expert, one linguist, and one media expert. The three variables are explained in several e-module validation statements which can be determined from the average percentage of all statements which can be seen in Figure 6.

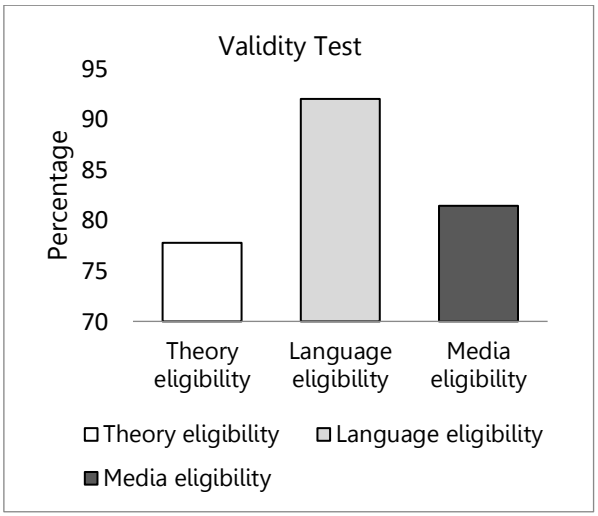

Figure 6. Data Graph of Validity Test Results of Material, Language, and Media

From Figure 6, the results of the STEM-based thermodynamic e-module data analysis on scientific literacy and environment-friendly attitudes on the thermodynamic material developed are very valid. According to Sugiyono (2011), validation is carried out by expert validators to see the advantages and disadvantages of the developed product.

The material aspect shows that the material contained in the e-module is in accordance with the curriculum and has paid attention to KI and KD as well as learning indicators. In line with Wahyuni et al. (2018), validation of the feasibility of content can be seen from the aspect of the accuracy of the material concept, the suitability of the material described, according to the topics presented in the teaching materials developed. According to Hamzah and Mentari (2017), from the aspect of content seen from the presentation of the material with a scientific approach and practice questions The validation results of the contents/materials feasibility by a validator who is a lecturer at UIN Imam Bonjol Padang obtained 77.77%, which is included in the valid category.

In terms of language use, it is stated that the aspects measured in language validity include accuracy (sentence structure, language), the use of language in accordance with the development of students, and the delivery of communicative language text, as seen from the validity of the language feasibility by a validator from language lecturer. The e-module has a validity of 92% with a very valid category. This shows that the writing and use of language in the e-module are in accordance with the rules of good and correct Indonesian spelling.

Judging from the media aspect, it is in line with Serevina (2018), there are several aspects of media feasibility, including compatibility with the content, cover design, typeface, text layout, and images, which are considered suitable for use as teaching material. In line with Ghaliyah et al. (2015), aspects of the feasibility of e-modules include the completeness of the components and the display format of the e-module. Meanwhile, according to Fonda and Sumargiyani (2018), aspects of the feasibility of e-modules include the use of letters in terms of type, color, size, animation, images, photos, and display designs. This shows that the appearance and size of the writing as well as the design of the e-module are very good. From the results of the media feasibility test by a media validator, it was obtained an average of 81.43% with a very valid category.

3.3. Practical Test

Practicality is given to teaching practitioners and students, there are 4 assessment variables: time efficiency, ease of use, benefits, and the appearance of learning media. In line with (Auditor & Naval, 2014) that e-modules are very suitable to be used as practical teaching materials that help to learn. This can prove that the e-module is suitable for use in learning. Practicality can be seen from the cost and time in the implementation and management in interpreting the results.

The STEM-based thermodynamic e-modules with the SDGs that have been validated are then carried out in a practical test. Practical data were filled in by two teachers and 20 students at SMAN 3 Solok Selatan. The average results of the practical test by teachers and students can be seen in Figure 7.

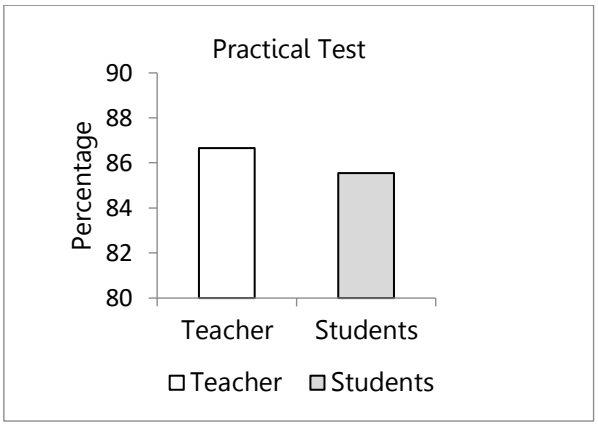

Figure 7. Data Graph of Practical Test Results by Teachers and Students

Figure 7 shows that the analysis results of the e-module practicality questionnaire by teachers are 86.66% in the very practical category and the student questionnaire analysis is 85.55% in the very practical

category. Based on the validity results above, the STEM e-module on scientific literacy and environment-friendly attitudes on thermodynamic material is practically used in learning so that there are differences in learning outcomes after using learning media at school (Andromeda et al., 2018). According to Perdana et al. (2017), learning using e-modules is better than conventional learning.

3.4. Effectiveness Test

The effectiveness test is used to see the scientific literacy ability and environment-friendly attitude of students when using STEM-based thermodynamic e-modules being developed. The effectiveness of scientific literacy is seen in a questionnaire filled out by students consisting of 11 statements and 20 test questions. while testing the effectiveness of environment-friendly attitudes using an environment-friendly attitude questionnaire filled out by students with eight statements. The effectiveness sheet was filled out by 20 students consisting of ten male students and ten female students. The average value of the questionnaire and scientific literacy test questions for male and female students and the average value of the environment-friendly attitude questionnaire can be seen in Figure 8.

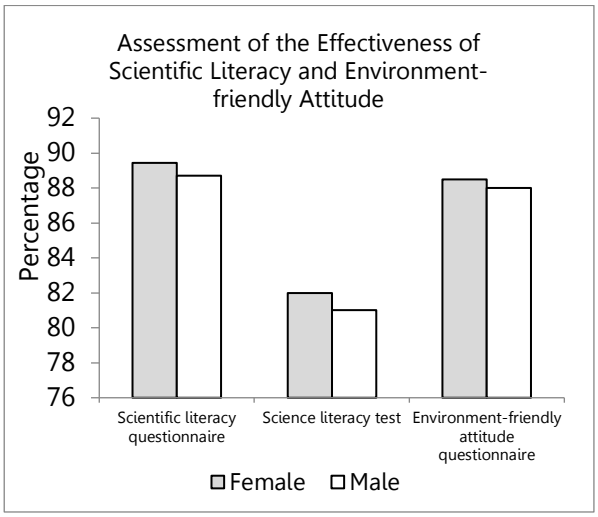

Figure 8. Data Graph of the Results of the Effectiveness Test of Scientific Literacy and Environment-friendly Attitude

Seen from the analysis results of the STEM-based e-module effectiveness of male and female students on the scientific literacy questionnaire for male students of 88.72% and 89.45% for female students. for the test results of male students 81.00% while women 82.00%. For the environment-friendly attitude questionnaire, male students are 88.00% while female students are 88.50%. it can be said that the STEM-based thermodynamic e-module is categorized as very effective.

The STEM e-module shows its effectiveness in scientific literacy and environment-friendly attitudes on thermodynamic material. This is because the material in the e-module is coherent and presented by providing information that occurs in the environment around students. In addition, e-modules are developed in accordance with the abilities of students who are able to explain and detail a problem then can provide a better understanding of scientific literacy and benefit the everyday environment and increase environment-friendly attitudes because students can use waste to be used as teaching aids. In line with Genc (2015), scientific literacy uses attitude skills, values, problem-solving, and decision-making processes and becomes a lifelong learner. Meanwhile, an environment-friendly attitude is in line with Gumelar (2017), which is a form of attitude theory combined with beliefs and feelings about an attitude object.

The developed STEM-based thermodynamics e-module has been able to improve students' scientific literacy and environment-friendly attitudes. STEM is very important in learning based on the effectiveness test research by Muzijah et al. (2020) which are categorized as effective and suitable to be used to train students' scientific literacy.

In general, it can be defined that an e-module is a form of presentation of teaching materials that are systematically arranged into the smallest learning units to achieve certain learning objectives which are presented in an electronic format. This format includes animation, audio, and navigation that creates user interaction with the program (Arnila et al., 2021).

The attitude of teachers towards scientific literacy is positive. From the survey results, it seems that teaching experience helps teachers to increase knowledge, as well as an emphasis on learning objectives in solving problems in everyday life, and action on environmental issues should be integrated into learning that aims to improve scientific literacy (Dragoş & Mih, 2015).

For students to develop scientific literacy and environment-friendly attitudes, they need to improve their mental processes. Scientific literacy is understanding and applying scientific principles to everyday life. Students are expected to be able to reason, understand, interpret, analyze, and solve problems in everyday life so that students have the potential to support students' scientific literacy skills (Bauer & Booth, 2019). Scientific literacy can measure the extent to which an individual has scientific abilities and uses knowledge to identify questions, acquire new knowledge and skills, explain scientific phenomena, and draw conclusions based on evidence and experiences that students have about related science issues (Stocum, 2015; Archer-Bradshaw, 2014).

Environment-friendly attitudes in students can be exemplified by not littering, utilizing waste as useful materials, keeping the air from being polluted by going to school by bicycle or walking, making environment-friendly places to live, and saving water (Samarasinghe, 2012). The environment-friendly attitude is a behavior that is carefully carried out to reduce the impact it has on the environment (Samarasinghe, 2012).

This STEM e-module on scientific literacy is an e-module related to solving real-world problems associated with science, technology, engineering, and mathematics. Through STEM learning, students are stimulated to be proficient in solving problems, able to design and find new ideas, have sensitivity to increase their capacity and have a good mastery of technology (Suwarma et al., 2015).

E-modules developed on thermodynamic material contain elements of good teaching materials, and the use of good and appropriate learning media provides great benefits for teachers and students (Emda, 2011). The developed e-module has advantages in terms of the material contained in core competencies and basic competencies related to STEM as well as a wider discussion. The material is related to the four pillars of STEM science in it (Irmawati et al., 2021).

In addition to improving scientific literacy, this e-module also looks at the environment-friendly attitude of students after using this e-module in learning. This environment-friendly attitude is conscious behavior that is carried out to reduce negative impacts on the environment, such as the efficiency of natural resources, saving energy consumption, using non-toxic substances, and reducing waste production (Septian et al., 2016).

In line with the research of Hidayati et al. (2008), environment-friendly attitudes of students develop by linking STEM learning by using insight into the environment in which they live. It is also supported by research results from Khoiriyah and Toro (2014) and Kirmani et al. (2017) found that a positive attitude towards the environment will affect a person's willingness to recycle waste that is around him.

4. Conclusion

The results of the development and discussion that have been carried out in this study resulted in a STEM-based thermodynamic e-module with the principle of sustainable development of scientific literacy and environment-friendly attitudes for 11^{th} grade students in terms of gender that is valid, practical, and effective. The validity of the STEM-based thermodynamic e-module with the principle of sustainable development in terms of material/content, language, and media with an average score of 83.72% with a very valid category. Practicality in terms of time and convenience with an average score of 86.16% in the very practical category. Its effectiveness on scientific literacy from the male questionnaire scores was 88.72% and female students 89.45%. for the results of the

scientific literacy test, male students are 81.00% while female students are 82.00%. For the environment-friendly attitude questionnaire, male students are 88.00% while female students are 88.50%. in the very effective category. The results of the students' scientific literacy test questions with an average score of 81.50% in the very effective category. There are differences between men and women in using the STEM-based thermodynamic e-module with the principle of sustainable development. Therefore, STEM-based thermodynamic e-modules with the principle of sustainable development can be developed by teachers on other materials so that learning is more meaningful.

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