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The Ecosystem Problem-Based Learning E-module To Train Critical Thinking Skills During COVID-19 Pandemic

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Abstract

The form of Biology teaching materials nowadays was still limited, in contrast with digital platforms' fast development. Incomplete learning experiences cause difficulties in understanding difficult topics such as ecosystems, which lead to critical thinking skills training obstacles, more so during the COVID-19 pandemic. Therefore, it was necessary to develop teaching materials to train this skill. The problem-based learning model required the students to actively solve the problems, in turn training them to think critically. The purpose of this research is to develop a valid, readable, and practical ecosystem problem-based learning e-module to train high school students' critical thinking skills. This research used the ADDIE model, data gathering use validation, Fry Graph, and questionnaire method on the 10 students of SMAN 1 Dawarblandong grade 10 as the participant, and the descriptive-quantitative techniques used to analyze the data. The result of this research, namely the developed e-module with authentic problems and hands-on activities; the 3.78 validity score; the suitable readability for 10th-grade students; and 96.94% positive response on practicality. Accordingly, the ecosystem problem-based learning e-module to train high school students' critical thinking skills declared very feasible in terms of validity, readability, and practicality.

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INTRODUCTION

COVID-19 pandemic changes a lot of things, one of them can be seen in the government's order to keep the physical distance to contain the spread of the virus. These protocols resulted in some great adjustments in various activities, including learning activities that were forced out to do from home by online learning. Ultimately, various digital platforms and electronic devices were being used. Thus, has an impact on the increasing use of electronic devices and the internet. Research conducted by Siste *et al*. (2020) shows that the use of the internet and electronic devices in Indonesia during the pandemic increased by 52% compared to before the pandemic. This situation gives rise to the idea that the use of digital platforms should support the development of appropriate teaching materials for online learning (Wargadinata et al., 2020). The implementation of online learning requires educators to be more creative in using digital platforms to meet their needs. There are lots of free digital platforms, so the development of various forms of teaching materials is highly available as well. However, based on the results of the interview with the students of SMA Negeri 1 Dawarblandong, showed that Biology online learning was using a limited form of teaching material, namely through PDF files and PowerPoint. This causes a less than optimal understanding because the material and assignments are not delivered interactively, so the students faced some difficulties in understanding the concept.

One of the suitable teaching materials to help students master the concepts by learning independently, but still in tune with digital developments, is the module (Selviani, 2019). A module is teaching material that contains a complete structure of subject matter, so it is expected to help the students to understand the concept. The module is also useful to provide a complete learning experience for the students to learn independently (Ariefiani *et al*., 2016). In order to keep up with digital developments, modules should be presented in digital form (Suarsana & Mahayukti, 2013). E-module is the digital form of a module that operated by utilizing technology so the material is presented interactively in the form of text, audio, video, images, animations, literature references, competency tests in the form of quizzes or formative tests, and answer keys to provide feedback directly for the students as soon as possible (Suarsana & Mahayukti, 2013). In addition, an e-module is a teaching material with self-instructional characteristics, where the learning steps included in it can help students to become independent learners (Lestari, 2019).

This independent learning environment is very much needed by the students, more so during the pandemic. Moreover, the students are also required to master 21st-century skills, one of them being critical thinking skills. So, according to Diana *et al*. (2015), an e-module is a qualified teaching material that can support the training of critical thinking skills in high school students to meet the needs in this fast-changing and highly competitive world. However, the learning system in Indonesia has not reached the optimal environment to train critical thinking skills, thus Indonesian students' critical thinking skills are still considered low. Based on the results of the Program for International Student Assignments (PISA) held by the OECD in 2018, Indonesia ranked 71st out of 79 countries with 396 points in sciences. This result has decreased by 7 points from the 2015 PISA. The OECD (2018) sets a standardized science score of 489 points, which Indonesia has not yet been able to achieve. The ability to answer about 40% of Indonesian students so far is only at 2, 3, and 4 levels. Meaning, Indonesian students are yet to conquer the required ability to answer critical thinking questions (OECD, 2018).

Critical thinking skills according to the National Council for Excellence in Critical Thinking (2017) are an intellectual discipline process that actively and skillfully finds concepts, applies, analysis, synthesizes, and or evaluates any information collected or obtained from the process of observing, experiencing, reflecting, reasoning, or communicating. The process of training students' critical thinking skills should use the appropriate learning model. Ibrahim (2014) stated that the critical thinking training process can be implemented through a problem-based learning model. This is also supported by Hunaidah *et al.* (2018) which explain that problem-based learning is effective to improve learning outcomes and practicing critical thinking skills. Furthermore, Larassati & Rachmadiarti (2021) also states that authentic problems faced by students through problem-based learning model will help them to build critical thinking patterns during the problem-solving process, so they can construct their knowledge.

The process of active knowledge construction can be carried out on Biology subjects in high school. One of the suitable materials is the ecosystem topic which was taught in grade 10 of senior high school. This topic is also closely related to the conditions around the students, including the various components that make up the ecosystem, the processes that take place in it, the benefits, and the impact of human activities on the ecosystem balance. However, based on the results of the National Biology Examination for high school students in Mojokerto Regency, this topic scored 42.81 in absorption value, which was considered low. More specifically, the students were not able to propose predictions and solutions for the impact of human activities in certain areas on the ecosystem balances (Kemendikbud, 2019).

This difficult topic can be presented in the form of thinking activities that are integrated within a problem-based learning model, then equipped with hands-on activities. Erti (2017) mentions that hands-on activities are effective in improving critical thinking skills because, through hands-on activities, the students are allowed to freely apply the concepts that have been obtained through thinking activities so that the concepts can last longer in their long-term memory. This is in line with the benefits of the problem-based learning model which can increase the retention of concept, because various authentic problems, in this case, related to ecosystems, are reasonable to lead the students into reasoning and analyzing to propose problem-solving solutions (Yew & Goh, 2016).

Based on the description above, it is known that there has been a gap between the limited form of Biology teaching materials and rapid digital developments during the pandemic, resulting in the cascading effects, namely incomplete learning experiences on difficult topics such as ecosystem, which in turns causing obstacles in training critical thinking skills. The development of teaching materials in the form of an e-module that suits digital development, contains complete learning experience on ecosystem topics, and follows a problem-based learning model is required to train critical thinking skills during this pandemic. Therefore, the purpose of this research is to develop a valid, readable, and practical ecosystem problem-based learning e-module to train critical thinking skills of high school students during COVID-19 pandemic.

RESEARCH METHOD

This research is a developmental research, conducted at the Department of Biology, Faculty of Mathematics and Natural Sciences, State University of Surabaya, and SMAN 1 Dawarblandong from September to December 2021. This research refers to the ADDIE model through 5 stages, namely analysis, design, development, implementation, and evaluation.

The analysis (A) stage was going through several steps, 1) Problem analysis used to locate the learning problems, which resulted in the use of basic competencies 3.10 and 4.10, learning indicators, and objectives. 2) Student analysis was aimed to determine the condition of the students to meet their needs. 3) Task analysis was aimed to map students' abilities according to the indicators. The design (D) stage was done by systematic planning, selecting the format, media, and creating the draft. The development (D) stage aimed to compile each subchapter into one e-module. After that, the validity test was being carried out by the assessment of material expert, education expert, and high school Biology teacher, using validation sheet to assess the content, presentation, and language feasibility on Likert scale. E-module declared valid if the total final score of ≥ 2.6 is obtained (Table 1).

Table 1. Validity score interpretation criteria

Score	Criteria
$3{,}51 \leq P \leq 4$	Very valid
$2{,}51 \leq P \leq 3{,}5$	Valid
$1{,}51 \leq P \leq 2{,}5$	Less valid
$1 \leq P \leq 1{,}5$	Not valid

Adapted from Çelik & Laptalı (2016)

The implementation (I) stage intended to determine the readability and practicality of the developed e-module using Fry Graph and students' response questionnaire sheet instruments. These steps were conducted on a limited trial on 10 students of SMAN 1 Dawarblandong grade 10. One hundred words was

taken from three different sections of the e-module. The number of sentences (Y-axis) and the number of syllables, multiplied by 0,6 (X-axis) is calculated. The meeting points of the X and Y axes will be determined using the Fry Graph and then interpreted by the category (Table 2). E-module declared readable for 10th grade students if the meeting points are within the 9th-12th zone as a difficult category.

Table 2. Readability level interpretation criteria

Graph Interpretation		Readability Category
If the meeting point is within:	1st-6th zone	Easy (1st – 6th Grades)
	6th-8th zone	Medium (6th – 8th Grades)
	9th-12th zone	Difficult (9th – 12th Grades)

Adapted from Kinanti & Raharjo (2021)

The students' response questionnaire aimed to determine the practicality. The answer statement is done with certainty, the "Agree" answer scored 1 and 0 for "Disagree". All the summed scores then converted into percentage. E-module declared practical if the total percentage of 71% is obtained, according to the practicality category (Table 3). Meanwhile, the last stage is the evaluation (E) stage, which aimed to make some small improvements to several detected deficiencies.

Table 3. Practicality score interpretation criteria

Score (%)	Criteria
86-100	Very practical
71-85	Practical
51-70	Enough
26-50	Less practical
0-25	Not practical

Adapted from Prihandono *et al.* (2017)

RESULTS AND DISCUSSION

This research resulted in the form of a developed e-module product, 3.78 scores for validity, suitable readability level for 10th grade students, and 96.94% positive response for the practicality of problem-based learning e-module on ecosystem topic to train critical thinking skills of high school students.

The Ecosystem Problem-Based Learning E-module

The developed e-module in this research contains several features that support the delivery of materials and concepts to train high school students' critical thinking skills. The resulting e-module is digital form, written in B5 size paper, 12 points Times New Roman font, which consists of 106 pages including cover (Figure 1), and divided into 3 parts, namely *Pembelajaran I* about components and the interactions within an ecosystem (Figure 2), *Pembelajaran II* about energy flow and ecological pyramid (Figure 3), lastly *Pembelajaran III* about the biogeochemical cycle (Figure 4).

Figure 1. E-module cover

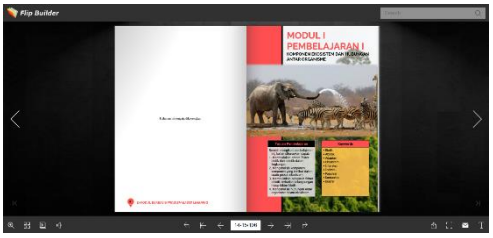


Figure 2. *Pembelajaran I*

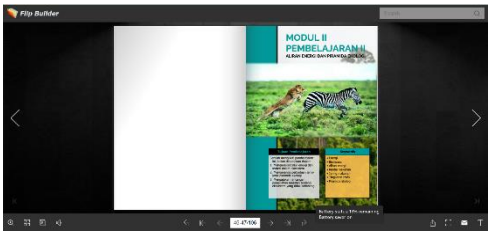


Figure 3. *Pembelajaran II*

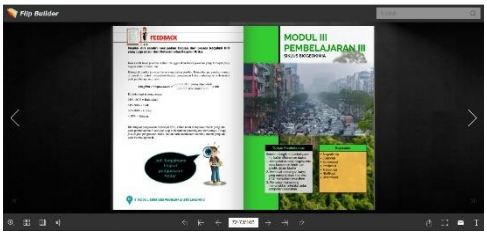


Figure 4. *Pembelajaran II*

The content of the e-module includes text, images, and videos related to the ecosystem topic (Figure 5), arranged by following the syntax of the problem-based learning model which contains structured learning activities for students to follow (Figure 6).

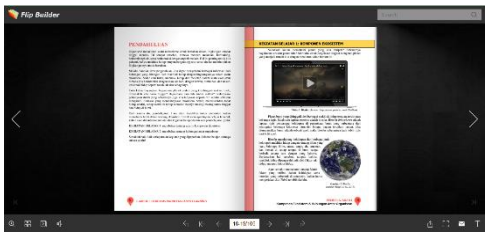


Figure 5. Preliminary activity of the e-module

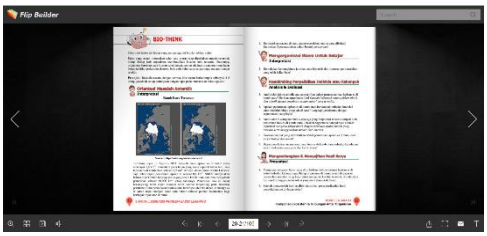
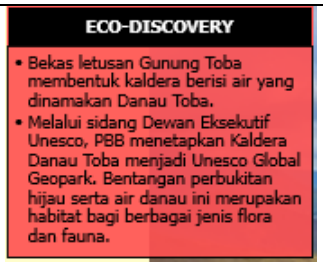
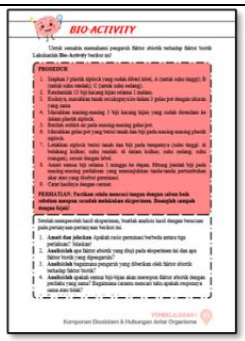


Figure 6. Thinking activities in Bio-Think by following the Problem-Based Learning syntax

The most important feature to train critical thinking skills in this e-module is "Bio-Think" (Figure 6), which will train students to learn actively and independently by including critical thinking elements in it, namely interpreting, analyzing, evaluating problems, inference, presenting results, and self-regulation. Other features that support Bio-Think as the main feature, are Eco-Discovery, Let's Learn, Bio-Activity, Reflection, Formative Test, and Feedback (Table 4).

Table 4. E-module features

E-module features		
 **Eco-Discovery,** is an abbreviation of Ecological Discovery which discusses interesting information about ecosystems, both from Indonesia and across the world.	 **Let's Learn,** presents material or concepts which students must understand to support thinking activities in Bio-Think.	 **Bio-Activity,** presented in each lesso, provides a space for students to carry out direct activities in the form of actions, as a result of thinking activities.
 **Reflection,** contains evaluation procedure, independently filled	 **Formative Test,** contains questions related to the	 **Feedback,** contains formulas and criteria for mastery level, so the

by the students after completing each lesson. If it meets the set standards, students can continue to take the Formative Test.	ecosystem, and must be filled in by students every time they complete a lesson.	students can find out their position after taking the Formative Test. If it meets the set standards, students can move on to the next lesson.

The developed problem-based learning e-module on ecosystem topic to train critical thinking skills of high school students has several characteristics as presented (Table 5).

Table 5. E-module characteristics

E-module interface	a. Digital form b. Flip transition effect every switch of pages c. Learning steps arranged following problem-based learning syntax d. There are hyperlinks that point to a certain section in the e-module e. There are links that connect to the internet resources f. Provides pictures, symbols, and videos to support the intended material
Use of e-modules	a. Available to use via mobile phone and laptop b. Access link: https://online.flipbuilder.com/wigdz/kxcn/
Content	a. Presented materials based on 2013 Curriculum, Basic Competencies 3.10 and 4.10 b. Presenting real-life (authentic) problems as the basic learning process c. Include 6 critical thinking elements d. "Let's Learn" feature intended to convey the concept and materials e. Bio-Think, Bio-Activity, and Formative Test are focused to train critical thinking

Validity of Ecosystem Problem-Based Learning E-module to Train Critical Thinking Skills

The e-module has been validated by three validators, namely material expert, education expert, and high school biology teacher, who assessed aspects of content, presentation, and language feasibility. The following is the recapitulation of the validity test result on problem-based learning e-module for ecosystem topic to train critical thinking skills of high school students (Table 6).

Table 6. Validity test result

No.	Assessed Aspect	Average
I. CONTENT FEASIBILITY		
A.	**Material Coverage and Accuracy**	
	1. Clear learning objectives.	3.67
	2. Fully presented ecosystem material.	4
	3. Presented in a complete e-module **(self-contained)**	4
	4. Presented through conceptual and theoretical truth.	4
	5. Easy-to-understand material.	4
B.	**Material Recency**	
	6. In line with scientific and technological development **(adaptive).**	4
	7. The components reflect current conditions.	4
	8. References are no older than 10 years old.	4
C.	**The Practice of Critical Thinking Skills.**	
	9. Identify problems **(interpretation).**	4
	10. Develop arguments for each answer **(analysis).**	4
	11. Search through reliable sources **(evaluation).**	4
	12. Conclude logically **(inference).**	4
	13. Present the arguments **(presentation).**	4
	14. Assess and evaluate themselves **(self-regulation).**	4
	15. Elaborate the answers on Formative Test.	4
Content feasibility score / Criteria		**3.98 / Very valid**
II. PRESENTATION FEASIBILITY		
A.	**E-module Format**	
	1. Clearly-formulated title.	3.67
	2. Cover designed according to the topic.	3.67
	3. Simple designs and color choices.	3.67
	4. Accessible via mobile phones and computers.	4
	5. Clear and easy to understand instruction **(user friendly).**	4

	6. Properly functioned components.	3.67
	7. The features support the material delivery.	4
	8. Independent teaching material **(stand-alone).**	3.67
B.	**Problem-Based Learning Syntax Implementation**	
	9. Trigger students to recognize and interpret authentic problems.	4
	10. Stimulate students to organize themselves to learn.	4
	11. Contain instructions to assist independent/group investigations.	4
	12. Encourage students to share information during developing and presenting work syntax.	4
	13. Instruct the students to self-evaluate the problem-solving process.	4
C.	**Sentence Arrangement**	
	14. Sentences are arranged coherently according to the concept.	3.67
	15. Consistent use of font type and size.	3.67
	16. Font type and size selection are easy to read.	3.67
	17. Consistent use of spaces.	3.67
D.	**Use of Symbols, Images, and Videos**	
	18. Clear picture numbering and description.	3.67
	19. Relevant use of illustrations and symbols.	3.67
	20. Relevant videos to the material.	4
Presentation feasibility score / Criteria		**3.82 / Very valid**
III.	**LANGUAGE FEASIBILITY**	
A.	**Dialogic and Interactive**	
	1. The language is easy to understand by the readers.	3.33
	2. Interactive to stimulate independent learning **(self-instructional).**	3.67
	3. Use motivating language.	3.67
	4. Correct grammar application.	3.67
B.	**Language Suitability to Student Development**	
	5. The language suits the level of students' intellectual development.	3.67
	6. The language suits the level of students' emotional development.	3.33
C.	**Language Supports**	
	7. The e-module uses Indonesian terms according to KBBI.	3.67
	8. Consistent use of foreign terms.	3.67
	9. Foreign terms are written in italics.	3.33
Language feasibility score / Criteria		**3.56 / Very valid**
E-module feasibility / Criteria		**3.78 / Very valid**

The validity results as presented in Table 6, shows that the total average validity score is 3.78, interpreted as very valid. These results have covered must-considered aspects during the development of e-modules, namely self-instructional, self-contained, stand-alone, adaptive, and user-friendly aspects according to Ditjen Pendidikan Dasar dan Menengah (2017). These five aspects obtained a score ranging from 3.5-4, which indicates that they have been fulfilled and declared as very valid.

The highest score of 3.93 with a very valid category is achieved for the content feasibility. This result shows how the e-module provides clear steps to practice critical thinking skills. These steps are structured through thinking activities on "Bio-Think" for each section (*Pembelajaran*) by following problem-based learning syntax and reinforced by hands-on activities through "Bio-Activity". For example, investigating the influence of abiotic factors on biotic factors on *Pembelajaran I*, investigating the energy flow from the surrounding ecosystem on *Pembelajaran II*, and making a creative terrarium to understand the components, factors, and biogeochemical cycle within the ecosystem on *Pembelajaran III*. These hands-on activities through "Bio-Activity" were chosen to enforce the learning process because according to Erti (2017), they are effective to improve critical thinking skills. During hands-on activities, students have the opportunity to deepen the concepts that have been obtained through thinking activities. Learning Pyramid by Edgar Dale (Masters, 2020), shows only 10% of information will be remembered by the students through hearing, 20% through reading, and this percentage will increase by 10% every time they perform tasks. Therefore, by "Bio-Activity" the students become active learners, which resulted in enhanced memory, so it will be easier for them to retrieve and apply information to think critically (Markant *et al.*, 2016).

The principle of e-module development that pays attention to the accuracy of concepts, literature references that are no older than 10 years old, and components that reflect current conditions also got a perfect score of 4 with a very valid category. These principles are intended so that the ecosystem material within the e-module can accommodate the fast developments in science and technology, such as information and problem within the "Bio-Think" on *Pembelajaran I,* which presented the latest condition of Arctics sea ice to discuss ecosystem factors and its components. This problem encourages the students to understand the maps, data, and pictures to know what has and what will happen if the Arctic ice melted away. Zabidi *et al*. (2017) states that the recency of the components is one of the crucial points that will determine the teaching materials quality. Later, it will determine the fulfillment of the objective, namely to prepare critically thinking students.

The critical thinking skills aspect of the developed e-module was scored 4. "Bio-Think" help the students to present and formulate problems, collect and interpret various information either through e-modules or the sources provided, as well as decide the solutions to authentic problems, namely massive melting sea ice threat on *Pembelajaran I,* plant pests resistance that affects the balance of energy flow on *Pembelajaran II,* and mining that causes barren land on *Pembelajaran III*. By doing so, the students will be able to solve various problems in everyday life, both related to and outside of learning (Birgili, 2015).

The aspect of presentation feasibility was scored 3.80 with a very valid category. In the aspect of the e-module format, there was a small revision advised by a material expert to the e-module title, namely the words "*Modul*" and "*Ekosistem*" had to be written on different lines. The presentation feasibility also contains the assessment of video, symbol, and image as audio-visual features to aid the learning process through "Let's Learn". The information processing theory conveys that, students in order to be able to gather, hold, and retrieve the information, there should involve three types of memory, namely sensory, short-term, and long-term memory. Sensory memory can only be acquired if various senses are involved, in this case, hearing and seeing. Then, by doing an exercise, through "Bio-Activity" the information will be aided through the short-term memory, and with the help of imagery and information arrangement, the information were converted to long-term memory, therefore there will be no difficulty to retrieve the information when needed (Loc *et al.*, 2019).

One of the principles to note of e-module development is the user-friendly aspect, which scored 4, because according to King-Heiden & Litster (2019), e-modules must contain clear and easy-to-understand instructions so that students can learn independently. The clarity of the instructions given in the e-module is also inseparable from the language and terms' simplicity. This is in accordance with Terzian & Corbalán (2021), which found that simplicity, the use of common terms, and easy-to-understand language are essential points to help the students in understanding scientific information, and eventually assist them to successfully apply that information.

The implementation of problem-based learning syntax was also scored 4 with a very valid category, because its implementation was done accordingly coherent with the problem-based learning syntax by Arends (2012). All the problem-based learning syntax were very much present on the "Bio-Think" feature for each *Pembelajaran*. The entire activity in "Bio-Think" is following these syntax which anchored to constructivism theory to control how they want to construct their knowledge, therefore instilling the systematic thinking and working process as a sign of critical thinking skills (Lapuz & Fulgencio, 2020).

The language feasibility is divided into three assessment aspects, namely dialogical and interactive, language suitability with the level of students' development, and language support. In the dialogical and interactive aspect, it covers one of the important principles of e-module development, namely "self-instructional" which was very valid with 3.67 scores. This result is an important note because according to Serrat *et al*. (2014), the main focus of e-module development is to create independent learners. Thus, to stimulate students to learn independently, interactive and dialogical language are needed. While in terms of students' development, well-structured terms and sentences are essential to not cause misconception. But at the same time, the sentences in the developed e-module are not using rigid or too formal language to match their intellectual and emotional development, because 12-18 years old students are entering the stage five of social-emotional development where lots of confusion are happening, according to psychological theory by

Erik Erikson (Maree, 2021). High school students tend to spend more time communicating with friends from the same age than with older people, so the students who are entering the age of 16 during 10th grade often prefer colloquial speech (slang), which resulted in lots of misunderstanding and confusion (Lubis & Bahri, 2021). Therefore, this developed e-module pinpoint not only to embrace and put the students' intellectual and emotional development into consideration by using semi-formal language, but also to not cause trouble in the future by using well-structured terms and sentences.

Readability of Ecosystem Problem-Based Learning E-module to Train Critical Thinking Skills

After several revisions according to the validity test, the e-module was then tested by Fry Graph to determine its readability level. Three passage samples containing one hundred words were taken from three different sections, namely the beginning, middle, and end of the e-module, to be precise from the "Let's Learn" feature, which contains material and concepts explanations. The number of syllables and sentences were calculated and resulted in the meeting points of Fry Graph's X and Y axes (Figure 7).

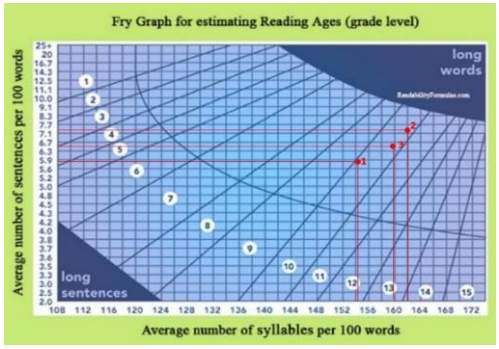


Figure 7. Meeting points of X and Y axes

These results show that all the passage samples are considered difficult according to Kinanti & Raharjo (2021) (Table 2). This is also supported by the result of the validity test in terms of language suitability to students' intelligence and emotional development which considered very valid and valid respectively. The readability level must suit the intended reader because the use of language will affect the level of understanding (Susantini *et al.*, 2021). This is related to the level of students' development, which high school students according to Flint & Spaulding (2021) were considered intelligently and emotionally well-developed, so they should be able to comprehend information from any texts with difficult and complex vocabulary. Since the intended reader for this developed problem-based learning e-module is 10th-grade students, the readability results are in the right readability category.

Practicality of Ecosystem Problem-Based Learning E-module to Train Critical Thinking Skills

The practicality test of problem-based learning e-module was conducted using a questionnaire sheet to determine students' responses. This test is limited only to 10 students of SMA Negeri 1 Dawarblandong, due to the COVID-19 pandemic. The results below indicate that the developed e-module received a positive response from 10th-grade students of SMA Negeri 1 Dawarblandong, marked by the positive response with an average score of 96.94%, categorized as very practical (Figure 8).

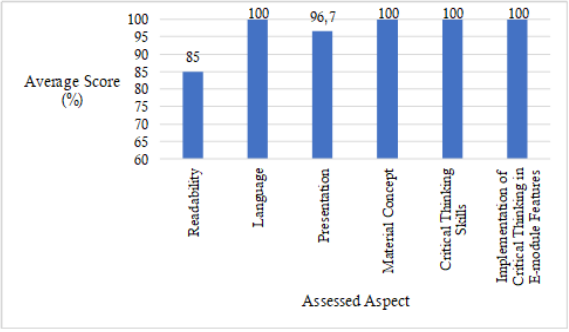


Figure 8. Practicality test result

The readability aspect received 85% positive responses from the students which included in the very practical category. This aspect focuses on the amenities of access and use of the e-module. So, it includes the criteria, whether the developed e-module provides user instruction or not and the use of font size and type. The procedure for using e-modules is one of the main characteristics of the module that distinguishes it from the other teaching materials (Ditjen Pendidikan Dasar dan Menengah, 2017). Nevertheless, more attention should be paid to the font size and font type selection, because out of 10 students, only 4 stated that the selected font size and type were easy to read. The e-module content (other than the title page and subsections) uses Times New Roman font, 12 points size. The reason for this selection was supported by Halamish *et al*. (2018) which stated that Times New Roman 12 points are perceptually clearer, therefore should be easier to read. Font size and font type are important aspects to consider in preparing teaching materials because according to Abubaker & Lu (2012), one of the many factors that influence understanding speed and accuracy is the font size. Halamish *et al.* (2018) reinforce, that grades 9-12 students are considered adults, therefore they are mostly able to understand and memorize the text with 12 points size. However, based on the practicality test, it is known that 6 students disagreed regarding the font size. They suggest that the font size should be larger, to provide comfort for the eyes when they operate the e-modules via mobile phones.

Both, the language and presentation aspects, get a score of 100% as very practical. The students felt that the e-module has embraced and encouraged them. This is due to the language aspect because instead of using the term "*Anda*" which is more formal, the e-module rather uses "*kalian*" to address the students in order to feel closer and connected to them (Reese, 2020). By doing so, the students will act differently because they feel safe and secure in those semi-formal learning environments (Chik, 2020). Meanwhile, the presentation aspect consists of quality and ease of access to images, symbols, and videos. This is important because e-module should have an appealing presentation to increase students' motivation to provide exciting learning conditions (Lari, 2014).

The concept material aspect which also scored 100%, indicates that several features provided in the e-module can support the understanding process on ecosystem topic. The "Eco-Discovery" feature, which contains interesting information related to the ecosystem, was assessed by the students as being able to enhance their insight about the ecosystem and they feel happy that they get to know a lot of ecosystem information from some places they have never visited before. This feature was added as a form of apperception for lesson preliminary to attract their interest, make them relax, so they are eager to learn (Alnajdi, 2018). In the "Bio-Think" feature, students think that the concept of ecosystem topic is well-conveyed. This feature contains problem-based learning syntax that requires them to interpret, analyze, and solve authentic problems related to ecosystems. This is in accordance with Arends (2012), that authentic problems as learning centers can stimulate students' curiosity about the related material and the problem itself. Thus, students actively seek to be involved in learning as well as become critical thinkers. For example, the students were mostly curious about the first problem on "Bio-Think" of *Pembelajaran I*, which presented the data showing 10 years differences in sea ice extent on the Arctic Sea.

Aspects of critical thinking skills and implementation of critical thinking skills within the e-module's features, both were scored 100%. These results indicate that the six elements of critical thinking skills were integrated for each *Pembelajaran* through "Bio-Activity", "Formative Test", and problem-based learning syntax in "Bio-Think". Starting with the element of interpretation in "Orient students to the problem" and "Organize students for study" syntax. In this section, students are trained to formulate and present problems from the presented text. The elements of analysis and evaluation are trained on the students in "Assist independent and group investigation" syntax, through problem analysis activities. The presentation element in "Develop and present artifacts and exhibits" syntax trained students to construct the solution for the problem and present it in front of the class. Through the presentation process, there will be classroom discussions. Furthermore, a lot of inputs will be given by the teacher and fellow students. The discussion results will help them to conclude the whole problem as well as its solution. The element trained in this section is the inference element within the "Analyze and evaluate the problem-solving process" syntax. Lastly, the element of self-regulation is implemented in the "Reflection" feature at the end of each "Let's

Learn" activities, which aims to train students to consciously and independently monitor the critical thinking process they have gone through (Facione, 2016).

Elements of critical thinking skills are also distributed within the "Formative Test", which aims to evaluate the students' critical thinking process through written tests, and the "Bio-Activity" feature, which focuses more on the implementation of critical thinking discussion at the end of every practicum. The critical thinking skills elements in "Bio-Activity" namely, 1) *Pembelajaran I,* the reason for different results of each treatment (interpretation), what biotic factor is influenced (analysis), what kind of evidence to prove the response of biotic to abiotic factors (evaluation), concluding the experiment result (inference); 2) *Pembelajaran II,* the meaning of arrow on energy flow (interpretation), decreasing width for each box of the pyramid (evaluation), and the reason why only certain amount of energy is transferred to the next level (analysis); 3) *Pembelajaran III*, the selection of terrarium placement (interpretation), the reason of using gravels as terrarium base and adding earthworms or woodlice to the terrarium (analysis), as well as the reason for water restriction and the selection of terrarium container material (evaluation).

The elements of critical thinking skills implemented in various features of this e-module show the seriousness of this research to instill critical thinking skills in high school students. The critical thinking skills are essential to prepare students with the ability to solve day-to-day problems (Larassati & Rachmadiarti, 2021) as well as prepare them for future problems (Chaiyasut *et al.*, 2014). The compatible teaching materials to assist critical thinking learning will develop students who are clear in the sense of mindfulness, originality, and high responsibility (Kang *et al.*, 2015). Changwong *et al*. (2018) enforce that proper training of critical thinking skills will generate high-quality and high-capacity human-being. These characters are needed to compete, not only in pursuing higher-level education but also in achieving long-term goals, namely obtaining good opportunities in the working field. This condition is possible because during the problem-solving process, the learning process will be permanently implanted, thus creating critical-mindedness, furthermore instilling the systematic habitual works which they will carry through adulthood (Lapuz & Fulgencio, 2020).

CONCLUSION

Ecosystem problem-based learning e-module to train critical thinking skills of high school students obtained good results with 3.78 scores for validity, 10th-grade suitable category in readability, and 96.94% positive response in practicality. Therefore, the developed ecosystem problem-based learning e-module is declared valid, readable, and practical to train critical thinking skills of high school students.

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