



Development of Problem-Based E-Modules on Environmental Change and Preservation to Improve Critical Thinking Skills of High School Students

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Abstract

This study aims to determine the validity, feasibility, and effectiveness of problem-based Environmental Change & Preservation E-Modules as teaching materials to improve the critical thinking skills of high school students. This research uses the Research and Development (R&D) research type with the ADDIE development model (Analysis, Design, Development, Implementation, and Evaluation). The subjects in this study were students of class X SMA N 15 Semarang. The data collection methods used include interviews, validation questionnaires (media experts, materials, and teachers), student response questionnaires, and pretest-posttest questions. The results showed that the problem-based Environmental Change & Preservation E-Module product developed was valid, feasible, and effective in improving students' critical thinking skills with media expert validation results amounting to 96.25% with a very valid category, material expert validation results amounting to 91.25% with a very valid category, teacher validation results amounting to 100% with a very valid category, students gave a positive response, as well as the n-gain test results amounting to 0.58 in the medium category and the results of the Wilcoxon signed rank test with Asymp. Sig. (2-tailed) of 0.000 < 0.05 which means there is a significant difference in the average pretest-posttest score. It can be concluded that the problem-based Environmental Change and Preservation E-Module is very valid, feasible, and effective to use in learning to improve the critical thinking skills of high school students.

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INTRODUCTION

The process that occurs in learning activities cannot be separated from the components of learning, one of which is teaching materials. Teaching materials are a set of subject matter given to students to study either in the form of textbooks, textbooks, learning videos, student worksheets, and other materials that can be used to teach (Gunawan et al., 2023). Teaching materials have a major influence in determining the success of the learning objectives to be achieved (Husnita & Saputri, 2023). In addition to having a major influence on the success in achieving learning objectives, the teaching materials prepared should also be able to accommodate the fulfillment of 21st century learning demands.

21st century learning requires every student to have certain thinking and social skills in order to excel in academics and careers (Nahriyah & Rachmadiarti, 2023). One of the thinking skills referred to in 21st century learning is the ability to think critically. Critical thinking skills need to be possessed by a student, especially in learning biology because it can support the learning process. This is supported by Sudarisman's (2015) statement in (Supriyati et al., 2018) which states that learning biology requires high-level thinking skills, one of which is the ability to think critically. Good mastery of critical thinking skills will help improve reasoning skills and the ability to deal with problems in the learning process (Ardiansyah et al., 2022). In fact, despite efforts in K13, students' higher-level thinking skills in Biology material are still relatively low (Angraini & Sriyati, 2019). The low critical thinking skills of students in Indonesia are influenced by several things, including the selection of methods by educators, learning resources, and teaching materials (Husnita & Saputri, 2023).

The results of interviews with Biology Teacher SMA N 15 Semarang show that students' critical thinking skills, especially in Environmental Change material, are still not optimally empowered because students are only fixated on the material and questions given by the teacher. Teaching materials in the form of printed books used are less able to stimulate students' critical thinking skills because students do not play an active role in it. In addition, another obstacle faced by students in the learning process is the lack of variety of learning media used, because the media that is widely used is only limited to power point so that students cannot understand the material presented properly.

The gap between Biology Learning practices and the demands of 21st century learning causes a lack of maximizing students' critical thinking skills. Therefore, innovation is needed in the teaching materials that are prepared to be able to improve students' critical thinking skills. Nugraha et al. (2023) revealed that the technology that is currently developing can be utilized by teachers to create interactive teaching materials so that learning becomes more interesting and can empower the abilities possessed by students.

One example of interactive teaching materials that are in line with the development of technology is E-Modules or Electronic Modules. E-Modules are teaching materials that are methodically arranged into electronic form that can be read using a PC or electronic book user (Najuah et al., 2020). The use of interactive electronic learning modules is a good learning media because its use is easy to understand Novita Santri (2022). In addition, the use of teaching materials in the form of E-Modules can help students learn actively through activities so that students' critical thinking skills can be stimulated (Hanida et al., 2023). This is in line with the statement of Kumalasani & Eilmelda (2022) which states that the use of interactive E-Modules can increase learning motivation, independence, science literacy, and students' critical thinking skills.

In developing electronic modules that aim to improve students' critical thinking skills, appropriate learning models can also be integrated (Aulia & Prahmana, 2022). The combination of electronic modules with learning models is considered effective in improving students' critical thinking skills. This is supported by the statement of Nia et al., (2022) which states that E-Modules prepared with problem-based are effective in improving students' critical thinking skills. Problem-based learning can be used in the learning process to improve critical thinking skills because through the activity of solving / solving problems provided, students' critical thinking skills can be stimulated (Ramadhanti & Agustini, 2021). The problem-based learning model is a learning model that uses a learning approach to everyday life problems (Santoso et al., 2023).

The problem-based learning model is in accordance with the characteristics of the material on environmental change and preservation whose subject matter is closely related to daily life or related to the surrounding environment. The material of environmental change and preservation requires active student involvement in learning activities so that learning becomes more meaningful so that students can be further involved in environmental conservation. In line with the opinion of Nahriyah & Rachmadiarti (2023) which states that students' awareness of the environment will foster a tendency that makes students literate to the environment so that students can take more roles in maintaining the health of their environment.

Based on the description above, it is necessary to develop a Problem-Based E-Module on Environmental Change and Preservation Material to Improve Critical Thinking Skills of High School Students.

RESEARCH METHODS

This research is a Research and Development (R&D) research with the ADDIE development model which consists of five stages, namely Analysis, Design / Design, Development, Implementation, and Evaluation.

At the analysis stage, it was carried out with the aim of identifying the problems that occurred in the field and the potential that existed in the school obtained through the results of interviews with the Biology Teacher of Class XI SMA N 15 Semarang. The design stage aims to make the design / framework of the E-Module developed through the selection of E-Module titles, the collection of books / references used in the elaboration of the material in the E-Module, the division of Environmental Change and Conservation material into several sub-chapters of learning activities, the preparation of the menu display in the E-Module, the determination of the form of evaluation, the manufacture of instruments, and the realization of the product in electronic form with the help of *PDF Flip Professional*. The development stage aims to test the validity of the E-Module through a series of evaluations conducted by validators to find out and analyze the validity level of the E-Module that has been created. After the product is declared valid, then proceed to the next stage, namely implementation. At the implementation stage, the product is tested on both small and large scales. The small-scale trial was carried out by providing a response questionnaire to 12 students in grades XI-4 of SMA N 15 Semarang with heterogeneous abilities, then the product was also tested on a large scale to students in grades X-1 and X-2 of SMA N 15 Semarang with a total of 65 students to test the effectiveness of the E-Module developed through the results of *pretest and posttest* students and student response questionnaire data was also taken. The evaluation stage aims to see the suitability of the E-Module developed with the initial expectation/initial goal of developing the E-Module. The evaluation carried out in this stage consists of two, namely formative evaluation and small trials.

RESULTS AND DISCUSSION

RESULTS

The result of this research is Problem-Based Environmental Change and Preservation E-Module teaching materials made with the help of professional flip pdf software. The product of the teaching material development research can be accessed online through the following QR Code scan.



Figure 1. QR Code E-Module for Environmental Change and Conservation

Research on the development of teaching materials in the form of Problem-Based E-Modules on Environmental Change and Preservation has been carried out based on the type of Research and Development (R&D) research with the AADIE model approach which consists of five stages, namely Analysis (analysis), design (design), development (development), implementation (implementation), and evaluation (evaluation). The results of the E-Module development research are fully described in the following subchapters:

Characteristics of Problem-Based E-Modules on Environmental Change and Preservation Materials Development Results

The results of research on the development of teaching material products, namely problem-based E-Modules on environmental change and preservation material in B5 size with a total of 59 pages which are equipped with pictures, videos, and articles relevant to the material. The problem-based E-Module on environmental change and preservation consists of the front cover, opening section, content section, and closing section which are described in detail as follows:

1) E-Module Cover Page

On the cover page of the E-Module contains the title of the E-Module, a cover with a background of burning garbage which illustrates one of the problems related to the environment, the target of the E-Module, namely Class X SMA / MA students, the logo and name of the compiling agency, as well as the names of the authors and editors. The cover page is made with the help of the Canva application.

2) Opening Section of E-Module

The opening section of the E-Module contains a preface, table of contents, learning outcomes and objectives, instructions for using the E-Module, E-Module profile, overview, and material map which are described as follows:

- a. Preface, contains greetings or offerings of gratitude for the success in completing the development of this E-Module product.
- b. Table of contents, contains the sequence of contents in the e-module which is equipped with page captions
- c. Learning outcomes and objectives, contains a description of the competencies that must be achieved by students in a phase and the learning objectives to be achieved
- d. Instructions for use, contains a description of the operation of features or components in the E-Module which is equipped with a video tutorial
- e. E-Module profile, contains a summary of all features or components contained in the E-Module with a brief explanation
- f. Overview, contains a general description of the overall activities in the E-Module and what is expected to be mastered by students after learning the material using the E-Module
- g. Material map, contains the learning flow of Environmental Change and Preservation material

3) Content Section

The content section consists of the cover of learning activities, introduction, and core learning activities (containing Smart Biology, Learn The Materials, Summary, Reflection, Formative Test, Feedback) which are described in more detail as follows:

- a. The cover of the learning activity, contains the title of the learning activity, learning sub-materials, learning objectives, and keywords made with the help of Canva application.
- b. Introduction, part of each learning activity located after the cover of the learning activity. This page describes the general description of the sub-chapter material and the description of activities that will be carried out in learning.
- c. Core Learning Activities, in this section is subdivided into 6 sections, namely Smart Biology, Learn The Materials, Summary, Reflection, Formative Test, Feedback.

1. Smart Biology is a section that contains thinking activities using reasoning, analysis, and communication to discuss and find solutions related to environmental change, environmental pollution, and waste handling problems whose activities contain problem-based learning models and train critical thinking skills.
2. Learn The Materials, a section that presents materials or concepts that students must understand to build thinking activities in Smart Biology. Summary, contains a summary of the material that has been learned in each learning activity. In this section there is a Quick Check box (short random questions about the material) and Enviromental Fact (information about facts related to the environment).
3. Reflection, a section that contains self-evaluation by each learner to find out the extent of their understanding after participating in a learning activity which can determine whether or not students continue to the next activity, namely the formative test.
4. Formative test, contains questions related to the material that has been learned. Questions are designed to train learners' critical thinking skills.
5. Feedback, contains formulas and mastery level criteria that learners can use to calculate their mastery percentage independently after working on the Formative Test. If they have met they can continue to the next learning activity.

4) Closing Section

The closing section consists of a bibliography, glossary, key answers, and author profile which are described in more detail as follows:

- a. Bibliography, containing a list of reference sources used in the preparation of the E-Module
- b. Glossary, contains a list of foreign terms or scientific names contained in the E-Module
- c. Key answers, containing the answer keys to all activities that contain questions in the E-Module
- d. Author profile, contains a synopsis and brief description of the author

The validity of E-Module Development Results

The E-Module was tested for validity through a series of evaluations from three validators, namely media expert validators, material expert validators, and teachers to determine the level of validity. Validators appointed as media and material expert validators are Biology Lecturers FMIPA UNNES who are experts in their fields, while teachers who act as validators are Biology Teachers SMA N 15 Semarang. The results of the validity test are described more clearly as follows:

a. Validity of E-Module According to Media Expert Validators

Development research products that have been completed are then tested for validity by media experts. The results of validation by media experts are as follows.

Table 1. Results of the Assessment of the Validity of E-Modules by Media Experts

Aspects	Sub Aspects	Scores obtained	Maximum Score	Percentage
Presentation Eligibility	E-Module Format	30	32	93,75%
	Implementation of PBL model syntax	20	20	100%
	Sentence Arrangement	16	16	100%
	Symbols, images, and videos	11	12	91,67%
	Total score obtained	77		
	Maximum score	80		
	Percentage (%)	96,25%		
	Validity Criteria	Highly Valid		

Based on the results of the validity analysis according to the media expert, a percentage of 96.25% was obtained in the very valid category, so that the problem-based E-Module teaching material on Environmental Change.

b. Validity of E-Modules According to Material Expert Validators

Development research products that have been completed, in addition to being tested for validity by media experts, are also tested for product validity by material experts. The results of the E-Module validation based on the assessment of material experts are presented in the following table.

Table 2. Results of Validity Assessment by Material Experts

Aspects	Sub Aspects	Scores obtained	Maximum score	Percentage
Content eligibility	Breadth and accuracy of the material	15	16	93,75%
	Material up-to-date	12	12	100%
	Critical thinking skills practice	14	16	87,5%
Content eligibility percentage		93.18% (Strongly Valid)		
Language qualifications	Dialogical and interactive	14	16	93,75%
	Language adaptation to the level of development	7	8	87,5%
	Language supports	11	12	83,33%
Percentage of linguistic eligibility		88.89% (Extremely Valid)		
Total score obtained		73		
Maximum score		80		
Percentage (%)		91,25%		
Validity Criteria		Highly Valid		

Based on the results of the validity analysis according to the material expert, a percentage of 91.25% was obtained with a very valid category, so that problem-based E-Module teaching materials on environmental change and preservation can be used in the learning process with revisions.

c. Validity of E-Modules According to Teacher Validators

Development research products that have been completed are not only tested for validity by media experts and material experts conducted by UNNES FMIPA lecturers who are experts in their fields, but also validity tests by teachers. The teacher validity test was conducted to see how the validity of the product developed based on the teacher's point of view. The results of the E-Module validation based on teacher assessments are presented in the following table.

Table 3. Results of Validity Assessment by Teachers

Aspects	Sub Aspects	Scores obtained	Maximum Score	Percentage
Presentation	E-Module Format	32	32	100%
Eligibility	Implementation of PBL model syntax	20	20	100%
	Sentence Arrangement	16	16	100%
	Symbols, images, and videos	12	12	100%
	Presentation eligibility percentage	100%		
Content eligibility	Breadth and accuracy of the material	16	16	100%
	Material up-to-date	12	12	100%
	Critical thinking skills practice	16	16	100%
	Content eligibility percentage	100%		
Language	Dialogical and interactive	16	16	100%
qualifications	Language adaptation to the level of development	8	8	100%
	Language supports	12	12	100%
	Percentage of linguistic eligibility	100%		
	Total score obtained	160		
	Maximum score	160		
	Percentage	100%		

Based on the results of the validity analysis according to the teacher, a percentage of 100% was obtained with a very valid category, so that the problem-based E-Module teaching materials on environmental change and preservation were declared to be used in the learning process without revision.

Feasibility of E-Module Development Results Based on Student Response (Small and large scale trials)

The results of the analysis of student responses to the feasibility of the developed E-Modules can be seen in Table 4 and Table 5.

Table 4. Results of E-Module Feasibility Based on Student Response Small Scale Trial

Aspects	Scores obtained	Maximum score	Percentage
Material aspects	291	360	80.83% (Good)
Aspect of presentation	623	780	79.87 (Good)
Readability aspect	53	60	88.33 (Excellent)
Total score obtained	967		
Maximum score	1.200		
Percentage (%)	80,58 %		
Student response criteria	Good		

Table 5. Results of E-Module Feasibility Based on Student Large Scale Trial

Aspects	Scores obtained	Maximum score	Percentage
Material aspects	1.680	1.950	86.15 (Very Good)
Aspect of presentation	3.587	4.225	84.90 (Very Good)
Readability aspect	288	325	88.62 (Very Good)
Total score obtained	5.555		
Maximum score	6.500		
Percentage (%)	85,46%		
Student response criteria	Excellent		

The difference in student response results in small-scale trials and large-scale tests is also presented in the following figure.

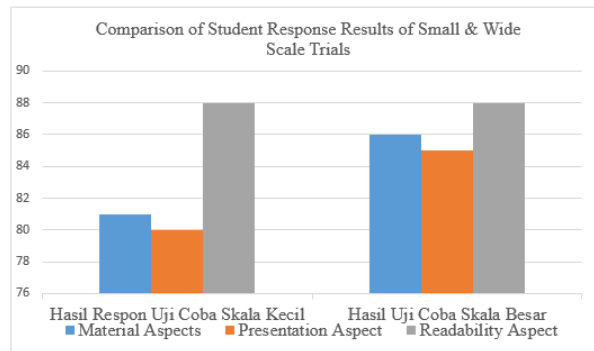


Figure 2. Comparison of Student Response Results of Small and Large Scale Trials

Based on Table 4, Table 5, and Figure 2, it is known that there is an increase in the feasibility assessment of E-Modules based on student response questionnaires from small-scale trials to large-scale trials.

Effectiveness of E-Modules on Improving Students' Critical Thinking Skills

Measurement of students' critical thinking skills in this study was carried out with the help of test instruments in the form of pretests and posttests presented in the form of description questions or essay questions. The data generated is the value of the pretest and posttest results which are then analyzed for the results of improving students' critical thinking skills through, testing the average of each indicator of critical thinking skills, n-gain test and the average difference in pretest and posttest results on the use of problem-based E-Modules on environmental change and preservation material. The product is given after students work on pretest questions, then followed by a posttest after giving the product to students. The product effectiveness test was conducted in class X-1 and X-2 SMA N 15 Semarang with a total of 65 students. The results of the effectiveness test were analyzed and explained as follows:

a. Average Test Results of Each Critical Thinking Ability Indicator

Based on the results of students' pretests and posttests analyzed with the help of Microsoft Excel, the average value of each indicator of students' critical thinking skills is presented in Figure 3 below.

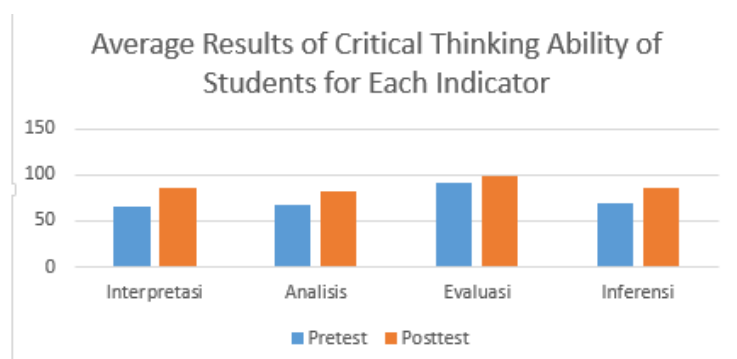


Figure 3. Average Results of Students' Critical Thinking Skills for Each Indicator

The average results of each indicator of students' critical thinking ability are then interpreted to find out the category achieved from each indicator of students' critical thinking ability. The results can be seen in the following Table 6.

Table 6. Pretest-Posttest Average Score of Critical Thinking Indicator

No.	Test	Indicators	Average grade	Category
1.	Pretest	Interpretation	65	Medium
		Analysis	68	Medium
		Evaluation	92	Very High
		Inference	69	Medium
2.	Posttest	Interpretation	86	Very High
		Analysis	82	Very High
		Evaluation	98	Very High
		Inference	86	Very High

b. N-Gain Test Results

The N-Gain test is needed to determine the increase in students' critical thinking skills after receiving treatment, in this case the use of problem-based E-Modules. The data used in the N-Gain test is the value of the pretest and posttest results which are analyzed using the Microsoft Excel application.

Based on the results of the N-Gain test calculation, the average N-Gain is 0.58 which is classified into the moderate category. This shows that problem-based E-Module teaching materials on the material of environmental change and preservation are effective in improving students' critical thinking skills as evidenced by the results of the calculation of the N-Gain average that has reached the target, which is ≥ 0.3 .

c. Results of Average Difference Hypothesis Test

Statistical tests with the aim of comparing mean differences can be carried out after the fulfillment of the prerequisite test. In this study, the prerequisite test carried out was the normality test. The homogeneity test was not carried out, because the homogeneity test is a prerequisite test that is not mandatory (Ayu Raoda et al., 2022).

Based on the results of the normality test, it was determined that the pretest and posttest data were not normally distributed so that the conditions for conducting a paired sample t-test were not met. In these conditions, to analyze or determine whether there is a significance of increasing critical thinking skills in pretest and posttest scores, the Wilcoxon Signed Rank non-parametric test is used as an alternative.

The Wilcoxon Signed Rank Test is a non-parametric test which is a paired sample t-test when the assumptions of the paired sample t-test are not met. Table 7 provides information about the results of the Wilcoxon Signed Rank Test analysis.

Table 7. Wilcoxon Signed Rank Test Results

Hypothesis Test	Asymp. Sig. (2-tailed)	Information
Uji Wilcoxon Signed Rank Test	0,000	There is a difference
Pretest-Posttest Results		

Based on the results of the Wilcoxon Signed Rank Test analysis, it is known that the value of Asymp. Sig. (2-tailed) is $0.000 < 0.05$ which means H_1 is accepted and H_0 is rejected. This means that there is a significant difference between students' critical thinking skills before and after studying the material of Environmental Change and Preservation using problem-based E-Modules (Both the average pretest and posttest scores are significantly different).

DISCUSSION

Teaching materials are one of the important components in the continuity of the learning process. In facing the challenges of the 21st century, innovation is needed in the teaching materials used in order to meet the demands that exist in 21st century learning. Teaching material innovations carried out by combining learning models with electronic teaching materials can help in overcoming the demands of 21st century learning, namely in relation to empowering students' critical thinking skills (Nia et al., (2022).

Problem-based E-Modules on environmental change and preservation were developed to improve students' critical thinking skills.

The results of the effectiveness test of the developed problem-based E-Module show that the problem-based E-Module on environmental change and preservation is effective in improving students' critical thinking skills which can be seen based on the results of the average value of each indicator of critical thinking skills, the results of the N-Gain test, and the results of the Wilcoxon Signed Rank Test.

Students' critical thinking skills are measured using test instruments in the form of essay questions that represent indicators of critical thinking skills consisting of indicators of interpretation, analysis, evaluation, and inference. Figure 4.3 shows that the average value of each indicator of students' critical thinking skills has increased from pretest to posttest with the category of improvement that can be seen in Table 4.6 This can occur because in the learning process using problem-based E-Modules, students' critical thinking skills have been trained consistently, especially in Smart Biology activities.

The presentation of Smart Biology which is equipped with problems related to the environment and questions to interpret, analyze, and evaluate (solve) authentic problems is able to trigger students' critical thinking skills so that there is an increase in the average value of each indicator of students' critical thinking from pretest to posttest. This is in accordance with Hanida et al., (2023) which states that authentic problems used as the center of learning can stimulate student curiosity so as to make students actively find out and engage in learning, thus forming critical thinking skills. Supported by Tobing et al., (2021) which states that the use of E-Modules can improve higher order thinking skills, including critical thinking.

The highest contribution of E-Modules in improving students' critical thinking skills is in the interpretation indicator which is characterized by the highest N-Gain value compared to other indicators. This shows that after carrying out learning with the help of problem-based E-Modules, students have been able to understand and express intentions or provide interpretations related to the environmental problems presented. Students' interpretation ability can be seen when students can answer questions about "the relationship between drought and environmental balance". In this aspect, students are required to provide an assessment or interpretation accompanied by relevant reasons based on their opinion about why drought can affect environmental balance. The following is presented the answer of one of the students on the interpretation indicator

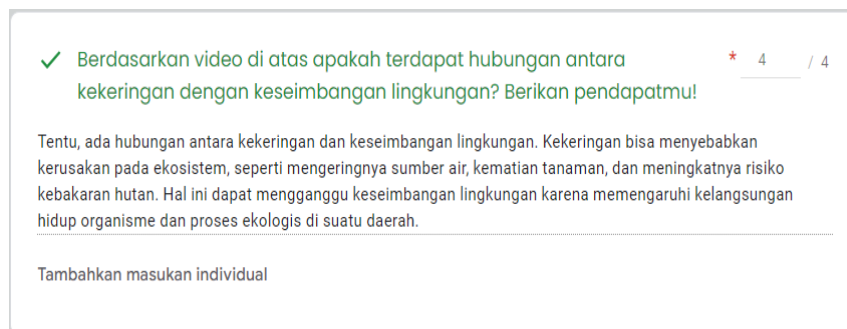


Figure 4: Student's Answer on the Interpretation Indicator Question

Students' correct answers to the questions with the interpretation indicator show that through continuous practice both in solving problems in Smart Biology and solving formative test questions that represent indicators of critical thinking skills in the E-Module can train students' critical thinking skills. In line with the statement of Nia et al., (2022), which states that critical thinking skills cannot appear by themselves but require practice that can be done during the learning process. This is also supported by the statement of Supriyati et al. (2018) which states that to improve critical thinking skills it is necessary to practice continuously accompanied by giving advice and improvements to students' critical thinking results.

The results of the increase in the average value of each indicator of students' critical thinking skills are relevant to the results of the N-Gain test and the results of the Wilcoxon Signed Rank Test conducted on the

E-Module effectiveness test. The results of the N-Gain Test with a value of 0.58 in the moderate category show that there is an increase in students' critical thinking skills in the moderate category and the results of the Wilcoxon Signed Rank Test with Asym Sig. 0.000 < 0.005 shows that there is a difference in the average pretest-posttest scores of students' critical thinking skills on the material of environmental change and preservation after implementing learning with problem-based E-Modules. This shows that learning models combined with learning media such as teaching materials can improve students' critical thinking skills. In line with the statement of Agnesa & Rahmadana (2022) which states that, to improve critical thinking skills, problem-based learning models can be combined with various learning media such as image media, teaching materials, LKS, E-modules, or animations. Supported by the opinion of Sarwastuti & Wahyu Purnomo (2023) which states that the application of problem-based E-Modules can help students train critical thinking skills and also help students build scientifically correct knowledge or conceptions.

Effective problem-based E-Modules in improving students' critical thinking skills are inseparable from the results of the E-Module validity assessment conducted by media expert validators, material experts and teachers. The three validators gave a very valid assessment of the E-Module developed with a percentage of assessment of 96.25%, 91.25%, and 100%, respectively.

Media expert validators gave a validity assessment with a percentage of 96.25% on all aspects assessed, namely the presentation feasibility aspect. The presentation feasibility assessment aspect is further divided into several sub-aspects which include sub-aspects of the E-Module format, implementation of problem-based learning model syntax, sentence structure, and symbols, images, and videos. The acquisition of a validity value of 96.25% indicates that the media expert validator gave a very good assessment of each statement in the validated sub-aspects.

One of the sub-aspects that received a very good assessment by the media expert validator, namely the E-Module format sub-aspect, precisely on the statement of clarity of instructions and ease of understanding (user friendly). User friendly (ease of access with the availability of clear instructions) is one of the characteristics that must be considered in the preparation of E-Modules. This sub-aspect received a very good assessment by the media expert validator, because the E-Module developed already contains clear and easy-to-understand instructions that make it easy and motivate students to learn even without direct teacher guidance. In line with Sitepu's statement in Najuah et al., (2020) which states that E-Modules with learning instructions that are easy to understand can motivate students.

A very valid assessment with a percentage of 91.25% given by the material expert validator is one of them because in the E-Module developed the material has been presented widely and accurately which can be seen through the use of articles and videos related to environmental problems presented in each learning activity. The articles and videos used have contained accurate facts in the form of environmental problems experienced by Indonesia within 10 years. The breadth of material can be obtained by students through the videos they see in each learning activity. Watching videos that are suitable for learning can expand students' visualization skills, hone their listening skills, and provide opportunities for students to obtain extensive information through the videos they hear (L. A. Putri & Dewi, 2020).

The highly valid assessment given by the material expert was also given because in the development of the E-Module, the novelty of the material had been applied well. The principle of material renewal can be seen in the age of the references used in the E-Module, which is not more than 10 years old and its components reflect the conditions in the present. One of the crucial aspects that can affect the quality of learning which can then have an impact on students' readiness to think critically is the novelty of teaching material components (Hanida et al., 2023).

The teacher validator gave an assessment of 100% on the developed E-Module with the assessed aspects covering all aspects of the media and material expert validation. The teacher did not provide suggestions on the validation results, but only commented that the E-module developed was in accordance with the needs of students. Giving a very valid score by the teacher validator is seen from the aspect of the feasibility of the

language used in the E-Module. This aspect is further divided into several sub-aspects consisting of dialogic and interactive, language suitability to the developmental level, and language support.

In the dialogical and interactive sub-aspect, the teacher validates the characteristics that must be considered in making E-Modules, namely self-instructional characteristics. These characteristics are essential to be considered in the preparation of E-Modules, because E-Modules are developed with the aim that students can learn independently and not depend on others Sitepu in Najuah et al (2020). In the sub-aspect of linguistic suitability with the developmental level, the teacher validator also gave a very valid assessment with a percentage of 100%. The success or failure of learning is also determined by the choice of words and language used in the delivery of learning. Moku & Boangmanalu (2021) in their research stated that according to Erik Erikson's Psychosocial Theory, high school students who are in the age range of 16-18 years old cause them to belong to the fifth phase in social-emotional development (age 12-18 years) where there is a lot of confusion. Therefore, the words and language used are recommended not to be too rigid so as not to cause confusion and in accordance with the level of social-emotional development of students.

The results of the E-Module effectiveness test which show that the problem-based E-Module developed is effective for improving students' critical thinking skills, apart from being inseparable from the results of the validity assessment by the validators who showed a valid assessment, are also inseparable from the results of the feasibility assessment by student responses on small and large scale trials. In both trials, students were given a questionnaire to assess the feasibility of the e-module developed before it was used in collecting data on the effectiveness of the E-Module.

In the feasibility assessment of E-Modules based on small and large scale student responses, there are three aspects studied which include material aspects, presentation aspects, and readability aspects. Students gave good ratings on all aspects. Table 4 and Table 5 show that the E-Modules developed have obtained good and very good grades based on student responses in small-scale trials and large-scale trials with a percentage of 80.58% and 85.46%. This shows that the problem-based E-Module on Environmental Change and Preservation with the help of Flip PDF Professional has been declared feasible for use in learning which is indicated by the proportion of student response assessments that have exceeded 60% (>60%).

In Figure 2, it can be seen that each aspect of the E-Module that is assessed based on student responses has increased from small-scale trials to large-scale trials. In the material aspect in the small-scale trial, students gave an assessment that the E-Module developed was categorized as good with a percentage of 80.83%, while in the large-scale trial students gave a very good assessment on the material aspect with a percentage of 86.15%. The material in the E-Module teaching materials is clearly described so that it helps make it easier for students to understand the material presented. Teaching materials that are conceptualized and easy to understand make students more enthusiastic in following learning (Maulida et al., 2022).

The presentation of material in the E-Module which is equipped with the "Smart Biology", "Quick Check", and "Environmental Fact" features can stimulate students' critical thinking skills on the material studied. In line with the statement of Andira et al., (2021) which states that teaching materials that are made coherently, systematically, completely, informatively, and accompanied by examples or facts that are in accordance with the user's level of understanding can enrich the insight and knowledge of students (2021).

In the presentation aspect, students also gave a positive assessment of the developed E-Module. In the small-scale trial, students gave a good assessment with a percentage of 79.87%, while in the large-scale trial students gave a very good assessment with a percentage of 84.90%. The E-Module has been developed as much as possible with the aim of achieving a clear display representation.

In the development of E-Modules, a careful selection of text size, color design, font, text color, background, and graphics is carried out in the hope that the E-Module design developed can be visually appealing with a harmonious blend between all its components. In line with research conducted by (Prestiya, 2023), the selection of the right color and background combinations on E-Modules can create a comfortable and easy-to-read visual experience.

The E-Module also adds color images that are close to students' daily lives, for example, the addition of photos about environmental pollution problems. The use of real color images can increase learning interest, participants' critical thinking skills, and provide a meaningful learning experience for students (Andira et al., 2021). In line with Maulida et al. (2022), learning media that are presented complete with attractive and colorful images are preferred to be learned, remembered, and understood by students rather than learning media that prioritize verbal. In addition to images, videos are also used in E-Modules to support the presentation of material. Through videos, students can obtain broader information related to the material being studied. Videos that are suitable for learning can expand students' visualization abilities, hone their listening skills, and provide opportunities for students to obtain extensive information through the videos they hear (L. A. Putri & Dewi, 2020).

In the aspect of Language / Readability, students also gave a positive assessment of the developed E-Module. In the small-scale trial, students gave a very good assessment with a percentage of 88.33%, while in the large-scale trial students gave a very good assessment with a percentage of 88.62%. This shows that the use of language in the E-Module developed is clear and easy for students to understand.

The final result of this study shows that the problem-based E-Module on environmental change and preservation material developed is very valid, feasible, and effective to improve the critical thinking skills of high school students. Apart from this, the research conducted still has several limitations, namely a) Making E-Modules takes a long time and requires a lot of reading, b) E-Modules can only be accessed in areas with adequate internet networks, c) The use of E-Modules is limited to independent curriculum rules that do not allow assignments outside the school environment so that the implementation of problem-based learning and independent use of E-Modules is less visible.

CONCLUSION

Based on the results of the research and discussion, it can be concluded that the problem-based Environmental Change and Preservation E-Module product developed is valid, feasible, and effective in improving the critical thinking skills of high school students.

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