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Development of STEM-Based Student E-Book Using PBL Model in Improving Critical Thinking Ability

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Abstract: The ability to think critically is an ability needed by students in the 21st century. Problem-based learning is one of the learning models that can stimulate students' critical thinking skills. Students' difficulties in solving contextual problems of temperature and heat material oriented to students' critical thinking skills and the unavailability of teaching materials that facilitate students in improving students' critical thinking skills. This study used Research & Development with Plomp's development model. The research subjects were 36 students of class XI in each high school in Solok City. Research data in the form of needs analysis (curriculum analysis, material, learner character analysis) development analysis (product design, formative evaluation) and assessment analysis (normality test, homogeneity, critical thinking ability hypothesis). The results showed that student e-books were in the valid category while in terms of material experts were in the valid category and the practicality of student e-books was seen in the results of student responses with an average of 93% with a very practical category and the effectiveness of student e-books seen in the average N-gain value of 0.683. The resulting student e-book is feasible to be used by teachers in the learning process, problem-based learning models will be more effective in spurring critical thinking skills if teachers use this student e-book.

Keywords: Critical thinking skills; Development; Student e-book

Introduction

Entering the 21st century, it is clear that technological development, globalization and competition are intensifying, demanding that individuals have 21st century skills. The 21st century needs the development of qualified science and technology, in line with this in principle in the 21st century. In reality what is found in the field is still far away. In the 21st century, it is necessary to develop 4C abilities, one of which is the ability to think critically. This ability is important in learning because it is a key competency for the future (Bouckaert, 2023). The indicators of critical thinking are indicators put forward by Ennis (2018) in Pradesa (2015), namely the ability to provide simple explanations, build basic skills and provide simple explanations.

The importance of critical thinking of students has a role in increasing reasoning power and creativity, especially in dealing with physics learning. This ability does not only make students memorize theories (Mahanal et al., 2019). In addition, learners must also be able to analyze arguments, ask and answer questions that all support problem solving in science learning (Heard et al., 2025).

In an effort to improve students' critical thinking skills, the government has made many efforts, namely by changing the curriculum, which is marked from the 2013 curriculum change which still uses authentic assessment to the curriculum that we currently feel is the independent curriculum and conducting research.

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Various studies have shown that the level of critical thinking ability is in the low, medium to high category (Agustiana, 2019; Fitriani, 2023; Zurhaimi et al., 2022). In this difference, more action is needed to improve students' critical thinking skills. Basically, there are various differences, but the reality of the field needs to be tested through tests to determine the level of critical thinking skills in different schools.

Various studies have been conducted showing the variation of critical thinking skills, based on the circumstances that occur in the field this ability is rarely tested at school, basically it is often done through oral tests in the teaching process at school. So it is necessary to test in three schools in measuring the critical thinking skills of students.

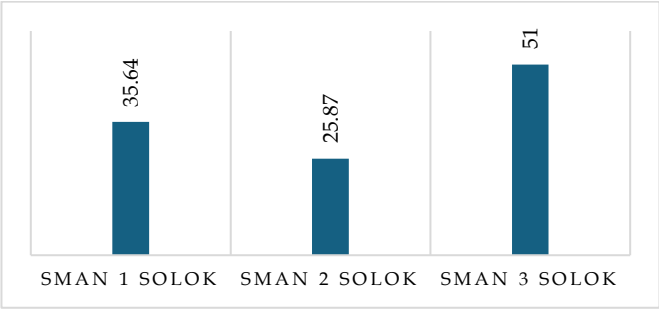

Figure 1. Initial analysis of critical thinking ability

Based on the first real condition of the results of observations in three schools namely SMAN 1 Solok, SMAN 2 Solok, SMAN 3 Solok obtained the results of critical thinking skills conducted through tests and obtained results of 35.64, 25.87 and 51 overall the average critical thinking skills of students are still very low. Seen in the form of the following graph. From these results, it is clear when classroom observations show that only a few learners actively respond to teacher questions, while most others tend to be passive. The same learners were often the most active in answering and explaining their thinking. While others mostly listened without participating. In fact, when asked directly to learners, some of the learners seemed to have difficulty expressing their thoughts. This indicates that critical thinking skills have not been developed in the classroom during physics learning.

From these results, it is clear that each school has low critical thinking skills. The Ennis indicators used have 5 indicators with an average value of each per indicator, namely giving simple explanations with a value of 42; organizing strategies and tactics with a value of 38, giving advanced explanations with a value of 37.33, building basic skills with a value of 44, and concluding with a value of 41.33, when classroom observations show that only a few learners actively respond to teacher questions, while most others tend to be passive. The same learners were often the most active in answering and explaining their thinking. While others mostly listened without participating. In fact, when asked directly to learners, some of the learners seemed to have difficulty expressing their thoughts. This indicates that critical thinking skills have not developed evenly in the classroom during physics learning.

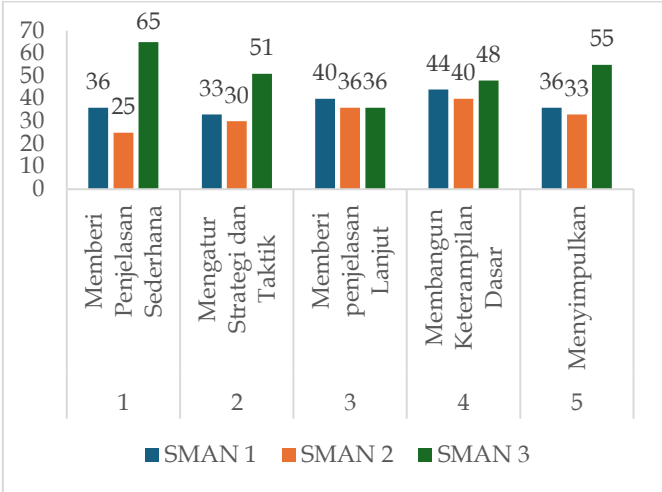

Figure 2. Analysis of critical thinking ability indicators

Based on the second real condition from the results of observations of the use of e-books in schools conducted by observation techniques. The instrument used is an observation sheet conducted in three schools. Based on the results of the analysis of the observation sheet, the use of books in schools is still conventional or print-based. Print books used are not for the whole physics material, but only on certain materials. In learning activities, students use package books in the library as a learning resource, and do the questions in the book are in the category less 53.68. The learning process still relies on printed books as the main source that has not trained students and minimal use of electronic media. The presentation of student printed books on the material tends to be boring, with a rigid and formal format (Alford, 2019).

The third real condition is obtained from the analysis of STEM integration in student textbooks. Book analysis was conducted on the same three physics books in each school. The criteria assessed in the three books were based on indicators of each STEM component. The instrument used in this analysis is a document analysis sheet. The results of the analysis of high school phase F student books obtained an average value of 51.60 in the sufficient category. This value explains that the student books used in learning are not in accordance with the indicators of each STEM component. Clearly, the analysis of STEM integrated data in the books used by students at schools.

The STEM approach is a combination of science, technology, engineering and mathematics. The STEM approach contains 4C skills that are in accordance with the demands of the 21st century (Beers, 2014) based on research that has been done before, the STEM approach can encourage learners to design, develop and utilize technology. The STEM approach focuses on developing various expertise, so that learners will be able to use their skills to solve problems creatively, be able to collaborate with others and be able to innovate in learning. So that the development of interactive multimedia based on the STEM approach is a solution used to answer the challenges of 21st century education. Learning in the 21st century should be contextual, related to community life, student-centered and collaborative. Education graduates must have good competencies to compete in the 21st Century (Asrizal et al., 2018).

In order for the STEM approach to be applied properly, it is necessary to have a learning model that is able to direct students to think critically, namely the Problem Based Learning (PBL) Model. Problem-based learning model is that students are involved in the learning process actively and independently, with the material presented integrated and relevant to real situations, often referred to as a learner-centered approach). In addition, the problem-based learning model has a significant influence in improving critical thinking skills (Adawiyah et al., 2022). The problem-based learning model is an innovative model and has an influence in improving students' critical thinking skills and learning activities (Bramastia et al., 2023; Kardoyo et al., 2020; Rinesti et al., 2019; Zulkarnaen et al., 2022).

Similar research has been carried out, but it is not integrated with STEM, and does not see the effect on students' critical thinking skills. The emergence, interest in conducting this research because this research was conducted by integrating STEM with Student E-books that were packaged electronically using Heyzine Flip Book Software. So, the title of this research article is based on the description of the background of the problem that has been stated, so the author proposes the research title "Development of Student E-Book Using PBL Model Based on STEM Approach (Science, Technology, Engineering, and Mathematics) To Improve Students' Critical Thinking Ability".

Method

This research is a Research and Development (R&D) study using the Plomp model) with steps: preliminary research, development or prototyping phase (iterative design phase), and assessment phase (semi- summative evaluation) (Gravemeijer et al., 2013). The research stages are presented in the following figure 3.

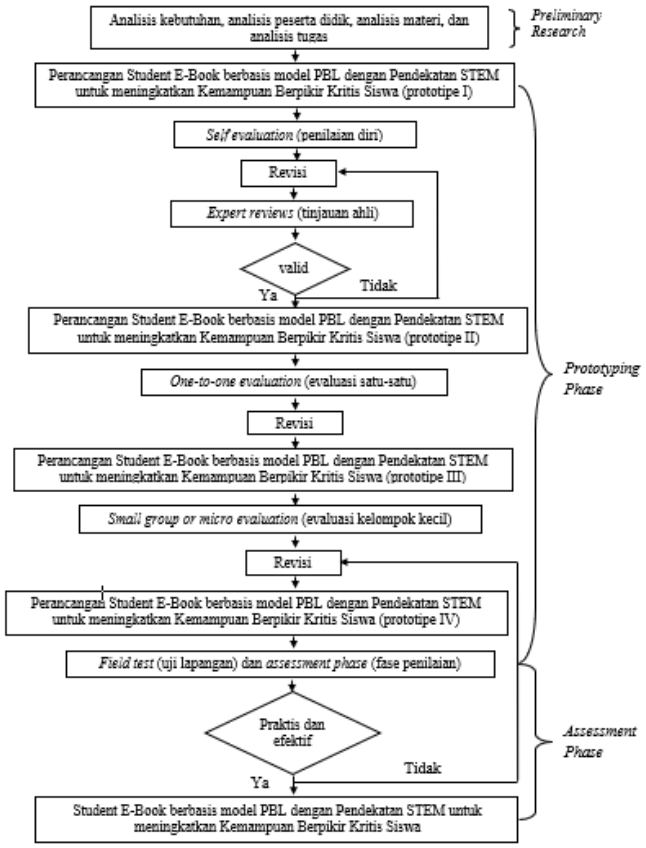

Figure 3. Plomp model research stages

This research was conducted in three schools in Solok city namely SMAN 1 Solok, SMAN 2 Solok, and SMAN 3 Solok with the research subject in 11th grade students with Temperature and Heat material. The instruments used in this study are media expert validation instruments, material expert validation used to measure the feasibility level of the Student E-Book product developed and student response questionnaires used to see the level of emodule practicality after using Student E-Book. Then the preparation of pre-test and post-test questions used to measure the effectiveness of the Student E-Book.

The data analysis technique used so that the product is declared valid with quantitative and qualitative data analysis. The validity of Student E-Book is obtained through the validation results of material experts and media experts and to measure the practicality of Student E-Book obtained through student responses and to measure effectiveness using descriptive statistical analysis for validity and practicality and parametric analysis (paired sample ttest) to measure the achievement of students' critical thinking skills using Student E-Book. Then conduct an N-gain test to determine the effectiveness of the Student E-Book developed. Data analysis to measure the level of effectiveness. Explanations related to these criteria are as follows:

Validity Student E-Book

The validity analysis aims to obtain valid qualifications of the developed learning tools. By comparing the average validity scores of all material and media experts using the criteria validity presented in Table 1.

$$V = \frac{\sum s}{n[c-1]} \quad (1)$$
$$s = r - lo$$

Table 1. Criteria Validity

Interval	Criteria
V ≤ 0.4	Less Valid
0.4 < V ≤ 0.8	Valid
V > 0.8	Very Valid

The product is said to be valid from material and media experts if the average validity based on valid criteria obtained is at least valid.

Practicality of Student E-Book

Analysis of the practicality of Student E-Book in this study was assessed based on student response questionnaires to the use of student e-books given to students. Criteria. Practicality is presented in Table 2.

$$N = \frac{Total\ Weight}{Maximal\ Weight} X\ 100\ \% \quad (2)$$

Table 2. Criteria Practicality (Riduwan, 2008)

Interval %	Category
0-20	Not good
21-40	Less Good
41-60	Good enough
61-80	Good
81-100	Very good

Student e-book learning devices are said to be practical from student responses with an average score based on the minimum assessment criteria Practical.

Effectiveness Analysis

The effectiveness of Student E-Book can be seen from the achievement of the Criteria for Achieving Learning Objectives (KKTP) of critical thinking and increasing students' critical thinking skills. KKTP critical thinking ability is 70. Then do an average comparison using a paired sample t-test. Before doing the t-test statistical test, it is necessary to do a normality test to see whether the data is normally distributed or not with a sig level. The paired sample ttest test is used to see if there is a difference before using the emodule or after using the Student E-Book with sig and the n-gain test to see the difference in pretest and posttest scores. N-gain criteria can use formula (3):

$$Gain = \frac{\mu_{post} - \mu_{pre}}{Maximum\ score - \mu_{pre}} \quad (3)$$

Description:
μ_{post} = average post test score
μ_{pre} = average pre test score
The normalized gain value criteria can be seen in Table 3.

Table 3. Value N-gain (Sesmiyanti et al., 2019)

Value	Criteria
$(g) \geq 0.7$	High
$0.7 \geq (g) \geq 0.3$	Medium
$(g) < 0.3$	Low

Result and Discussion

Preliminary Research
Curriculum and Materials Analysis

The curriculum used by teachers during the classroom learning process is curriculum-13 and the materials used are static fluids, dynamic fluids, thermodynamic calendars.

Learner Characteristics Analysis

Analysis on the characteristics of students at SMAN 1 Solok, SMAN 2 Solok and SMAN 3 Solok includes students' cognitive abilities and knowledge of physics learning. The results show the lack of students' ability in learning physics, this can be seen in the results of working on assignments given by the teacher to students there are only 50% of students who are complete. This is because the learning model used by the teacher is a conventional learning model and the teacher does not provide an overview when solving contextual problems so that students have difficulty in solving the problems given in addition to that in the learning process students are also not given the opportunity to solve in groups and this makes students bored with the learning provided.

Then the material presented by the teacher during the learning process has not been integrated into critical thinking skills so that students are not familiar with the presentation of contextual problems that are integrated with critical thinking indicators. The indicators of critical thinking skills according to Firdaus et al. (2019) are being able to formulate problems, analyze, answer questions, assess the credibility of information sources.

Development or Prototyping Phase

Student E-book stem-based physics using pbl model in improving students' critical thinking skills. Researchers designed student e-books on f at SMAN 1

Solok which in this study was used as one of the samples. In designing a stem-based student e-book using the PBL model and indicators of critical thinking skills and making an initial design of the student e-book

The design of the student e-book consists of a cover, student e-book guide, preface, table of contents, introduction, material review, learning activities to assessment. the sequence of using the emodule that is integrated using the student e-book, PBL syntax and symbols, indicators of critical thinking skills and concept maps contained in the student e-book so that the resulting student e-book can be a teaching material that meets the criteria of teaching materials that can be used to spur students' critical thinking skills. The following is an e-module display in spurring students' critical thinking skills presented in Figure 4.

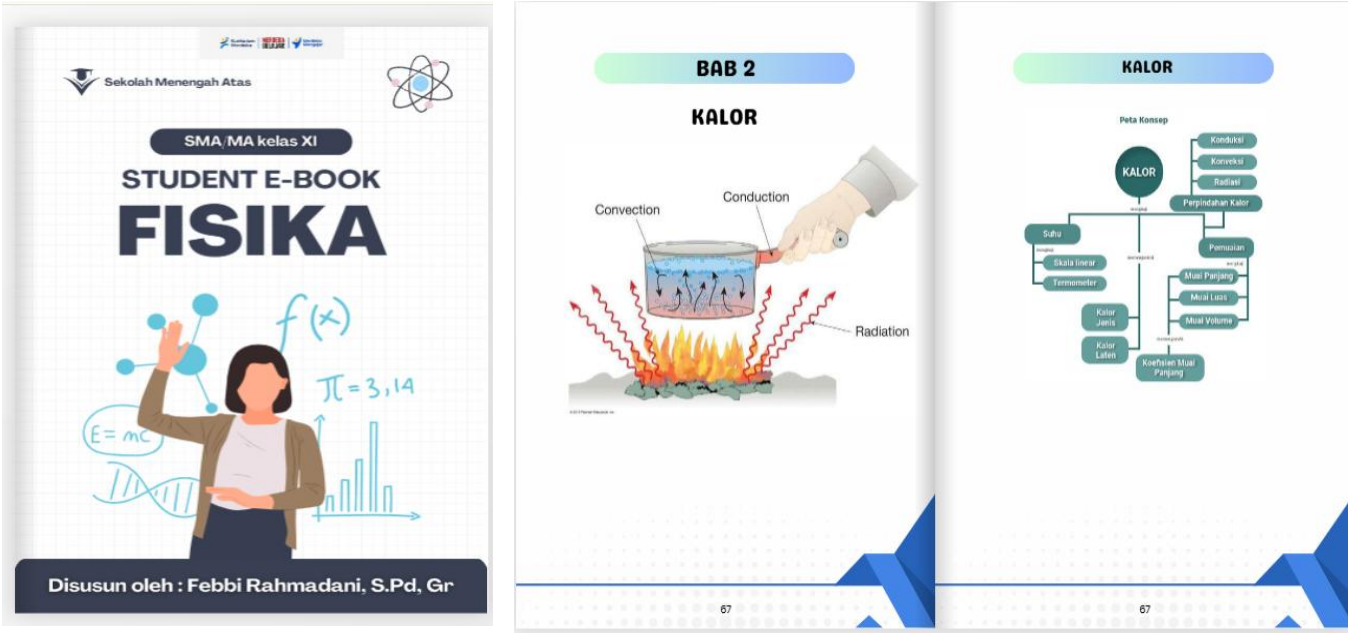

Figure 4. STEM-based student e-book using PBL model

The results of the test analysis are as follows:

Validity Test Results

The Student E-Book validity test is carried out after the instrument validity test is carried out. The results of the validity test of the Video-assisted Student e-book prototype were obtained after analyzing the validity sheet data by three experts using Aiken's V statistics. The results of the validity of the Student e-book prototype can be seen in Table 4.

Table 4. Student E-book Prototype Validity Score

Aspects	Value V	Criteria
Content eligibility	0.87	Valid
Presentation feasibility	0.88	Valid
Language feasibility	0.84	Valid
Graphics feasibility	0.83	Valid
Average	0.86	Valid

Practicality Test Results

Prototype Practicality Test Results One to One Evaluation

At the One to One Evaluation stage, the Video-assisted Student e-book to be assessed is given without being taught and students only read and understand well. The practicality value of the Student e-book at the One to One Evaluation stage can be seen in Table 5.

Table 5. Practicality Score of Student E-Book at One to One Evaluation Stage

Aspect	Value	Practicality Criteria
Easy	80.00	Good
Practicality	84.72	Very Good
Attractiveness	79.17	Good
Average	81.30	Very Good

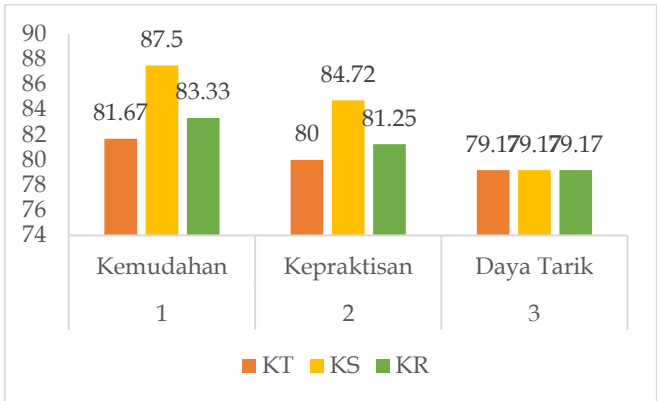

Figure 5. Practicality of student e-book stage one to one evaluation

This can be seen from the average value of student e-books at the One to One Evaluation stage, which is 81.30 with very practical criteria. The practicality of student e-books based on the academic ability level of the sample can be seen in Figure 5.

Prototype Practicality Test Results on Small Group Evaluation

These results illustrate for three indicators of practicality assessment in the Table. The value of student e-book practicality at the Small Group Evaluation stage can be seen in Table 6.

Table 6. Practicality Score of Video-assisted Student E-Book at Small Group Evaluation Stage

Aspect	Value	Practicality Criteria
Easy	80.28	Good
Practicality	83.80	Very Good
Attractiveness	81.25	Very Good
Average	81.78	Very Good

This is from the average value of student e-books at the Small Group Evaluation stage, which is 81.78 with very practical criteria. The practicality of student e-books based on the level of ability at the Small Group Evaluation stage can be seen in Figure 6.

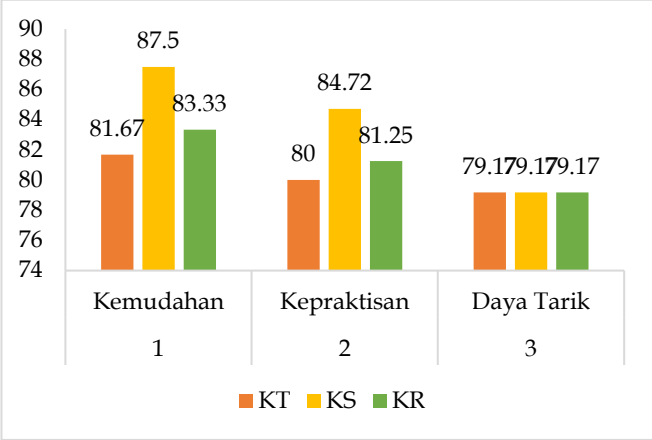

Figure 6. Practicality of student e-books at the small group evaluation stage

Results of Student E-book Practicality Test according to Field Test Learners

Table 7. Practicality Score of Student e-book according to Learners at the Field Test stage

Aspect	Value	Practicality Criteria
Easy	79.99	Good
Practicality	80.05	Good
Attractiveness	77.44	Good
Average	79.16	Good

Practicality Score of Student E-Book According to the Field Test Stage Teacher

Table 8. Practicality Score of Student E-book according to the Field Test stage Teacher

Aspect	Value	Practicality Criteria
Practicality	86.11	Very Good
Easy	85.72	Very Good
Applicability	88.89	Very Good
Time Effectiveness	83.33	Very Good
Average	86.01	Very Good

Assessment Phase

Data on knowledge research results are taken from learning outcomes or posttests at the end of the study. The test was in the form of a written test of 5 essay questions. Posttest questions are designed to refer to indicators of critical thinking questions. Posttest questions are designed to refer to critical thinking indicators. Before being used, the questions were tested so that the questions were suitable for use for the posttest.

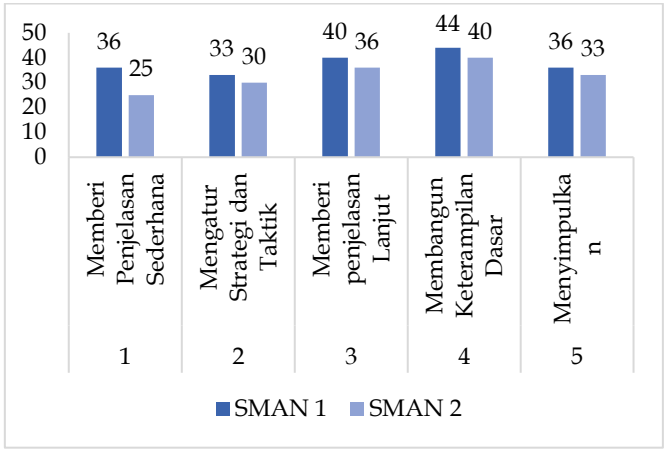

Figure 7. Critical thinking ability indicator results

The test questions were made in accordance with the indicators of critical thinking skills from Ennis' 1986 theory. There are 12 indicators of critical thinking ability according to Ennis, from 12 indicators of critical thinking ability are classified into 5 aspects, namely giving simple explanations, building basic skills, concluding, giving further explanations, and organizing strategies and tactics. The average difference in critical thinking skills of the two sample classes is stated in the figure above in accordance with the indicators of critical thinking skills. The results of data analysis from both sample classes for knowledge can be explained in Table 9.

Then to find out whether the difference in the scores of the two sample classes is significant or not, a statistical analysis is carried out in the form of a normality test, homogeneity test and equality test of two means..

Table 9. Mean, Standard Deviation and Variance on Critical Thinking Ability of Students of Both Sample Classes

Class	N	$\bar{x}$	S	S^2	Description
(Ex) F 2.2	35	80.34	15.78224	249.079	Normal
(Cntrl) F 2.3	35	59.42	15.30272	234.1731	Normal

Normality Test

The normality test used in this research is the Liliefors test. Normality test was conducted on students' knowledge. The instrument used to measure student knowledge uses a written test. The results of the normality test of the two sample classes on knowledge can be described in Table 10.

Table 10. Normality Test

Class	N	α	Lo	Lt	Description
Ex	35	0.05	0.070102	0.1499	Normal
Cntrl	35	0.05	0.142289	0.1499	Normal

Homogeneity Test

The homogeneity test was carried out to see whether the two sample classes had homogeneous variants or not. The homogeneity test conducted in this research is the F test. The results of the homogeneity test of the two sample classes on knowledge are described in Table 11.

Table 11. Homogeneity Test

Class	N	S^2	A	F_h	F_t	Description
Ex	35	112.34	0.05	1.772	1.542	Homogeny
Cntrl	35	173.3	0.05			

Hypothesis Test

Based on the results of the normality test analysis and the homogeneity test of the final test of the two sample classes, the data were normally distributed and had homogeneous variants, so the hypothesis test of the equality of the two means was carried out. The results of the t-test analysis of the two sample classes are as described in Table 12.

Table 12. Hypothesis Test

Class	N	A	$\bar{x}$	S^2	t_h	t_t
Ex	35	0.05	80.34	112.34	1.995	1.667
Cntrl	35	0.05	59.42	173.31		

The level of effectiveness of using student e-books can be seen from the results of the N-gain score which has an average of 0.683. The acquisition of the N-gain value is carried out by qualifying normally distributed data using Kolmogorov-smirnov with a value of 0.200 and meeting the criteria α> 0.05, thus it can be said that the data is normally distributed. Next is the t test analysis, the use of this t test is to see the difference between before and after using the e-module, using the pretest and posttest. The pretest and posttest results in the t test have a sig (2-tailed) value of 0.000 <0.05, which means that there is a significant difference in the use of STEM-based student e-books using the PBL model to improve students' critical thinking skills and is quite effective to use. This is in line with Restu et al. (2015) that the learning process using PBL is able to improve students' critical thinking skills.

Conclusion

Based on the results of the research and discussion that have been presented, it can be concluded that the development of a stem-based student e-book using the Plomp model produces a problem-based learning-based student e-book to achieve students' critical thinking skills that have been measured for validity, practicality and effectiveness so that the student e-book used has achieved students' critical thinking skills which can be seen in the average student score of 80 which is greater than the KKTP score of 75. The results of the study show that the student e-book is in the valid category while in terms of material experts it is in the valid category and the practicality of the student e-book can be seen from the results of student responses with an average of 93% with a very practical category and the effectiveness of the student e-book can be seen from the average N-gain value of 0.683. The resulting student e-book is suitable for use by teachers in the learning process, the problem-based learning model will be more effective in stimulating critical thinking skills if teachers use this student e-book. Further research is expected to develop student e-books in addition to being able to increase the small sample size, limited material coverage, length of intervention so that limitations will provide a more balanced perspective on the results with other materials with a more attractive design so that students are more interested in mastering the material in the learning process.

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Author Contributions

This research article was published thanks to the collaboration of the first author, Y. F, and the second author, A. The authors' contributions to the article: creating learning media and

tools; conducting research; analyzing data; and drafting the article. All authors reviewed the results and approved the final version of the manuscript.

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