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Development of an E-Book Based on STEM-Integrated Creative Problem Solving on Environmental Change Material to Improve Students' Critical Thinking and Creative Thinking

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Abstract: Critical and creative thinking skills are very important in the 21st century. The creative problem-solving learning model and the STEM approach are suitable for training critical and creative thinking skills in learning. This study aims to: 1) analyze the need for an e-book based on creative problem solving integrated with STEM, hereinafter referred to as BOTIPOSTEM and 2) analyze the eligibility of BOTIPOSTEM. This type of research is research and development (R&D) using the ADDIE model. Research data were obtained through interviews, questionnaires, validation sheets, and readability sheets. The data were analyzed descriptively quantitatively and using Aiken's V. The results showed that: 1) the development of BOTIPOSTEM is in the very needed category based on the teacher's response; 2) BOTIPOSTEM obtained an average Aiken score of 0.96 by material experts and 0.92 by media experts, the percentage of readability obtained an average score of 96% by teachers and 93% by students. Data analysis shows that BOTIPOSTEM has a high level of validity and readability. Thus it can be concluded that BOTIPOSTEM is very much needed and eligible to used in learning to train students' critical and creative thinking skills at school.

Keywords: Creative problem solving; Critical and creative thinking skills E-book; STEM

Introduction

Currently, the environment is starting to be threatened by the increasing damage caused by various changes in the form of environmental pollution. The occurrence of climate change (Ford et al., 2020), loss of biodiversity, the emergence of various diseases, decline in agricultural yields (Adyatma & Kartika, 2013; Pratama & Parinduri, 2019), floods, storms, and the emergence of various natural disasters are evidence of change environment (Adedeji et al., 2014). Environmental pollution that occurs is closely related to population growth and human activities (Adyatma & Kartika, 2013). In the future, environmental damage will be more severe and complex, causing huge losses (Cahyani, 2016).

Environmental problems are an important issue so the government provides special policies related to environmental change by including the theme of environmental change in the 2013 Curriculum and the Merdeka curriculum. The theme of environmental change in the 2013 Curriculum and the Merdeka Curriculum is used as one of the chapters in the Science subject at the senior high school level. This is intended to increase knowledge, behavior, and make decisions in the future (Septaria, 2019) and so that students can create solutions to problems based on local, national, or global issues related to environmental change.

Students' ability to create solutions to problems is inseparable from the ability to think critically and creatively. Critical and creative thinking skills are higher-order thinking skills and skills needed in 21st-

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century learning (Agustyaningrum, 2015; Tindowen et al., 2017). Critical thinking skills are one of the keys to success in both education and work (Kivunja, 2015; Nold, 2017), as well as creative thinking skills (Alrubaie & Daniel, 2014; Byrge & Gomes, 2019; Mullet et al., 2016). Therefore, these skills are crucial to be trained and can be integrated into learning activities.

The critical and creative thinking skills of Indonesian students are still low. Indonesian students' scientific literacy ranking based on data from the Program for International Student Assessment (PISA) ranks 60th out of 65 countries, 64 out of 65 countries, 69 out of 75 countries, and 71 out of 79 participating countries in 2009, 2012, 2015 and 2018 (OECD, 2010, 2014, 2016, 2019). PISA questions require students' abilities in reasoning, problem solving, analytical abilities, evaluation, and creation in the process (Kurniati et al., 2016), which abilities are high-order thinking skills (Brookhart, 2020). To be able to do reasoning, problem solving, analyzing, evaluating, and creating requires the ability to think critically and creatively. This means that if students' scientific literacy skills are low, it can be said that students' critical and creative thinking skills are low (Rahayuni, 2016). The results of the 2015 Global Creativity Index (GCI) survey also show that Indonesia is ranked 115 out of 139 countries (Florida et al., 2015).

Unsupportive learning activities are one of the causes of students' low critical and creative thinking skills (Happy & Widjajanti, 2014; Sunaryo, 2014). The education process in Indonesia is still at the initial level of thinking, namely remembering, understanding, and applying (Imamah & Muqowim, 2020; Irwandi et al., 2018). This ability is not enough to face the era of globalization (Suarjana et al., 2020). During classroom learning the teacher focuses more on order and class management, emphasizes memorization, lacks confidence in fostering student creativity (Kettler et al., 2018), and provides less stimulus to stimulate critical and creative thinking skills (Supardi, 2011; Wahyuni, 2015). In addition, currently, available teaching materials direct students more to mastering the material and pay less attention to aspects of soft skills (Kurniawati & Amarlita, 2013).

One type of teaching material that can be developed in the current digitalization era is an electronic book (e-book) (Susilo & Pahlevi, 2021). E-books are electronic versions of traditional printed books that can be read on laptop screens or other portable devices and can incorporate features such as images, videos, audio, and hyperlinks to enable interaction between students and teachers (Maulida et al., 2022; Muhammad et al., 2017). The results of the study show that e-books are very effective for use in learning as evidenced by student learning outcomes (Alwan, 2018).

The use of appropriate learning models in the development of teaching materials including e-books is an important thing to note (Zohri et al., 2022). The Creative Problem Solving (CPS) learning model can be a solution to overcoming learning activities that are not optimal in training students' critical thinking skills and creative thinking. The CPS model is in following 21st-century skills (Widya et al., 2022) and emphasizes solving problems systematically by strengthening creativity (Kamalasari et al., 2019; Malahayati, 2017).

An appropriate approach to 21st century learning is Science, Technology, Engineering, and Mathematics (STEM). STEM which is integrative in nature allows various learning methods to be used to support its application (Davidi et al., 2021). The STEM approach supports students to learn as a whole by studying the material in four elements at once, namely science, technology, engineering, and mathematics. STEM is an approach that can help students improve 21st-century skills (Erdogan & Ciftci, 2017). STEM implementation that encourages students to think from all fields helps students develop their creativity (Kakarndee et al., 2017; Kuhn et al., 2016).

The advantages of an e-book based on STEM integrated creative problem solving (BOTIPOSTEM) are: 1) based on a learning model that supports student activities to think critically and creatively, 2) provides scientific, technological, engineering, and mathematical dimensions so that student learning becomes more complete and meaningful, 3) equipped with pictures and videos so that it can attract students' interest in learning, 4) more practical because it can be accessed anytime and anywhere. Based on the advantages of BOTIPOSTEM, "Development of STEM-integrated Creative Problem Solving (CPS) Based E-books to Improve Critical Thinking Skills and Creative Thinking" on environmental change material is important to develop. The developed e-book is expected to provide benefits to the improvement of critical thinking skills and creative thinking for high school students.

Method

This study is a research and development (R&D) type. The development model used is the ADDIE model which has 5 stages, namely analyzing, designing, developing, implementing, and evaluating with the cycle described by (Muruganantham, 2015). The ADDIE model is fairly simple and easy to learn so it's easy to apply. As for this article, it is modified to describe it up to the developing stage. Each stage has certain activities carried out.

The analyzing stage is the initial stage to find out the conditions, characteristics, needs, and constraints in the learning process. This stage is carried out through interviews, and distributing questionnaires with a scale of 1-5 to teachers and students. The analyzing stage includes student analysis, material analysis, needs analysis, and smartphone usage analysis. Scores obtained based on student analysis and material analysis are converted into percentages using the following equation 1:

$$\text{Response value} = \frac{Total\ score\ obtained}{Maximum\ total\ score} \text{ x } 100\% \quad (1)$$

The needs analysis data and analysis of smartphone use are calculated by finding the average value obtained and then interpreted into modified categories from the research results of Barustyawati & Adnyani (2018) as presented in Table 1.

Table 1. Category Analysis of Needs and Use of Smartphones

Average Range	Category
4.21-5.00	Very needed/very easy/very interested
3.41-4.20	Needed/easy/interested
2.61-3.40	Quite needed/quite easy/quite interested
1.81-2.60	Less needed/less easy/less interested
1.00-1.80	Not needed/not easy/not interested

The design stage aims to compile a product design based on the analysis that has been carried out in the defining stage. At this stage, the framework for the product to be developed is carried out. This stage includes selecting the type of product and compiling the components and features of the product.

The development stage aims to develop the product. At this stage, the validity of the material and media is tested by experts and practitioners. The suggestions and comments obtained are then used for product revision. The revised product is then used for readability tests by teachers and students to determine the suitability of the product for users.

The product eligibility test in this study was assessed based on the validity test and readability test. The validity test was carried out on the material and media aspects, each by 4 validators consisting of lecturers and teachers. Material and media validity is calculated using Aiken's V coefficient with the following equation 2 (Oktariyanti et al., 2021):

$$\text{v} = \frac{\sum(r_i - l_o)}{[n(c-1)]} \quad (2)$$

Description:
r : the number is given by the validator
l_o : the lowest validity rating score
c : the highest validity rating score
n : the number of validators who carry out the assessment

The scores obtained are then converted based on the validity criteria according to Zakaria et al. (2020) as presented in Table 2.

Table 2. Aiken's V Coefficient Criteria

Correlation coefficient	Validity Interpretation
V ≤ 0.4	Weak validity
0.4 > V < 0.8	Medium validity
V ≥ 0.8	High validity

Furthermore, the readability test was carried out by the teacher and students. Data is measured using a questionnaire arranged on a scale of 1-5, then qualified by finding the percentage of all aspects using the following equation 3:

$$\text{P} = \frac{n}{N} \text{ x } 100\% \quad (3)$$

Description:
P : percentage of score obtained
n : the number of scores obtained
N : total maximum score

The results of teacher and student response scores based on the above calculations are then converted according to the criteria in Table 3.

Table 3. Readability Response Criteria

Score and Percentage Intervals (%)	Criteria
85-100	Very good
69-84	Good
53-68	Pretty good
37-52	Less good
20-36	Very less good

Result and Discussion

The results of this study were obtained through research and development of the ADDIE model. The ADDIE model adopted in this article uses three of the five stages, there are analyzing, designing, and developing. Each stage has certain activities to produce a product in the form of an e-book in which there are learning components that are arranged based on the *creative problem-solving* model and integrated with the STEM approach.

Analyzing Stage

Before developing a product, an initial stage is carried out to find out the needs for teaching materials which are developed through the analysis stage. The analysis phase consists of three aspects including

student analysis, material analysis, needs analysis, and analysis of the use of smartphones in learning.

1) Student Analysis

Student analysis aims to determine students' ability to think critically and creatively in Biology subject. At this stage, students are given a questionnaire containing statements regarding various aspects and indicators of critical and creative thinking. Respondents used in the ability analysis amounted to 60 students of class XI SMA Negeri 7 Semarang. Data on students' analytical abilities are presented in Table 4.

Table 4. Summary of Student Analysis Results

Aspect and Indicators		Response (%)		
		Capable and Very Capable	Adequately Capable and Inadequate	Total
Critical Thinking	I can to identify or formulate problems well	48.3	51.7	100
	I can present arguments and provide the correct evidence	45.0	55.0	100
	I can to identify assumptions well	46.7	53.3	100
	I can conclude something based on facts	47.7	53.3	100
	I can select criteria to consider a solution	46.7	53.3	100
	Average	46.68	53.32	100
Creative Thinking	I can to provide many ideas, ideas or answers	48.3	51.7	100
	I can see a problem from a different perspective	45.0	55.0	100
	I can generate solutions that are new, unique, and unusual	36.6	63.4	100
	I can develop an idea or product well	28.3	71.7	100
	Average	39.55	60.45	100

The results of the student analysis showed that 53.32% of students stated that they were quite capable or even less capable of critical thinking, and 60.45% of students stated that they were quite capable or even less capable of creative thinking. This shows that students' critical and creative thinking skills still need to be improved. The ability to think critically and creatively is crucial to note in the development of students' thinking. Critical and creative thinking skills are higher-order thinking skills and skills needed in 21st-century learning (Agustyaningrum, 2015; Tindowen et al., 2017).

The teacher also stated that students' critical and creative thinking skills were still not optimal. Teachers experience problems in training students' critical and creative thinking skills because students' initial abilities are still lacking and students are difficult to invite to think critically and creatively. Miswari et al. (2020) explain that critical thinking skills are not innate abilities so these abilities can be applied, trained, and developed. Creative thinking skills according to Hasanah & Priyantoro (2019) are influenced by genetic factors (innate) and environmental factors, and creativity will grow optimally if the two factors are combined.

2) Material Analysis

Material analysis aims to determine the material to be used in product development. The material used as a reference for product development has at least the criteria of having or being able to be integrated with elements of technology, engineering, and mathematics, contains many problems around students, and requires a variety of alternative solutions. Based on the analysis conducted on Biology class X material, the most suitable material is environmental change material. Environmental change contains material about problems in the environment and requires various solutions that can be integrated with aspects of technology, engineering, and even mathematics.

In addition, material analysis was also carried out on students through a questionnaire to determine the level of difficulty of the material to be developed. As many as 95% of students stated that environmental change material was quite difficult so it was difficult to understand. Constraints experienced by students include that the material presented is universal, the teaching materials used do not contain environmental problems around students, and the teaching materials used are less attractive. Students also state the teaching materials that students expect include: 1) presenting the material in full; 2) the material is explained briefly, concisely, and clearly, 3) the reading is accompanied by pictures and illustrations; 4) containing information related to surrounding issues; and 4) has an attractive design. Based on this, teaching materials for environmental change that suit the needs of students have the potential to be developed.

3) Need Analysis

Needs analysis aims to determine the level of need for critical and creative thinking skills that are integrated with teaching materials in schools. This research offers electronic-based teaching materials which include *creative problem-solving* learning models and STEM approaches to help students practice critical and creative thinking skills. Needs analysis data is presented in Table 5.

Table 5. Summary of Needs Analysis

Aspect	Teacher Response (%)	Category
The need for critical thinking skills in Biology subjects	4.67	Very needed
The need for creative thinking skills in Biology subjects	4.67	Very needed
The need for the development of teaching materials oriented to critical and creative thinking skills	4.67	Very needed
The need for integration of *creative problem-solving* models and STEM approaches in Biology subjects	4.00	Very needed
Average	4.50	Very needed

The results of the needs analysis show that the average score obtained based on the teacher's response is 4.50 in the very needed category. This can be interpreted that the development of teaching materials to improve critical and creative thinking skills is urgently needed. The solution offered to train these skills is to combine STEM-integrated creative problem-solving models contained in teaching materials. (León, 2015) explains that the implementation of learning in schools including the learning methods and facilities used, influences on the development of children's critical thinking skills. Furthermore, Risnanosanti et al., (2019) explained that learning that provides space for children to be able to solve problems and make decisions independently and creatively is one of the learning strategies that can be used to improve children's critical thinking skills and creative thinking.

4) Analysis of the Use of Smartphones in Learning

This step aims to determine the level of need for smartphones in biology learning, as well as the ease and interest of students in operating smartphones and using electronic teaching materials. A summary analysis of the use of smartphones in learning is presented in Table 6.

Table 6. Summary Analysis of Smartphones Use in Learning

Aspect	Teacher response	Student response	Average	Category
Utilization of smartphones in Biology Learning	3.33	3.50	3.42	Needed
Easy access to teaching materials via smartphone	3.67	4.40	4.03	Easy
Interest in using teaching materials that can be accessed via smartphone in Biology learning	3.67	4.12	3.89	Interested

Table 6 shows that the average score for smartphone utilization in Biology learning is 3.42 in the needed category. The use of smartphones in Biology learning is generally used by students to find references related to learning material, look for answers, view pictures, work on questions, and open learning files. Both students and teachers stated that access to teaching materials via smartphones was easy and interested in using teaching materials that could be accessed via smartphones in Biology learning. This is by the results of research conducted by The Harris Poll (2018) which shows that students tend to prefer using applications compared to printed books to complement their learning.

Almost all students currently own and bring smartphones to school. Activities carried out by students via smartphones include searching for subject matter, communicating, or playing social media and games. If this activity is not managed properly, it will be used more for less productive things (Hendrastomo & Januarti, 2018). Thus the development of teaching materials that can be accessed via smartphones is something that needs attention. This is supported by Istiawan & Kusdianto (2018) who explain that the use of internet-based teaching materials and technology is a trend in learning in the industrial era 4.0 due to the high intensity of the use of devices and applications in them by students.

Analyzing Stage

The design stage aims to design teaching materials according to the problems and needs at the analyzing stage. The teaching material to be developed is an e-book based on STEM-integrated creative problem-solving. The e-book that will be developed consists of an initial section, a contents section, and an ending section. Each section consists of several components described in Table 7.

Table 7 shows that the design of the e-book to be developed consists of three parts, there are the initial section, the contents section, and the final section. The first part explains the identity and characteristics of the e-book. The content section contains the competencies that must be achieved by students and learning materials with the theme of environmental change which are presented based on CPS steps and integrated with STEM elements. Learning material is equipped with various pictures and illustrations and videos to

make it easier for students to understand learning material. E-book features such as Bio News Info, Bio Info, Let's Observe!, Let's Count!, Let's Do It!, and Let's Think! are also included in this section. The final section contains a summary, evaluation, and relevant information related to the e-book.

Table 7. STEM-Integrated *Creative Problem-Solving* Based E-book Framework

Section	Components	Description
Initial section	Title page (cover)	Contains information regarding the title of the e-book, the name of the author, and the target user of the e-book
	Foreword	Contains a brief description of the contents of the e-book
	List of contents	Contains the title of the content or material in the e-book
	Instruction for use	Contains a description of the button or icon contained in the e-book along with an explanation of its function
	Introduction to the CPS model and the STEM approach	Contains information about the syntax of the CPS learning model and the STEM approach
	E-book features	Contains an explanation of the special characteristics contained in e-books such as Bio News Info, Bio Info, Let's Observe!, Let's Count!, Let's Do It!, and Let's Think!
Content section	Learning achievement and learning objectives	Contains competencies that must be achieved by students according to the curriculum regarding the abilities and skills of students
	Material map	Contains an overview or structure that explains the material contained in the e-book
	Material	Contains learning material that is presented based on the CPS syntax and which is integrated with the STEM approach, accompanied by practice questions at the end of the explanation of the material.
Ending section	Summary	Contains the main idea in the book
	Evaluation	Contains questions to measure student understanding
	Glossary	Contains important terms in the e-book which is equipped with explanations
	Bibliography	Contains the references used by the author in compiling the material

According to Rahmadani et al. (2018), good teaching materials at least include study instructions, competencies to be achieved, lesson content, supporting information, exercises, work instructions, evaluation, and responses to evaluation results. Based on Table 7, the components contained in the e-book have fulfilled the requirements for developing teaching materials.

Developing Stage

The developing stage aims to compile teaching materials in electronic form according to the product designs that have been made at the design stage. The e-book was developed using several applications, namely Microsoft Office, Canva, and Flip Pdf Professional. Microsoft Office is used to compile environmental change materials. Canva is used to design the appearance of e-books. The Flip Pdf Professional is used to convert files into electronic and translate them into HTML language. E-books that have been successfully developed are then tested for eligibility based on validity and readability tests. Some displays of e-book material arranged based on the syntax of the STEM-integrated creative problem-solving model are presented in Figure 1.

1) Validity Test

A Validity test was conducted to determine the validity of the product being developed. The validity test consists of two aspects (material and media). Material validation was carried out by 4 validators consisting of 1 Biology lecturer and 3 Biology subject teachers. The validation on the media aspect was carried out by 4 validators consisting of 2 Biology lecturers and 2 Science teachers. The results of the validity test analysis are presented in Table 8.

Table 8. Result of Material and Media Validity Test Analysis

Expert	Aspect	Number of Items	Aiken's V	Criteria
Material	Content Eligibility	15	0.98	High Validity
	Eligibility of presentation	14	0.95	High Validity
	Language of presentation	11	0.94	High Validity
	CPS and STEM components	11	0.98	High Validity
		Average	0.96	High Validity
Media	Eligibility of presentation	21	0.93	High Validity

Expert	Aspect	Number of Items	Aiken's V	Criteria
	Language of presentation	8	0.91	High Validity
	Graphic eligibility	4	0.92	High Validity
		Average	0.92	High Validity

The results of material and media validation in the e-book developed based on the validator's assessment showed that the average Aiken score obtained was 0.96 for material validation and 0.92 for media validation. It can be interpreted that the developed e-book has high validity. Validation is carried out by experts to ensure that the data is important and eliminate unnecessary data (Taherdoost, 2016). Validation is also carried out for product improvement and refinement based on the validator's suggestions and comments. Revision is very important to produce products that are appropriate and useful in classroom learning (Kurniawan et al., 2018).

According to material and media experts, the e-books developed are generally good, interesting, have complete features, are contextual, and able to stimulate students to think critically and creatively. The developed e-book is also easy to read for class X students and easy to operate. Even so, there were several suggestions and comments provided by the material and media validators as improvements in several sections to further refine the product being developed. Validator's suggestions and comments are presented in Table 9.

Figure 1. Creative Problem-Solving Stages (a) objective finding stage, (b) fact-finding and problem finding stage, (c) Idea finding and solution finding, and (d) acceptance finding

Table 9. Validator's Suggestions and Comments

Validator	Aspect	Repair
Material	The Biology info feature changed to Bio Info	Has been revised
	The sentence editor on the Google form is made up of procedural questions to make it easier for students to understand	Has been revised
	Learning achievement and learning objectives are delivered only once. Add a page to describe it at the beginning of the learning activity	Has been revised, and placed after the e-book feature page
	The Let's Think feature should contain a variety of question types (not just multiple choice)	Questions in the Let's Think feature consist of multiple-choice questions, true/false, and essays
Media	Images should belong to the author, especially on the cover	The image on the cover is replaced with a personal documentation image
	Navigation pages are colored	Has been revised
	The color of the writing is not yet contrasting and there is still blank space on page 4	The background color is changed to white and the color of each CPS step is changed to navy blue
	Image is enlarged	Has been revised

2) Readability Test

After testing the validity of the materials and media experts, the next step is to test the readability of the product on teachers and students. This stage was carried out by giving a readability response questionnaire to one Biology teacher and nine students at SMA Negeri 7 Semarang. The readability test is carried out without carrying out the learning process because students have received material on environmental changes. The results of the analysis of e-book readability by teachers and students are presented in Table 10.

Table 10. Result of Readability Test Analysis

Responses	Aspect	Number of Items	Value (100%)	Criteria
Teacher	Display	9	93	Very good
	Content	5	100	Very good
	Language	4	95	Very good
	Average		96	Very good
Student	Display	9	90	Very good
	Content	7	94	Very good
	Language	4	97	Very good
	Average		93	Very good

The results of the readability test by teachers and students based on Table 10 show that the developed e-book obtained an average score of 96% by teachers and 93% by students. This shows that the developed e-book is included in the very good category. Latifah et al. (2020) explained that a good book must pay attention to the readability level of its readers. Books are said to be appropriate if the vocabulary used is simple, light, and concise vocabulary so that readers can more easily understand the contents of the material (Khairoh et al., 2014). This is also supported by Yi et al. (2011) that text style, including typeface, font size, number of columns, and line spacing, as well as suitability for educational level, can influence reader comprehension, readability, and satisfaction.

Conclusion

Based on the results and discussion, it can be concluded that the e-book based on STEM-integrated creative problem solving is included in the very needed category based on teacher responses with an average score obtained of 4.50. E-books are proven to be suitable for use in learning based on validity and readability tests. The validity test obtained an average score of 0.96 for material and 0.92 for media in the high validity category. Readability gets an average score of 96% by teachers and 93% by students in the very good category.

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Author Contribution

Izza Melati Sukma: writing original draft preparation, methodology, results, discussion, and conclusion; Aditya Marianti and Ellianawati: proofreading, review, and editing.

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