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Improving Students' Critical Thinking Skills through the STEM Digital Book

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Abstract

One of the 21st century life skills that needs to be developed in the education process is critical thinking skills. The importance of being trained in critical thinking skills in learning science is motivated by the results of the 2015 PISA test. critical thinking as 'the correct way of assessing statements' and 'reasonable reflective thinking focused on deciding what to believe or do'. In this study, indicators of critical thinking skills measured are providing simple explanations, building basic skills, providing further explanations, and concluding. One potential learning approach to help students become actively involved in learning activities and be able to improve critical thinking skills is the STEM approach. The purpose of this research is to develop a STEM approach digital book with certain characteristics, determine its validity, its practicality, and its effectiveness of the product towards improving students' critical thinking skills. This study uses a development plan from Sugiyono. The subjects of this research are the 8th graders of SMPN 26 Semarang, academic year 2019/2020. The sample as an experimental class (the product is applied in the learning process) is VIII B class, and the control class (used ordinary textbooks) is VIII D class. Data analysis techniques used in this study include descriptive data analysis related to the validity and practicality of the product, while to find out the effectiveness of the product used a normalized N-gain test and a two-sample t-test. Results show that (1) the characteristics of the digital book contained all components of the STEM approach which included aspects of science, technology, engineering, and mathematics (2) the developed digital book has valid criteria regarding to the material, media and language aspects (3) digital book developed effectively to improve students' critical thinking skills, and (4) the practicality of using digital book is considered very good by students and teachers).

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INTRODUCTION

The observations and interviews result with teachers conducted at SMPN 26 Semarang, showed that the average student had difficulty understanding light material and optical devices. This can be seen from the result of 2nd term final exam from several previous years which are quite low. Light material and optical devices contain topics that require a high degree of understanding and analysis, such as the formation of shadows on lenses and mirrors, lens strength, anatomical structure of the human eye, the mechanism of action of optical devices, and identification of various types of eye defects. The difficulty is also influenced by the teaching materials used.

Teaching materials used by students are still in the form of textbooks printed on 25 x 15 cm in 298 pages. These types of textbooks are less supported of pictures and videos, no links to access related websites, and no questions to measure critical thinking skills.

According to Liu et al. (2015), one of the 21st-century life skills that need to be developed in the education process is critical thinking skills. The importance of training critical thinking skills in learning science is motivated by the results of the 2015 PISA test. In science subject (IPA), Indonesia ranks 62th out of 72 participating countries (OECD, 2018). This shows that the ability of Indonesian students to understand the science concept is still low. The science teaching system in Indonesia, which in general has not practiced critical thinking skills, is suspected to be one of the causes.

Critical thinking skills are one's skills in analyzing, synthesizing, conceptualizing, applying, and/or evaluating information from various sources. The ability to think critically can improve the quality of the individual to analyze, assess, and reconstruct what is thought to solve the problem (Scriven & Paul, 1987). Critical thinking skills are important things students must have in stimulating cognitive reasoning (Adeyemi, 2012). The ability to influence critical thinking is also seen in increased student learning motivation (Cholisoh et al., 2010), students 'scientific attitudes (Soh et al., 2010) and students' science process skills (Nugraha et al., 2017).

One potential learning approach to help students become actively involved in learning activities and be able to improve critical thinking skills is the STEM approach (Mutakinanti, et al., 2018). Science, Technology, Engineering, and Mathematics or commonly referred to as STEM, are disciplines that are related to each other. STEM education plays an important role in the development of 21st-century skills. This approach that provides integration of scientific, technological, engineering and mathematical disciplines is also an innovative approach that supports individuals for science and technology literacy (Erdogan & Ciftci, 2017). Education with the STEM approach is expected to be able to build students' conceptual knowledge about science and mathematics, as well as about engineering and technology (Hernandez et al., 2011).

In addition, to the critical thinking skills needed in the 21st century, another thing that cannot be avoided is the influence of Information and Communication Technology (ICT). All aspects of human life cannot be separated from the influence of ICT, ranging from the fields of economics, social communication, politics to education (Kong, 2014). Application of technology in education and learning is a form of innovation that aims to compensate and keep abreast of the times.

Therefore, it is necessary to develop an IT-based teaching material with a digital format with a STEM approach on the topic of light and optical devices to improve students' critical thinking skills. The objectives of this research are to (1) develop products such as digital book which is valid, effective, and practical, and (2) applying the product developed in the learning process to determine effectivity and practicality.

METHODS

The procedure in this research uses the development plan from Sugiyono (2003). The procedure are (1) research and data collection, (2) planning, (3) preparation of teaching materials, (4) expert validity testing, (5) phase I product revisions, (6) small-scale trials, (7) revision of phase II products, and (8) large-scale field trials.

Small-scale and large-scale trials were conducted at SMPN 26 Semarang on May 2019.

During large-scale trials, the effectiveness and practicality of this digital book were analyzed. During large-scale trials, the Pretest-Posttest Non-Equivalent Control Group Design was used, in which the experimental and control groups were not randomly selected. The test subjects were chosen using a purposive sampling technique based on certain considerations (the target subject was clear, that is two classes out of a total of eight classes). The sample consisted of two classes, namely the experimental class (VIII B, 32 students) and the control class (VIII D, 32 students). The experimental class uses digital book, while the control class uses common textbooks.

The instruments use interview sheets, questionnaire sheets, observation sheets, and tests. Meanwhile, the data analysis technique uses quantitative descriptive analysis techniques.

RESULTS AND DISCUSSION

This digital book contains content sourced from class VIII material, specifically light and optical devices. The advantage of this product compared to other products is a web file (.html). Some of the advantages of html files are, (1) can be used in various types of computers with different operating systems (Windows, Linux, Chrome OS), (2) simply open using a browser (Google Chrome, Firefox, Microsoft Edge), so the file will still be opened smoothly without any lag or error.

By BSNP, a learning book must contain several components so that the development objectives of the book can be achieved. This digital book is composed of six components, that are basic competencies and learning objectives, learning materials, practice questions, characters info, STEM concepts, and a concept map.

Meanwhile, another characteristic of digital book is the presence of distinctive features presented. These distinctive features are, (1) *Stunning Science*, contain concepts and theories from related topics that students must master, (2) *Advanced Technology*, examples of technology developed based on related concepts and theories, (3) *Exciting Engineering*, contain knowledge of how a tool or technology is made (designed), (4) *Marvelous Math*, contain how the role of mathematics is used in the development or use of the technology, (5) *Let's Think Critically*, contains questions about everyday phenomena related to the topic being studied, so students can look for the best answers based on their ideas or knowledge, (6) *Let's Discuss,* contain specific questions to be used as discussion material, (7) *Let's Open the World*, contains links that can be clicked on and automatically will be connected to the internet, and finally (8) *Let's Remember*, contains important science concepts and needs to be fully understood.

The development of digital book can be a solution to support the movement of paperless education and digital learning. This is consistent with Solikin & Komalasari (2017), they had a research on the use of digital book in the era of IT literacy. In addition to digital orientation, this teaching material is also a STEM approach. By research from Siswanto (2018) which states that teaching materials approaching STEM can improve students' critical thinking skills, creative thinking and soft skills.

Digital Book Validity

The validity of this digital book was assessed by three experts (material, media, and language). The material and language expert are a lecturer of Natural Sciences Department at Universitas Negeri Semarang, and the language expert is an educator graduating from the same university. The questionnaire was given to each expert with an assessment indicator, so the results obtained were by the indicators and objectives. The results of the validity of the three experts can be seen in Table 1.

Table 1. Expert Validation Results

Expert	Percentage (%)	Notes
Learning Content	83	Valid
Media	90	Valid
Language	95	Valid

Digital Book Effectiveness (Critical Thinking Improvement)

This digital book is used during in four meetings in the experimental class aimed at increasing the value of critical thinking skills.

Increasing the value of both classes before and after treatment can be seen in Table 2.

Table 2. Class Test Result

	Experiment	Control
Pre-test	53.68	53.06
Post-test	76.67	74.17
Gain	22.99	21.11
N-gain	0.50	0.45
Improvement	Medium	Medium

Table 3. N-Gain Normality Test

Class	Sig.	df	Category
Experiment	0.419	32	Normal
Control	0.160	32	Normal

Table 3 shows that the N-gain data is normally distributed (the significance value is more than 0.05). Next, the data were analyzed by parametric statistics (independent sample t-test). This hypothesis test aims to find whether there are significant differences in the increase in the value of critical thinking skills between the experimental class and the control class. T-test results based on the increase in N-gain can be seen in Table 4.

Table 4. N-Gain t-test Result

Class	N-Gain	t value	t table
Experiment	49.54	1.780	1.670
Control	44.89		

Table 4 shows that t value > t table, so that Ha is accepted (there is a significant difference in the increase in the value of critical thinking skills between the two classes). From these results, it was concluded that digital book applied affect the students' critical thinking skills.

There are four indicators of critical thinking skills that were investigated in this study, they are elementary clarification, basic support, advance clarification, and inference. The results of the critical thinking skills test for both classes based on percentages and categories can be seen in Table 5 and Table 6.

Elementary Clarification

Table 5 shows that there was an increase in the value of critical thinking skills in the experimental class on the indicator giving a simple explanation of 8%. During four sessions in the export class, learning is carried out using an IT-based STEM approach with a student-centered learning model. One such learning model is Problem Based Learning (PBL). The IT media-assisted STEM approach combined with this PBL model can have a positive effect on student learning outcomes. This is by research from Furi et al. (2018). She states the STEM-PBL approach can improve students' understanding of concepts, problem-solving abilities, and critical thinking skills.

Basic Support

Table 5 shows that there was an increase in the value of critical thinking skills in indicators building basic skills in the experimental class by 12%, while in Table 6 (in the control class) the increase was 7%. This increase in value is influenced by an appropriate learning strategy using the help of STEM Learners Worksheet (LKPD). The role of LKPD as a tool to train students' critical thinking skills can indeed be a good step. This is consistent with previous research from Irfana et al. (2019) and Lestari et al. (2018), that STP-related LKPD can have a significant influence on students' critical thinking and creative thinking skills.

Advance Clarification

Table 5 shows there is an increase in the value of critical thinking skills of the experimental class (the indicator provides a basic explanation) by 32%. Meanwhile, the increase in control class was 31% (Table 6). This increase in value is influenced by learning models that hone and train students' ability to investigate and solve problems or phenomena that occur. The learning model is the inquiry model and the cooperative model (applied at the first and third meetings). The results show that with inquiry and cooperative models, student learning outcomes can be improved from before. Research conducted by Amatullah et al. (2019) which revealed that the inquiry and cooperative model (Think Pair Share) had a positive influence on critical thinking skills and student learning outcomes.

Table 5. Critical Thinking Skill Test Results for Experimental Class Students

Critical Thinking Indicator	Pre-test				Post-test			
	No.	Score (%)	Average (%)	Category	No.	Score (%)	Average (%)	Category
Elementary Clarification	1	63	58	Moderate	1	70	66	Good
	2	53			2	63		
Basic Support	3	50	63	Moderate	3	58	75	Good
	4	64			4	84		
	8	70			8	83		
Advance Clarification	5	57	55	Weak	5	89	87	Very Good
	6	54			6	86		
	7	53			7	86		
Inference	9	50	50	Weak	9	81	79	Good
	10	47			10	82		
	11	50			11	81		
	12	53			12	79		
	13	49			13	76		

Table 6. Critical Thinking Skill Test Results of Control Class Students

Critical Thinking Indicator	Pre-test				Post-test			
	No.	Score (%)	Average (%)	Category	No.	Score (%)	Average (%)	Category
Elementary Clarification	1	65	59	Moderate	1	77	70	Good
	2	53			2	63		
Basic Support	3	49	62	Moderate	3	60	69	Good
	4	63			4	70		
	8	50			8	73		
Advance Clarification	5	53	52	Weak	5	85	83	Very Good
	6	53			6	82		
	7	51			7	83		
Inference	9	51	50	Weak	9	75	77	Good
	10	46			10	78		
	11	50			11	78		
	12	53			12	80		
	13	49			13	76		

Inference

Table 5 shows there is an increase in the value of critical thinking skills on the indicators concluded by 29% (experimental class), while the control class by 27% (Table 6). The STEM approach that is applied with a mind-map strategy can help students to understand the concept before finally, they can give a conclusion.

Before students get concepts to build a conclusion, the teacher should provide hints to students. As expressed by Marin, L. & Halpern, D. (2011) and Malamitsa, K. et al. (2009), so students can deduce correctly, the teacher needs to provide an explicit explanation at the end of the lesson before concluding. From this, students are expected to truly understand the conclusions they get and formulate a concept, principle or procedure.

Digital Book Practicality

Based on the responses of students and teachers, this digital book is very good. The results of student responses can be seen in Figure 1. Meanwhile, the results of teacher responses can be seen in Figure 1.

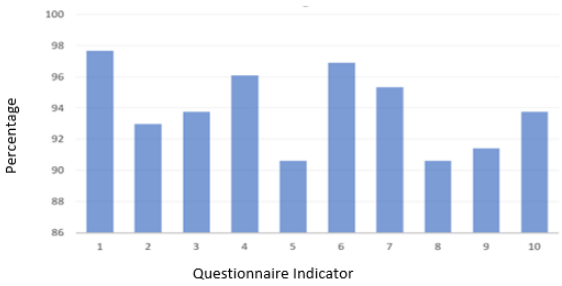

Figure 1. Practicality Questionnaire Result by Students

Indicator's description: (1) use of contextual examples (2) systematic / coherent presentation of material (3) presentation of material that is easily understood (4) presentation of material that is curiosity (5) grammar and sentence structure (6) letters and layouts (7)) interesting teaching materials (8) ease of use, (9) color proportions and (10) picture and video clarity.

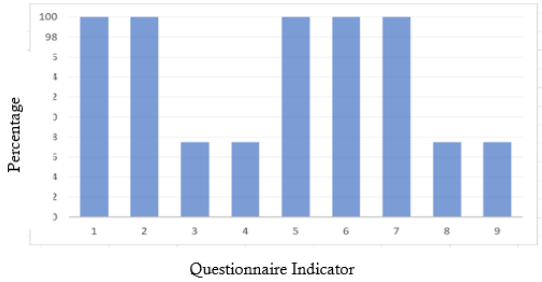

Figure 2. Practicality Questionnaire Result by Teacher

Indicator description: (1) Content supports the achievement of BC, (2) Material presented systematically, (3) Integrates STEM elements, (4) Easy use, (5) Composition of images and writing, (6) Quality of images and animations/videos, (7) Materials to train critical thinking, (8) Recommendations for the use of teaching materials

CONCLUSION

Based on the results of research and development carried out, the conclusions of this study are (1) the characteristics of digital book contain all components of the STEM approach that includes aspects of science, technology, engineering, and mathematics in a balanced manner and with the STEM approach, (2) digital book developed has a valid criteria in terms of material, media, and language, (3) digital book are effective for improving students' critical thinking skills, and (4) the practicality of using digital book is considered very good by students and teachers.

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