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THE STEM APPROACH: THE DEVELOPMENT OF RECTANGULAR MODULE TO IMPROVE CRITICAL THINKING SKILL

Research Article

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Abstract

The objective of the study is to find out: 1) how rectangular module with the STEM approach to improve valid and practical critical thinking skill; 2) the effectiveness of the rectangular module development with the STEM approach to improve critical thinking skill. It is a research and development (R & D) study. This research consists of two phases, namely preliminary study and product development. Product development consists of product testing using one group pretest - posttest design experimental research. The population in this study is the students of one State Junior High School in the Kebumen region by taking five students as the sample for individual tests, 32 students for limited scale tests, and 64 students for wide-scale tests. The results of this study indicate that 1) the rectangular module with the STEM approach on the aspects of content, presentation, graphical, and language feasibility are excellent, the STEM approach feasibility and components of critical thinking skills are good category; 2) the effectiveness shows that the rectangular module with the STEM approach to improve critical thinking skills is proven effective which can be seen from the average value of N-Gain in the experimental class of 0.37 with the category of medium improvement, while N-Gain in the control class is 0.03 with low increase category.

Keywords: rectangular module, STEM, critical thinking skill

1. Introduction

The industrial revolution is a real change from the existing condition. At the moment, the era of industrial revolution 4.0 replaces the industrial revolution 3.0. The emergence of cyber-physical and manufacturing collaboration (Irianto, 2017) is a sign of industrial revolution 4.0. Industry 3.0 emphasizes on high buildings, strategic places, and direct product promotion. However, those emphases are no longer important in 4.0 eras. The crucial thing in this era is literacy; data literacy, technology literacy, and human literacy. In the past, important literacy is *calistung* (reading, writing, and arithmetic). Today, it must be data, technology, and human literacy. These three literacies are significant for the development of all types of work in the era of industrial revolution 4.0. So inevitably, the educational world must follow this trend. In line with this condition, information technology has become the basis of human life (Kemristekdikti, 2018). The industrial revolution 4.0 is also marked by an

increase in digitalization through several factors such as the increase of data volume, computational power and connectivity; emergence of analysis, ability and business intelligence; the occurrence of new forms of interaction between humans and machines; and the improvement of digital transfer instructions into physical world such as robotics and 3D printing (Sukartono, 2018). As a consequence, a country needs to prepare the next generation that has good quality and can compete globally, and master technological developments (Kanematsu & Barry, 2016). In other words, if humans can compete globally, their life in the industrial revolution 4.0 era will be easier because human resources will be replaced by mechanical power and technology.

The next generation of the nation needs to have various abilities to face the era of the industrial revolution 4.0. Education is an appropriate place to train students' abilities. Education teaches students the way of thinking and provides accurate information to stimulate students' thinking skills. One of these thinking skills is critical thinking (Becanli, Dombayci, Demir, & Tarhan, 2011). The 21st-century skills and literacies, that include: basic skills, technology skills, problem-solving skills, communication skills, critical and creative skills, information/ digital skills, inquiry/ reasoning skills, interpersonal skills, and multicultural and multilingual skills. Critical thinking skill is one of the innovations in the 21st century, where students are expected to be able to handle problems in the future. It is also one of the 21st-century thinking skills that require to be emphasized in the field of education. It is also considered as one of the foundations of other skills including communication skill, collaborative skill, life skill, career skill, global awareness, and learning and innovation skill. The critical thinking model is an important attribute for success in the 21st century (Zivkonic, 2016).

Indonesia must prepare reliable human resources in Science, Technology, Engineering, and Mechanic (STEM) disciplines to deal with global competition (Firman, 2015). STEM education has many potential benefits for individuals and the nation as a whole (Beatty, 2011). The purpose of STEM education is to encourage students to have science and technology literacy which can be seen from reading, writing, observing, and doing scientific research. It aims at developing their competencies to face daily problems related to STEM (Bybee, 2013). In this regard, in the upcoming ten years, STEM-based employment will increase by 11%. The STEM expert in Indonesia is still lack (Kosasih, 2018). This case causes a shortage of experts from STEM backgrounds. Therefore, STEM is an important issue in education at this time (Becker & Park, 2011). STEM learning is an integration of science, technology, engineering, and mathematics which is considered as tools to deal with 21st-century skills (Beers, 2011). The concept of STEM in the 21st century is developing knowledge, skills, and beliefs related to subjects using an interdisciplinary approach (Corlu, Capraro, & Capraro, 2014). STEM has also taken a central role in projects that have been implemented in developing countries, one of which is Turkey, where the project aims to improve knowledge and technical skills using science concepts (Baran, Zonbazoglu, Mesutoglu, & Ocak, 2016). Regarding the phenomenon, the regulation of Minister of Education and Culture of Indonesia implicitly support STEM education. It can be seen from the regulation number 37 of 2018. It explains that there is a change in the 2013 curriculum for elementary, junior, and senior high school by adding informatics lessons.

Based on the observation results in one of junior high school in the Kebumen region, most of the students face difficulty in solving questions of rectangular form related to critical

thinking indicator. It is caused by the ability of students is only in the form of memorizing the concept and formula. Besides, they do not understand the use of mathematics materials, especially rectangular form in daily life. As a result, the students are not interested in learning rectangular form material. This case causes a lack of learning media. The teacher teaches using a conventional way by explaining and writing in the board without other media. Whereas, the students will be easier to understand if there are other media in supporting teaching and learning process. One of the effective media is the use of module. A module which can stimulate students' critical thinking and students' ability in mathematics is a module using STEM approach. Based on the problem arises in the observation, a research will be conducted which concerns on the development of rectangular module using STEM approach to enhance students' critical thinking practically and effectively. The objectives of the research are to find out: 1) how rectangular module with the STEM approach to improve valid and practical critical thinking skill; 2) the effectiveness of the rectangular module development with the STEM approach to improve critical thinking skill. It is carried out in one of the junior high school in Kebumen region.

2. Methodology

This is a research and development (R&D) study. (Borg & Gall, 1983) state that development research in the field of education is a process to develop and validate educational products. This research uses two phases, namely preliminary studies and product development. The product development in this study contains product trials consisting of individual tests, limited scale tests, and wide-scale tests. The individual and wide-scale test is employed to know the practical rectangular module. In the research process, the students get a practicality questionnaire after they study the rectangular module using STEM approach. Meanwhile, wide-scale test is employed to know the effective rectangular using the design of the experimental one group pretest-posttest. The population in this study is all of VII grade students in one of junior high schools in Kebumen region. Random clusters is employed as the sampling technique by taking 5 students for individual tests, 32 students for the limited scale test, and 64 students for the wide-scale test consisting of 32 students as the experimental class and 32 students of the control class. There are two variables in this study, the dependent variable and the independent variable. The dependent variable in this study is students' learning outcomes, namely students' critical thinking skill and the independent variable is rectangular module with the STEM approach. Data collection in this study is critical thinking skill task consisting of two essay questions in the form of pretest questions and posttest. Pretest questions are utilized to determine the initial level of ability, while the post-test questions are employed to find out how much change is produced after treatment. The obtained data are then be analyzed using the univariate t statistical test. N-Gain analysis is employed to find out the difference in value which can show students' knowledge differences at the beginning and end of learning in the experimental class and control class.

3. Findings and Discussion

3.1 The valid and practical rectangular module

The development of mathematics module as teaching materials aims at improving the quality of learning resources in schools, facilitating students in learning, enhancing students' critical thinking, enriching teachers' media in the learning process, and increasing students' knowledge and understanding of integrated mathematics lesson with science, technology,

engineering, and mathematics (STEM). The STEM module analysis is conducted through interviews, tests, and questionnaires to find out the validity of the STEM module.

3.1.1 Preliminary Study

There are several results based on the interviews with mathematics teachers of State Junior High School (SMPN) 1 Puring, namely: *first,* some schools use inappropriate handbooks. For example, it does not stimulate problems or books that refer to the 2013 curriculum and it still consists of some misprint. This case is complained about by the mathematics teachers because the students feel confused. As a consequence, teachers should repeat their explanation several times. *Second,* some schools do not have teaching materials either books or module. *Third,* the age of seventh-grade students is around 13 years old. This is also taken into researchers' consideration in compiling modules to fit the characteristics of students. Learning material is arranged from concrete things to abstract things by following their age. It is expected that it can facilitate the students' understanding process.

The researchers also obtain several initial problems and the need to support the learning process. For example, (1) learning process still emphasizes material content; (2) learning process is still lack of students' active participation; (3) the students consider that mathematics is a difficult subject to be understood; (4) the learning model is still dominated by lecturing; (5) the teachers is lack of time due to a lot of materials to be delivered; (6) learning tools in the form of textbooks and students' worksheet (LKS) is not able to motivate students to learn independently; (7) the teaching materials are not interesting enough for students; and (8) students' abilities are very diverse.

Teaching materials analysis intends to find out appropriate teaching materials to overcome obstacles during the learning process. Besides, the teaching materials must be adapted to the needs of students and school facilities, so that it can motivate students to learn independently. Based on the results of observations, the school facilities do not support the use of LCDs and computers. The facilities in the class are only whiteboards. As a consequence, the researchers cannot develop teaching materials using computer technology such as interactive teaching materials and audio-visual materials. Teaching materials which can be used are in the form of mathematics learning modules or printed teaching materials. The diversity of students' ability requires teaching materials that can be studied independently according to the pace of learning. Modules are chosen because they are printed teaching materials which are designed to stimulate students to learn independently. The chosen learning module is a mathematics learning module with the STEM approach. Modules with the STEM approach are chosen because STEM is an integration of science, technology, engineering, and mathematics which can improve students' critical thinking skill.

3.1.2 Critical Thinking Ability Test

The critical thinking skill of the seventh-grade students of SMPN 1 Puring is relatively low. This is shown from the results of tests of students' critical thinking skill shown in Figure 1. Critical thinking skills of students can be seen from several indicators to achieve the critical thinking aspects. The critical thinking aspects are Interpretation, analysis, evaluation, inference, explanation, and self-regulation (Facione, 2013).

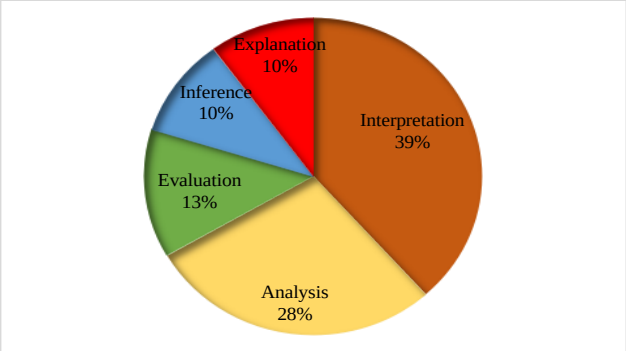

Figure 1. *The results test of students' critical thinking skill*

Figure 1 shows that the students are still not familiar with critical thinking tasks due to the low percentage of critical thinking aspects.

3.1.3 Product Development

1) Initial Product Planning

The purpose of developing a learning media is to obtain learning modules that can improve students' critical thinking skills. Learning media users are seventh-grade students of SMP in Kebumen Regency. Media specifications are the media characteristics and the media components that will be produced, the needed facilities and infrastructure characteristics, and the characteristics of the media users. The following are the module specifications that will be implemented in research planning:

a) The outer cover consists of the module title which describes the main materials.
b) Initial part; the inner cover contains author's identity, consultant, module validator; the preface as the opening page which explains the role of the module in the learning process; module content map which describes module components and learning activities; table of contents containing the module framework and it is completed with a page number.
c) Core part; introduction which includes background, objectives, material competency map, module usage instructions, and ability check sheets; learning activities which arranged according to the stages of problem-based learning; the final/post activity in the form of conclusions from each chapter.
d) Final part; exercises containing tests from all of the chapters; bibliography which contains a list of references in compiling the module; glossary that contains a description of terms, difficult and foreign words used in the module and it is arranged alphabetically.

2) Early Product Development

The planning of the design development of the initial learning media is carried out based on the need assessment, the study of the theories, and specifications of the media that have been obtained. In developing the design of early learning media, FGD (focus group discussion) activities can be carried out if there is a lack of need assessment and theoretical studies (Budiyono, 2017). FGD can be employed with users and/or with experts related to the developed products. This study uses a need assessment to decide the data from the STEM module. This initial media design development plan is in the form of theoretical planning of learning media. These theoretical products must be examined by related experts before they are made into prototypes. Based on the examination, experts present several suggestions to the researcher for improvement. This activity is called as an expert/expert validation activity.

In conducting expert validation, the researchers provide an assessment instrument (accompanied by a suggestion sheet) to the relevant experts.

a) The Results of Material Expert Validation

Validation of material experts is applied by involving competent experts. The researcher submits the prepared module to the material experts by including the grid and module assessment sheet. The assessment results from the material experts are shown in Table 1.

Table 1. *Assessment category of all components*

No	Component	Total Number	The Number of Ideal Score	Assessment Category
1	Content Feasibility	127	144	Excellent
2	Presentation Feasibility	124	144	Excellent
3	STEM Approach Assessment	123	160	Good
4	Critical Thinking Skill	64	80	Good

Based on Table 1, the score of content feasibility component of the three material experts is 127 out of a maximum score 144 or around 88.19% on a scale of four and it includes into the excellent category. The score of presentation feasibility is 124 from a maximum score of 144 or around 86.11% on a scale of four and it includes into the excellent category. The score of the assessment of the STEM approach is 123 from a maximum score of 160 or around 76.87% on a four scale and it includes into the good category. Meanwhile, the score of critical thinking ability shown in the module is 64 from a maximum score of 80 or around 80% on a four scale and it includes into the good category. Based on the score acquisition of the four material experts for four components, it shows that in terms of material, the module includes in the good category. It means that the whole assessments are categorized into a good category. There are several suggestions from the two material experts after validation as follows; repairing wrong typing or writing; adjusting the image of the cover with the material; avoiding writing that has no meaning; using contextual and real examples of problems; avoiding writing zero (0) in degree; improving the concept because there are several concepts that still need to be improved such as adjusting the angle context.

b) The Results of Media Expert Validation

Media expert validation is employed by submitting the compiled module into media experts accompanying by grids and assessment sheets. The summary of the assessment results obtained from the media expert questionnaire is shown in Table 2.

Table 2**.** *Assessment category of all components*

No	Component	Total Number	The Number of Ideal Score	Assessment Category
1	Graphical Feasibility	31	36	Excellent
2	Language Feasibility	22	24	Excellent

Based on Table 2, assessments from media experts show that in terms of graphics and language, the module is included in the excellent category. In terms of graphics, the score is 31 from a maximum score of 36 or around 86.11% on a four scale and it includes in the excellent category. In terms of language, the score obtained from the two experts are 22 from a maximum score of 24 or around 84.61% on a scale of four and it includes in the excellent category. In general, the components of the graphics and language of the module are excellent. There are some suggestions from media experts including; improving the writing

of mathematical notations, symbols, images, and tables; revising typographical errors; repairing the layout of the chart and its content; adding instruments on the page of the cover; adding answer key rubric. The following are some pages that are revised based on suggestions from experts.

c) Product Testing

1) Individual Test

Individual trial test is conducted on 5 students who are randomly drawn from the VII grade students in Kebumen region. Trial test of the product runs smoothly and interactively after the students reading, understanding the module, and doing on the questions. After that, interviews are conducted with students in depth. Overall, the students give positive responses to the module compiled by researchers.

2) Limited Scale Test

Limited trial test is conducted on two mathematics teachers and 32 students of VII grade students in Kebumen region. The results of the assessment are shown in Table 3 and Table 4.

Table 3. *Limited Trial Results for Mathematics Teachers*

No	Component	Total Number	Ideal Score	Category Assessment
1	Module Interest	32	40	Excellent
2	Material	47	60	Good
3	Language	39	50	Good

Based on Table 3. Limited trial test for mathematics teachers show that in terms of module practicality is included in the excellent category. In terms of module interest, the score is 32 from a maximum score of 40 or around 80% on a scale of four and it is included in the excellent category. In terms of material, the score is 47 from a maximum score of 60 or about 78.33% on a scale of four and it is included in the good category. In terms of language, the score is 39 from a maximum score of 50 or about 78% on a scale of four and it is included in the good category.

Table 4. *Limited Trial Test Results for Students*

No	Component	Total Number	Ideal Score	Category Assessment
1	Module Interest	672	800	Excellent
2	Material	608	800	Good
3	Language	640	800	Good

Based on Table 4. Limited trial test for mathematics teachers show that in terms of module practicality is included in the excellent category. In terms of module interest, the score is 672 from a maximum score of 800 or around 84% in a scale of four and it is included in the excellent category. In terms of material, the score is 608 from a maximum score of 800 or about 76% in a scale of four and it is included in the good category. In terms of language, the score is 640 from a maximum score of 800 or about 80% on a scale of four and it is included in the good both categories. After a limited trial test, several suggestions and input are obtained from mathematics teachers and students.

3.2 The effectiveness of the module

The effectiveness of rectangular module using STEM approach is tested using wide scale test with the design of experimental one group pretest posttest. The population in this study is all students in one of junior high schools in Kebumen region which the sample is 64 students with 32 students for experimental class and 32 students for control class. The results of the N-Gain test to determine the difference in value of students' knowledge at the beginning and end of learning of the experimental class and the control class is conducted with the SPSS program which can be seen in table 5.

Table 5. *The Summary of N-Gain Test Result*

Class	N-Gain Average Score	Category
Experiment	0.37	Medium
Control	0.03	Low

The average score of N-Gain test of experimental class is 0.37 which is included in the medium category, while the average N-gain of the control class is 0.03 which is included in the low category. Before applying the univariate t statistical test, the normality test, homogeneity test and balance test will be calculated first as a prerequisite.

3.2.1 Normality Test

The normality test in this study is the Liliefors test with a significance level of $\alpha = 0.05$. A summary of normality test results is shown in Table 6.

Table 6**.** *The Summary of Normality Test Result*

Class	L_{count}	L_{table}	Test Decision	Conclusion
Experiment	0.160	0.161	H_0 is accepted	Normal
Control	0.139	0.161	H_0 is accepted	Normal

Based on Table 6. it is found that the L_{count} in the experimental class which using the module is 0.160. Meanwhile, the score of the L_{count} in the control class is 0.139. Because of the $L_{count} \notin$ DK, it can be said that the two samples are originated from normally distributed populations.

3.2.2 Homogeneity Test

Homogeneity test in this study uses the Bartlet Test with a significant 5%. A summary of the homogeneity test results is shown in Table 7.

Table 7. *The Summary of Homogeneity Test Result*

b_{obs}	b_{table}	Test Decision	Conclusion
0.997	0.956	H_0 is accepted	Homogeneous

Based on calculations, $b_{obs} = 0.997$ with $b_{table} = 0.956$ where DK={b|b<0.956}, or in other word bobs $\notin$ DK, so that it can be concluded that H_0 is accepted. This shows that the population variance is homogeneous.

3.2.3 Univariat Statistical Test

This test is used to determine the effectiveness of the use of mathematical module for problem-based learning. This test is done by comparing the average learning outcomes achieved by the experimental class and the control class. The researchers used the t-test to

compare the results of critical thinking skills of the two classes. Assuming that the population is normally distributed and homogeneous as follows.

Table 8. *The Summary of Hypothesis Test Results*

Class	N	Score		t_{count}	t_{table}	Test Decision
		$\overline{X}$	s			
Experiment	32	76.406	9.691	63.176	1.645	H_0 is rejected
Control	32	61.250	10.473			

$H_0 : \mu_1 \leq \mu_2$ (There is no improvement in students' mathematics outcome before and after using the module)

$H_1 : \mu_1 > \mu_2$ (There is an improvement in students' mathematics outcome before and after using the module)

The results of the balance test analysis in table 6 shows that t_{count} = 63.176 with t_{table} = 1.645 while the critical area DK = {t | t> 1.645}. The results of the hypothesis test are fully shown in Appendix 10. Thus the $t_{count} \in$ DK, so that H_0 is rejected or it can be concluded that the average mathematics learning outcomes of students using mathematical modules with the STEM approach to improve critical thinking skill is better than that who do not use the module.

Based on the results of the study, it is found that the average value of the students' mathematics learning outcomes using the STEM approach module to improve students' critical thinking skill is better than that who do not use the module. This is because the learning process is characterized by the application of critical thinking skills is providing opportunities for students to play an active role, encouraging students to be able to identify possible solutions, being able to select data or information, being able to provide opinions about the selected data, and finally being able to provide the possibility of problem solving (Arikunto, 2007). It supports STEM learning because in STEM learning, students are also encouraged to be actively involved in groups to solve a problem and they are required to think critically by integrating disciplines that exist in STEM namely science, technology, engineering, and mathematics (Beers, 2011). The findings in this study support the results of previous study conducted that there are significant differences in students' critical thinking skills using the STEM approach with the learning process in the control class (Khoiriyah, Abdurrahman, & Wahyudi, 2018). The findings of this study support the results of previous study conducted that the increase in N-Gain is in the medium category (Lestari, Astuti, & Darsono, 2018). It means that the worksheets developed with the STEM approach can improve critical thinking skill. STEM can train students both cognitively, skill fully, and effectively (Becker & Park, 2011). In recent years, STEM learning also has been widely applied in several countries such as Taiwan. Taiwan begins to integrate STEM learning which makes students act as learning center (Lou, Shih, Diez, & Tseng, 2011). STEM learning has certain characteristics, one of which is to produce a product. The STEM module presents project activities by integrating STEM disciplines. Integration in the learning process is shown in table 9.

Table 9. *STEM Integration in the Learning Process*

No	STEM	Learning Process
1	Integration of Scientific Knowledge	Observe the images of a collapsed bridge, utilize knowledge skills and science processes in understanding natural phenomena, and manipulate these symptoms. So, they know the cause. How is the shape of the bridge structure to make it stronger?
2	Integration of Technology knowledge	Analyze how bridges can last for a long time and how technology can be developed. In this case, the students are asked to make artificial bridges using paper with to determine the stronger form of bridge. The students can also learn techniques about how to make the strongest bridge structures and techniques in the process of making the bridge structure. They can use the internet to determine stronger bridges.
3	Integration of technology knowledge and engineering	Students determine ideas for making artificial bridge structures that are considered stronger. The bridge structure uses the concept of a flat building.

Figure 2. *Problems of the bridge*

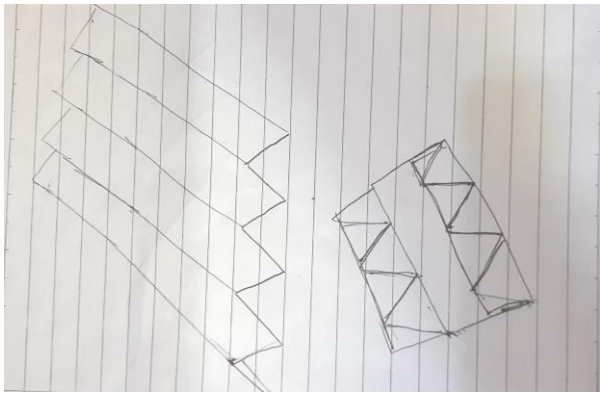

Figure 3. *The idea of a bridge structure*

Students utilize the skills that they have to assemble stronger bridge structures using the provided materials.

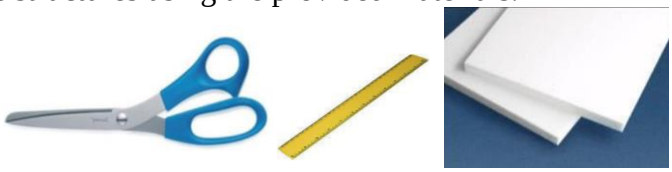

Figure 4. *Tools for making bridge structures*

4	Integration of technology knowledge, Engineering, and Mathematics	In this case, the students use skills to analyze, give reasons to communicate ideas effectively, solve problems, and interpret solutions why they choose the bridge foundation that has been made. The students can also find out that the flat shape that they learned is also very beneficial for life.

Figure 5. *Results of the bridge structure*

As known, every child has different abilities. Likewise in terms of the ability to think critically on each student is also different. There are students who have high critical thinking skill and there are also students who have low critical thinking skills. This can be seen from the results of data analysis obtained from the test of critical thinking skill given to students. Critical thinking is very important for the future of the students, because it prepares students to face many challenges that will arise in the future, career, and at the level of their personal obligations and responsibilities (Tsui, 1999). In this case, it is very necessary for educators to direct students in the STEM learning process to be able to improve critical thinking skills. This supports the results of previous research conducted by (Tekerek & Karakaya, 2018) on the importance of awareness of STEM education conducted at State Universities in Turkey.

4. Conclusion

Based on the results of research and discussion, it can be deduced that the development of a rectangular module with the STEM approach to improve critical thinking skill that begins with a preliminary study shows that there is a need to develop a rectangular module with the STEM approach. The results of the validation indicate that it has met the module eligibility standards and has met the media eligibility standards. The results of individual trials state that the rectangular module with the STEM approach receive a positive response. The results of a limited scale trial show that the rectangular module as a whole is in the good category. In conclusion, rectangular module using STEM approach is valid and effective.

The effectiveness of the module is tested using wide scale test using the design of experimental one group pretest posttest. The result of t univariat test is 63.176. It can be concluded that there is an improvement of the average of students' outcome after using the module. The result of N-Gain is 0.37 which is included into medium for experiment class and N-Gain result for control class is 0.03 which is included into low category.

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