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Development of STEAM-based Teaching Materials on Trigonometric Equations to Improve Students' Mathematical Creative Thinking Ability

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Abstract

This research was a development research that aims to develop and to know the quality of Science, Technology, Engineering, Art, and Mathematics (STEAM)-based teaching materials viewed by the suitability of characteristics, validity, readability, and improvement of students' mathematical creativity thinking ability. This research used the stages of Research and Development (R&D) those are: (1) potential and problems; (2) data collection; (3) product design; (4) product test (readability test); (5) trial test; (6) final product. The result showed that the teaching material met the suitability of the characteristic. The result of the validity test showed a percentage of 89.3%. The readability test result showed a percentage of 74.8%. The analysis of the pretest and posttest showed that teaching materials could improve students' mathematical creativity thinking ability with the N-Gain score of 0.34 in the medium category. Therefore, the Science, Technology, Engineering, Art, and Mathematics (STEAM)-based teaching materials is qualified.

1. Introduction

Educations is not devoid of human life. Education has an important role in the ingenuity of a nations. Therefore, education is one of the most persistent problems to development in Indonesia. National Education Law No. 20 of 2003 concerning the National Education System Chapter 1 Article 1 Paragraph 1 explains that education is a conscious and planned effort in realizing learning and learning situations so that students actively develop their potentials namely self-control, religious-spiritual, personality, intelligence, society, as well as the nation and country.

Based on the study result issued by The Program for International Students Assessment (PISA) in 2018 shown that the average score of Indonesian students' mathematics and science achievement scores are below the international average score. Indonesia was ranked 67th out of 73 countries that involved in PISA 2018. Based on the study result issued by Trends in International Mathematics Science Study (TIMSS) in 2015 shown that the average score of Indonesian students' mathematics ability is ranked 34th out of 49 countries.

One of the abilities in mathematics is the mathematical creative thinking ability. Mathematical creative thinking ability is essential for the purpose of mathematical learning. According to Patmalasari, Afifah, & Resbiantoro (2017), creative, critical, logical, and systematic thinking ability must be employed by humans to develop human resources. Based on research conducted by The Global Creativity Index (GCI) in 2015, which includes technology, talent, and resilience aspects, Indonesia is ranked 115th out of the 139 countries involved in the study.

According to Munandar as cited by Runisah *et al* (2016) state that the increased technological advance and the teeming human population need adaptation and the ability to find imaginative solutions. Therefore,

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Indonesian students must have the ability to think creatively, one of which is the mathematical creative thinking ability.

Mathematical creative thinking ability is one of the many abilities that students were required to have in the 21st century. According to Aizikovitsh and Udi as cited in Qadri, *et al* (2019), creative thinking is a cognitive ability to process various solutions to solve the problem. According to the Siswanto as cited in Aprilia *et al* (2016), creative thinking ability is the ability to come up with a number of possible solutions or a number of ways to solve problems.

According to Wahyudi *et al* (2018), indicators of mathematical creative thinking ability are published in four points, fluency, flexibility, originality, and elaboration. The fluency indicator is described as students capable of producing many relevant ideas or answers and the way of students' thinking. The flexibility indicator is described as students able to produce uniform ideas, able to change the way or approach, and the direction of thought. The originality indicator is described as students capable of giving unusual answers, unusual ones, and rarely given by most students. The elaboration indicator is defined as the student is able to develop, add to, enrich an idea, elaborate over details, and broaden a point.

The growth of technology in the world can be classed very rapidly, and the development of this technology is followed by development in another aspect, one of which is education. This goes hand in hand with research done by Georgette Yakman, known as science, technology, engineering, art, and mathematics. Art concepts in learning are a great need for students. According to Yakman (2008), students studied more actively in art lessons. This was reinforced by research conducted by National Endowment for the Art cited in Bush *et al* (2015) where students who studied art at school were four times better for their academic achievement and three times more likely to be good for their presence.

Yakman (2008) classified the definitions in STEAM as following. Science including physics, biology, chemistry, geoscience, space science and biochemistry. Technology including nature of technology, technology and society, design. Engineering include aerospace, architectural, agricultural, civil, computer, electrical, industry, mining, Ocean. Art including Physical, Fine, language and liberal (including; sociology, education, and more). Mathematics including numbers and operations, algebra, geometry, trigonometry, measurement, and more.

According to Aktürk *et al* (2017), STEAM-based education aims to prepare students to solve any problems through innovation, creative and critical thinking, cooperation and communication effectively from a fresh way.

According to Roh (2003), the model of Problem Based Learning (PBL) is a method of learning that describes the learning environment where problems drive learning, where learning begins with a problem that must be solved so that students acquire new knowledge before they can solve the problem. The Problem Based Learning (PBL) model provides students with more opportunities to think critically, present creative ideas, and communicate to their peers mathematically.

The teaching material are systematically designed to support the learning process by implementing the valid curriculum. According to Widodo and Jasmadi cited by Khulsum, Hudiyono, and Sulistyowati (2018), the teaching material is a set of materials designed by teachers in learning activities where it can sustain student study activities to achieve basic competence.

According to Daryanto (2014), there are four types of teaching material that are: (1) visual teaching materials that are printed teaching materials such as handouts, books, modules, student worksheets, brochures, leaflet, wallchart, and photos/pictures and non-printed teaching material such as models/figures; (2) listening teaching materials (audio) such as audiocassettes, radios, black disks, and compact audio disks; (3) audio-visual teaching materials such as compact video disks and movies; (4) multi-interactive teaching materials such as computer assisted instruction (CAI), and compact disks (CD) and web based learning materials.

Based on the description above, it is necessary to have further research on "Development of STEAM-based Teaching Materials to Improve Students' Mathematical Creative Thinking Ability ". This research is expected to be a more in-depth study of the development of STEAM-based teaching materials to improve students' mathematical creative thinking skills.

2. Methods

This research used the Research and Development (R&D) method. Research and Development method is a research method used to produce and test the effectiveness of the product (Sugiyono, 2018). In this study, STEAM-based teaching materials were developed to increase students' mathematical creativity thinking ability.

The R&D stages used in this study include: (1) potential and problems; (2) data collections; (3) product design; (4) design validation; (5) product test (that is readability test) (6) trial test; (7) final product. The data collections techniques that used in this study were the questionnaire of the character suitability, the questionnaire of the validity, a test of readability, and test of students' mathematical creativity thinking ability.

Data analysis techniques for the results of the validity and readability level of the teaching material will be analyzed by using the following equation.

$$P = \frac{f}{N} \times 100\%$$

(Sudijono, 2016)

where,

P : the score percentage
f : number of scores obtained
N : the maximum number of scores

The validity criteria based on Akbar as cited by Wahyuni (2017) are shown in Table 1 below.

Table 1 Criteria of Validity

Score Percentage	Criteria
$25\% \le P \le 50\%$	Not Valid
$50\% < P \le 70\%$	Rather
$70\% < P \le 85\%$	Valid
$85\% < P \le 100\%$	Excellent

Teaching materials are said to be valid and can be used for learning if the score percentage > 70%. The readability level criteria based on Rankin & Culhane as cited by Wahyuni (2017) are shown in Table 2 below.

Table 2 Criteria of Readability

Score Percentage	Criteria
$0\% \le P \le 40\%$	Difficult to understand
$40\% < P \le 60\%$	Rather understand
$60\% < P \le 100\%$	Easy to understand

Teaching materials are said easy to understand and can be used for learning if the score percentage $>$ 60%. The improvement of mathematical creativity thinking ability scores can be analyzed by using the N-Gain score. According to Sundayana (2015), the formula of N-Gain score is:

$$\text{Normalized Gain (g)} = \frac{posttest\ score - pretest\ score}{\max score - pretest\ score}$$

According to Sundayana (2015), the criteria of the N-Gain score are shown in Table 3 below.

Table 3 Criteria of N-Gain score

N-Gain Score	Criteria
$0.70 \le (g) \le 1.00$	High
$0.30 \le (g) < 0.70$	Medium
$0.00 \le (g) < 0.30$	Low
$(g) = 0$	Constant
$-1.00 \le (g) < 0.00$	Decrease

Teaching materials are said to improved mathematical creativity thinking ability and can be used for learning if the N-Gain score ≥ 0.30.

3. Results & Discussions

3.1. Potential and Problem

Based on an interview with a mathematics teacher, the mathematics teaching material used was the book entitled " Matematika (Peminatan Matematika dan Ilmu-Ilmu Alam) untuk SMA/MA kelas XI Semester 1" prepared by Rachma Gemilang. The book has given some examples of STEAM-based materials. However, the application of STEAM-based in books is not comprehensive.

Not only there has not comprehensive of STEAM-based learning, but also the teaching material that used on trigonometric equations has not facilitated the full increase of mathematical creative thinking ability. Whereas mathematical creative thinking ability is one of the many abilities that students need to learn. Thus, in this research it will be developed a STEAM-based teaching materials on Trigonometric Equality as one of the alternative to improve students' creative thinking ability.

3.2. Data Collections

Data collections started from core competencies, basic competencies, competencies achievement indicators, learning objectives, concept maps, benefits of the material being studied, and issues related to STEAM. Core and basic competencies sourced from Joint Decisions Minister of Education and Culture No. 01/KB/2020 concerning the core and basic competencies for mathematics in 11^{th} grade. In this study, basic competences of 3.1 and 4.1 are selected.

For the concept maps and benefits of the material being studied are sourced from several books such as "Matematika Jilid 2 untuk SMA/MA Kelas XI Kelompok Peminatan Matematika dan Ilmu-ilmu Alam" and "Jelajah Matematika 2 SMA Kelas XI Peminatan MIPA". Hence for the issues related to STEAM, it is sourced from some website and some books. For the example in engineering, trigonometric equality is used to determine what time are needed to generate a current of 20 Ampere.

3.3. Product Design

The STEAM-based teaching material was created by using Microsoft Office 2016 for writing, and Photoshop CS6 for designing. STEAM-based teaching material are conducted 53 pages and the text of the content was written with the dominant font is Times New Roman by size by 12-20. This was intended for the reader to feel comfortable with the material presentation.

The STEAM-based teaching material consists of three parts, the beginning, the main contents, and the conclusion. For the beginning, it consists of a cover page, introduction, table of contents, core competencies, basic competencies, competencies achievement indicators, learning objectives, concept maps, benefits of the material being studied, issues related to STEAM, and motivation letter.

For the main content, it consists of the prerequisite of the material, the main material, the example of some problems related to STEAM, exercises, and summary. For the outline of the materials arranged in detail, as well as associated with the Science, Technology, Engineering, Art, and Mathematics (STEAM) aspect. The daily-life problems related to STEAM presented in some different colours. For "Science" presented by dark green background colours. For "Mathematics" presented by light blue background colours. For "Engineering" presented by orange background colours. For "Technology" presented by dark blue background colours. And for "Art" presented by red background colours.

For the conclusion, it consists of competences test, glossary, and reference. Competences tests on these learning materials are available for essay. The issues related to STEAM that make it more interesting dan related to the daily life. The glossary in this part contains an explanation of the meaning of the terms used in the teaching material. According to Susanti (2016), the glossary is alphabetized and lies at the end of the section. The material presented on this teaching material refers to some of relevant and reliable source listed in reference.

3.4. Design Validation
Characteristics of STEAM-based teaching materials

The characteristic of STEAM-based teaching material was assessed by 4 validators. Based on the description of the achievement aspect of the characteristics characteristic of STEAM-based teaching material, STEAM-based teaching material in the Trigonometric Equation material met the suitability of characteristics and can be used in learning based on the validation result of 4 validators, but it must be revised. The suggested revisions include clarifying the scope of KI-1 and KI-2 in teaching materials, the need to add STEAM aspects in teaching materials, and adding integration to Problem Based Learning. After the revision had been done, STEM-based teaching materials have characteristics according to the format of the students' book analysis on the 2013 curriculum refresher mathematics subject published by the Ministry of Education and Culture in 2018.

The validity of STEAM-based teaching materials

The validity of STEAM-based teaching material is carried out with the aim of knowing whether STEAM-based teaching material can be used in learning. In this study, the validity of STEAM-based teaching material was assessed and evaluated by 4 validators consisting of 1 lecturer and 3 mathematics teachers. the validity of STEAM-based teaching material is carried out to determine whether the STEAM-based teaching material to be used are appropriate in learning.

There are three aspects in assessing the validity of STEAM-based teaching material, namely the content validity aspect, the presentation validity aspect, and the linguistic validity aspect. The validity score is presented on Table 4 below.

Table 4 The Validity Score of STEAM-based Teaching Materials

Aspect	***P***(%)	**Criteria**
Content validity	87.8%	Excellent
Presentation validity	89.3%	Excellent
Language validity	90.8%	Excellent
Average	89.3%	Excellent

Based on the results of the validity test, it shows that the STEAM-based teaching material in Trigonometric Equation which contains aspects of content validity, presentation validity, and linguistic validity are included in the very feasible category. Thus, the teaching materials have met the provisions of the validity of teaching materials in accordance with those set by the BSNP as well as in the aspect of STEAM-based teaching material.

3.5. Product Test (Readability Test)
The readability test was conducted at SMA Negeri 12 Semarang. The readability test of teaching materials was tested on students of class of XI MIPA 3. The readability test of teaching materials was carried out with a gap test. According to Hittelman as cited by Inawati (2019), the gap test is a test with a technique of systematically removing words from discourse in which the reader is expected to fill in the missing words with the appropriate words. In this study, the readability test of teaching materials consisted of 40 short questions that students had to answer correctly. This readability test is declared appropriate if the achievement score is >60% according to the readability rating scale of teaching materials.

Based on the results of the readability test of teaching materials by students, mathematics teaching materials with STEAM nuances get an average score of 74.8%. This shows that students can answer the readability test questions with an average of 30 questions correctly. According to the level of readability of teaching materials by Chulkin, the readability value of teaching materials which reached a value of 74.8% was included in the category of being easily understood by students. Thus, mathematics teaching materials with STEAM nuances are easy for students to understand so that students are easy to read and understand the learning materials contained in the teaching materials. This is confirmed by research conducted by

Nazilah, *et. al*. (2018) that easy-to-understand teaching materials are teaching materials that provide easy reading for readers.

Before the pretest and posttest questions were given to students, the questions were tested on a test class, that is class of XI MIPA 1 SMA Negeri 12 Semarang. The results of the trial show that the 10 items compiled are valid, the questions have high reliability, 10 items have sufficient discriminating power, and the level of difficulty is moderate as shown in Table 5 below.

Table 5 Result of trial test of mathematical creativity thinking ability

Question Number	Validity	Reliability	Difficulty Level	Discriminating Power
1	Valid		Medium	Well
2	Valid		Medium	Well
3	Valid		Medium	Well
4	Valid		Medium	Well
5	Valid	Very	Medium	Well
6	Valid	High	Medium	Well
7	Valid		Medium	Well
8	Valid		Medium	Well
9	Valid		Medium	Well
10	Valid		Medium	Well

Based on the test results on students' mathematical creative thinking ability, the questions can be used as pretest and posttest questions to improve mathematical creative thinking ability. The questions chosen for the pretest are questions numbered 1,4,6,7, and 9. Meanwhile, for the posttest questions, the questions chosen are 2,3,5, 8 and the researcher adds 1 additional question for the posttest.

The pretest and posttest questions were tested to 33 students of class XI MIPA 2 SMA Negeri 12 Semarang. In the learning process, students are given soft files of teaching materials, and assistance provided by researchers during the implementation of research.

Improvement of Mathematical Creativity Thinking Ability

Prerequisite

The prerequisite test that has been carried out is the normality test of the Pretest and Posttest data. The normality test was conducted to determine whether the data obtained were normally distributed or not. The hypotheses proposed are as follows:

H_0: pretest and posttest data are normally distributed

H_1: pretest and posttest data are not normally distributed

Pretest and Posttest data are said to be normally distributed if the value of $Sig.\ (2-tailed) > \alpha = 0.05$. Based on the result of normality test, the value of $Sig.\ (2-tailed)$ of pretest is $0.09 > \alpha = 0.05$ and the value of $Sig.\ (2-tailed)$ of posttest is $0.231 > \alpha = 0.05$.

Because of the value of the normality test, then H_0 accepted. It can be concluded that the pretest and posttest data are normally distributed. Since the result of the pretest and posttest are normally distributed, then the data can be analysed using normalized gain to find out the improvement of students' mathematical creativity thinking ability.

N-Gain

The N-Gain test result of the pretest and posttest values can be seen on Table 6 below.

Table 6 The N-Gain test results

Average		N-Gain Score	Criteria
Pretest	**Posttest**		
49,43	68,37	0,37	Medium

For the average value of the pretest and posttest data obtained an N-Gain test value of 0.37 which indicates that an improvement of students' mathematical creativity thinking ability on medium criteria. The average score of pretest and posttest is viewed by each indicator of mathematical creative thinking ability presented in Figure 1 below.

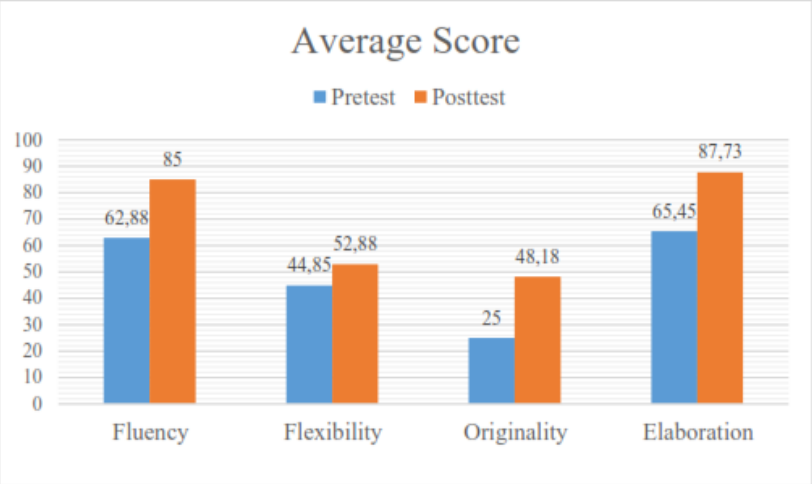

Figure 1 Graph of mathematical creativity thinking indicators on Pretest and Posttest

Based on Figure 1, there was an improvement in the average score of pretest to posttest on mathematical creativity thinking ability indicators. The improvement was analyzed using the N-Gain test and the results presented in Figure 2 below.

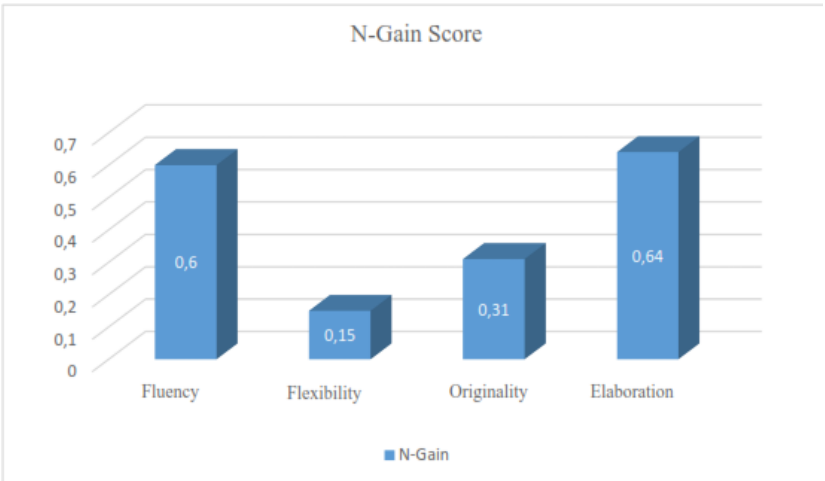

Figure 2 the N-Gain results on the mathematical creativity thinking indicators

For the fluency indicator, the N-Gain test value is 0.6 on medium criteria. This shows that students have been able to provide relevant ideas and answers. For the flexibility indicator, the N-Gain test value is 0.15 on low criteria. The low increase in flexibility indicators is because students still give answers only with less than or equal to one way of solving. Based on the analysis of answers given by students, students are not accustomed to working on questions in different ways. This is supported by research conducted by Nufus (2021) where one of the causes of the low score on the flexibility indicator is that students are not

accustomed to working on questions in different ways. For the originality indicator, the N-Gain test value is 0.31 on medium criteria. This shows that students have been able to use different ways than they have known before. For the elaboration indicator, the N-Gain test value is 0.64 on medium criteria. This shows that students have been able to work on the problem by solving it with detailed steps. These results indicate that STEAM-based teaching materials on trigonometric equality that applied in the PBL model have a positive influence on improving students' mathematical creativity thinking ability.

3.6. Final Product

The final product in this research is in the form of STEAM-based teaching materials on trigonometric equations. STEAM-based teaching materials on trigonometric equations is completed with a STEAM approach to Trigonometric Equations material and supports students' mathematical creative thinking ability. STEAM-based teaching materials on trigonometric equations are also equipped a color code for each aspect of STEAM to make it look attractive.

4. Conclusion

Based on the research results, it can be concluded that the STEAM-based teaching materials on trigonometric equations are qualified, for the following reasons: (1) STEAM-based teaching materials on trigonometric equations have fulfilled the characteristics of student book guidelines published by the Ministry of Educations and Culture in 2018; (2) STEAM-based teaching materials on trigonometric equations was valid and can be used in learning; (3) STEAM-based teaching materials on trigonometric equations are categorized easily understood by students; (4) Students' creative thinking ability after following the learning by using mathematics teaching material on PBL model beyond the average actual limit on average; (5) STEAM-based teaching materials trigonometric equations can improve students' mathematical creative thinking ability.

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