UJME 11 (1) 2022: 21-30
Unnes Journal of Mathematics Education
https://journal.unnes.ac.id/sju/index.php/ujme/
ISSN: 2252-6927 (print); 2460-5840 (online)

Development of STEM-Based Learning Tools to Increase Students' Mathematical Creative Thinking Ability through Inquiry Learning

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ARTICLE INFO

Article history:
Received 7 February 2022
Received in revised form 17 February 2022
Accepted 31 March 2022

Keywords:
Development, STEM Naunced, Learning Tools, Mathematical Creative Thinking Ability, Inquiry Learning

Abstract

This study aims to produce appropriate STEM nuanced learning tools on number material and find out the increase in students' mathematical creative thinking skills after the implementation of learning using STEM nuanced learning tools with inquiry learning models on number material. This study used the Research and Development (R&D) method. The R&D steps in this research are potential and problems, data collection, product design, product validation, testing, and the final product. The population in this study were students of class VII of SMP Negeri 8 Semarang, while the subjects in this study were students of class VII-F of SMP Negeri 8 Semarang, totaling 28 students. Data was collected using tests and questionnaires. The increase in mathematical creative thinking skills was analyzed using the N-Gain test from pretest and posttest data. The results showed that the learning tools with STEM nuances with the inquiry learning model developed had a decent level of feasibility, and there was an increase in students' mathematical creative thinking skills on each indicator after being given learning using STEM nuanced learning tools with inquiry learning models with moderate improvement criteria.

1. Introduction

The ability of students to find a mathematical idea and solve problems creatively is called the ability to think mathematically creatively (Bicer et al., 2020). Creativity is one of the main components that are included in learning mathematics. This is confirmed by Rochmad, et al. (2018) which state that creativity is the main part of mathematics learning and has been proposed as one of the major components to be included. In mathematics education, the essence of mathematics is creative thinking. This shows that creative thinking is an ability needed by students in learning mathematics.

However, the mathematical creative thinking ability of students in Indonesia is still not optimal, this can be seen from the results of the Trend in International Mathematics and Science Study (TIMSS) by the International Association for the Evaluation of Educational Achievement (IEA) and PISA (Programme for International Student Assessment) by the OECD (The Organization for Economic Co-operation and Development). In 2011 Indonesia obtained an average score of 380 from the TIMSS average score of 500 (IEA, 2012), and received an average score of 379 from the PISA average score of 489 (OECD, 2019). Jules and Cebold (2018) say that the analysis shows that creativity, while not one of the top three priorities for either PISA and TIMSS, is still in the top half of competencies expected the assessments measure. In addition, Sebastian & Huang (2016) stated that students' creative problem-solving skills were highly correlated with performance on the main PISA math assessment, which means that one of the main assessments in PISA is the ability of students to solve problems creatively. TIMSS and PISA make creative

To cite this article:
Nurintya, F. H., & Agoestanto, A (2022). Development of STEM-Based Learning Tools to Increase Students' Mathematical Creative Thinking Ability Through Inquiry Learning. *Unnes Journal of Mathematics Education*, 11(1), 21-30. doi: 10.15294/ujme.v11i1.55842

thinking one of the important assessments to be measured, so from the results obtained it is found that the creative thinking ability of students in Indonesia is still low, so it needs to be improved and developed.

One way to improve creative thinking skills is through learning. In the 21st century, learning that pays attention to aspects of creative thinking is needed for students to have. The Partnership for 21st Century Skills (2008) developed Frameworks for 21st Century Learning which contains learning activities in the 21st century by taking into account existing technological developments. The skills discussed include: (1) life and career skills, (2) learning and innovation skills consisting of critical thinking, communication, collaboration, and creativity, and (3) mastery of information, media, and information technology. Nakano & Wechsler (2018) state that creativity and innovation have been highlighted as essential skills for the 21st century, especially if we consider that both skills can promote human potential by eliciting positive aspects of the individual. This shows that creative thinking is an ability that must be possessed by students to address and solve problems that exist in learning and every their life because technological developments at this time required human resources who have creative thinking so that they can as well as the potential that exists in him can continue to be explored.

In supporting learning, appropriate learning planning is needed. According to Moore as quoted by Muzanni & Muhyadi (2016) stated that planning is essential to achieving excellence in instruction, which means that planning is important in achieving excellence in learning. The preparation of learning tools is one of the learning plans. Appropriate learning tools need to be prepared to improve students' creative thinking skills.

One of the efforts needed is learning that can stimulate students to achieve it, one of which is the learning model provided by the teacher in the classroom. Regulation of The Ministry of Education and Culture No. 22 of 2016 states that several learning models can be applied in 2013 curriculum learning, one of which is the inquiry learning model. Suarez, et al. (2018) explain that explained learning is defined as an educational strategy based on discovering knowledge that fosters active participation and learners' responsibility, the inquiry learning model encourages students to actively participate in learning, discover knowledge, and train student responsibility. In inquiry-based learning, students become engaged in many of the activities and thinking processes that scientists use to produce new knowledge (Abdi, 2014). The inquiry learning model involves students being involved in many activities and encourages students to think like a scientist to gain new knowledge. So that apart from being a recommended learning model to be implemented in the 2013 curriculum, the inquiry learning model can help to grow and improve students' creative thinking skills.

Approaches in learning are also needed to help teachers achieve learning objectives. STEM (Science, Technology, Engineering, and Mathematics) is one of the approaches used in the 21st century. Beswick & Fraser (2019) explained that STEM disciplines, including mathematics, provide ideal sites in which to develop students' 21st-century competence, which means that using the STEM approach can help students to develop abilities used in the 21st century. In its application, the four components from STEM do not always have to exist in full in learning, but teachers are expected to have an understanding of the relationship between these disciplines so that STEM understanding still reaches students (Kelley & Knowles, 2016). STEM was to provide all students with critical thinking skills that would make them creative problem solvers and ultimately more marketable in the workforce (Gonzalez et al., 2014). So using the STEM approach can help students face the 21st century and help students to build their creative thinking skills.

Based on the description above, research was carried out with the title " The Development Of STEM-Based Learning Tools to Increase Students' Mathematical Creative Thinking Ability through Inquiry Learning ". The purpose of this study is to determine the level of feasibility of STEM nuanced learning tools with inquiry learning models and to determine the increase in students' mathematical creative thinking skills after the implementation of STEM nuanced learning tools with inquiry learning models.

2. Methods

The research method that is used in this research is the research and development method. The Research and Development (R&D) method is a research method used to produce certain products and test the effectiveness of these products (Sugiyono, 2018). In this study, a STEM nuanced learning device with an inquiry learning model will be developed to improve students' mathematical creative thinking skills. The R&D steps in this research are potential & problems, data collection, product design, design validation,

trial test, and final product. The research was conducted from September to November 2021. The subjects in this study were seventh-grade students of SMP Negeri 8 Semarang.

The research instrument used in the form of questionnaires and tests. The questionnaire instrument in this study was used to test the feasibility of STEM nuanced learning tools with an inquiry learning model by a validator. While the test instrument in this study was used to measure the increase in students' creative thinking skills.

Sudijono (2011) stated to test the feasibility level of STEM nuanced learning tools with the inquiry learning model, the following formula is used:

$$p = \frac{f}{N} \times 100\% \qquad (1)$$

Where p is for score percentage, f for score obtained, and $N$for maximum score. According to Akbar (2013), the criteria for the feasibility level of learning devices are shown in the following table.

Table 1. Criteria for the Eligibility Level of STEM Learning Devices

Eligibility Interval	Criteria
$1\% < score \leq 50\%$	Not feasible
$50\% < score \leq 70\%$	Enough Feasible
$70\% < score \leq 85\%$	Feasible
$85\% < score \leq 100\%$	Very Feasible

Meanwhile, to measure the increase in students' creative thinking skills, the Normality-Gain (N-Gain) test is used. According to Sundayana (2015) the gain test formula is as follows.

$$N - Gain(g) = \frac{posttest\ score - pretest\ score}{ideal\ score - pretest\ score} \qquad (2)$$

The N-Gain category according to Sundayana (2015) is as follows.

Table 2. Criteria for the value of N-Gain

Value (g)	Categories
$0{,}70 \leq (g) \leq 1{,}00$	High
$0{,}30 \leq (g) < 0{,}70$	Medium
$0{,}00 < (g) < 0{,}30$	Low
$(g) = 0{,}00$	Constant
$-1{,}00 \leq (g) < 0{,}00$	Decrease

3. Results & Discussions

3.1. Potential and Problems

Based on the results of interviews with teachers at SMP Negeri 8 Semarang regarding the learning media used by students and the learning process in class, it was found that the learning media used are in the form of student books by the Ministry of Education and Culture, and power points and learning videos made by the teacher. The student books used are still complex so that students' interest in studying student books is very low, besides that students only have a small number of questions that contain many solutions (open ended) and many ways so that students are only motivated by one answer and tend to take steps to work on the questions. which is the same as what is taught by the teacher and written in student books, as well as the learning media used by students do not contain contextual problems referring to the fields of science, technology, engineering, and mathematics.

The learning that applies at SMP Negeri 8 Semarang is 50% of the total students doing face-to-face learning (PTM) while the rest do online learning. Due to the limited time, which is 30 minutes for every 1 hour lesson (JP), the teacher only teaches the material directly to the point, namely in the form of short

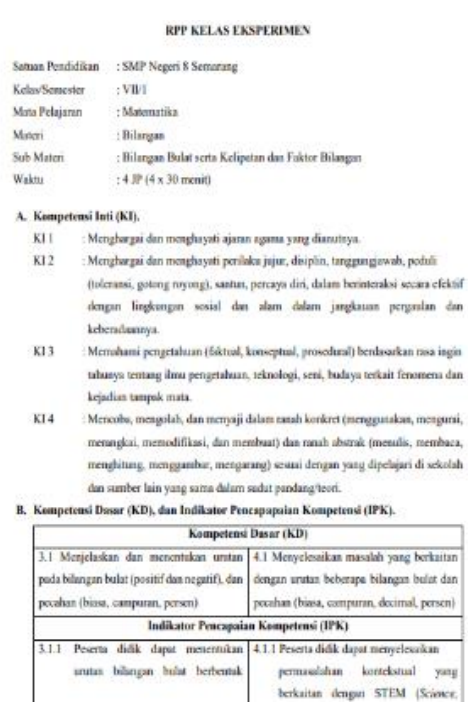
formulas and how to work on several types of questions so that learning becomes teacher-centered (teacher-centered).

3.2. Data Collection

Data collection is carried out from the curriculum that applies in schools, namely the emergency curriculum which refers to the 2013 curriculum, then an analysis of the core competencies and basic competencies of mathematics class VII is carried out. The basic competencies used in this study are basic competition number 3.1 and 4.1 with the learning material, namely the number material.

3.3. Product Design

At this stage, the design of learning devices is carried out, namely lesson plans and teaching materials. The preparation of the lesson plans uses the Microsoft word 2013 application with the font used is Times New Rowman with a size of 12pt and the spacing between lines is 1.5. Meanwhile, the preparation of teaching materials uses the Microsoft Word 2013 application for writing and Canva for image design. The fonts used in the teaching materials are Arial Rounded, Berlin Sans FB, Arial Black, Times New Rowman, Cooper Black, and Calibri (Body). The font size is 12pt for the content of the material, problems and discussions, competency test questions, and evaluation questions, while the title and subtitle font sizes adjust the blank space and design. The spacing between rows in teaching materials is 1.5, and the column and paper formats are adjusted to A4 paper size. Each sheet of teaching materials is designed with appropriate and attractive color combinations, pictures, and illustrations so that students are interested in learning the contents of the teaching materials. The following is a STEM nuanced learning device design with an inquiry learning model.



RPP KELAS EKSPERIMEN

Satuan Pendidikan : SMP Negeri 8 Semarang
Kelas/Semester : VII/1
Mata Pelajaran : Matematika
Materi : Bilangan
Sub Materi : Bilangan Bulat serta Kelipatan dan Faktor Bilangan
Waktu : 4 JP (4 x 30 menit)

A. Kompetensi Inti (KI).

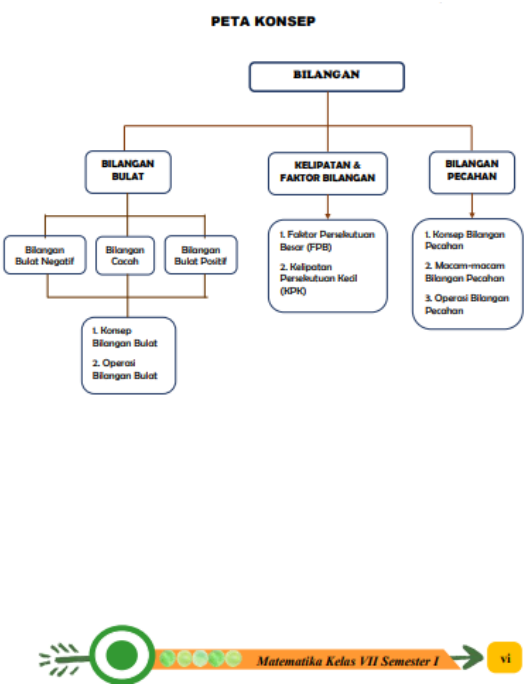
KI 1 : Menghargai dan menghayati ajaran agama yang dianutnya.
KI 2 : Menghargai dan menghayati perilaku jujur, disiplin, tanggungjawab, peduli (toleransi, gotong royong), santun, percaya diri, dalam berinteraksi secara efektif dengan lingkungan sosial dan alam dalam jangkauan pergaulan dan keberadaannya.
KI 3 : Memahami pengetahuan (faktual, konseptual, prosedural) berdasarkan rasa ingin tahunya tentang ilmu pengetahuan, teknologi, seni, budaya terkait fenomena dan kejadian tampak mata.
KI 4 : Mencoba, mengolah, dan menyaji dalam ranah konkret (menggunakan, mengurai, merangkai, memodifikasi, dan membuat) dan ranah abstrak (menulis, membaca, menghitung, menggambar, mengarang) sesuai dengan yang dipelajari di sekolah dan sumber lain yang sama dalam sudut pandang/teori.

B. Kompetensi Dasar (KD), dan Indikator Pencapaian Kompetensi (IPK).

Kompetensi Dasar (KD)	
3.1 Menjelaskan dan menentukan urutan pada bilangan bulat (positif dan negatif), dan pecahan (biasa, campuran, persen)	4.1 Menyelesaikan masalah yang berkaitan dengan urutan beberapa bilangan bulat dan pecahan (biasa, campuran, decimal, persen)
Indikator Pencapaian Kompetensi (IPK)	
3.1.1 Peserta didik dapat menentukan urutan bilangan bulat berbentuk	4.1.1 Peserta didik dapat menyelesaikan permasalahan kontekstual yang berkaitan dengan STEM (*Science,*

(a)

(b)



(c)

Figure 1. (a) Lesson Plan, (b) Text Book Cover, (c) Text Book Concept Maps.

3.4. Design Validation

At this stage, the validation of learning tools is carried out to test the feasibility of STEM nuanced learning tools with the inquiry learning model by the validator. The aspects assessed are the feasibility of the content, the feasibility of the presentation, and the feasibility of the language. The validation analysis used is based on the 2015 of National Education Standard Board. The following are the results of the feasibility test of STEM nuanced learning tools with the inquiry learning model.

Table 3. The results of the feasibility test of STEM teaching materials with the inquiry learning model

Aspect	P (%)	Criteria
Content Eligibility	90.84%	Very Feasible
Serving Eligibility	90.60%	Very Feasible
Language Eligibility	91.52%	Very Feasible

Table 4. The results of the feasibility test for STEM nuanced lesson plans with the inquiry learning model

Aspect	P (%)	Criteria
Content Eligibility	96.58%	Very Feasible
Serving Eligibility	87.49%	Very Feasible
Language Eligibility	93.75%	Very Feasible

Based on the results of the feasibility test for RPP and teaching materials with STEM nuances with the inquiry learning model, it was found that the learning tools developed in this study had a very feasible level of feasibility.

3.5. Trial Test

STEM nuanced learning tools were tested in learning with the learning model used, namely inquiry. The learning in this study was carried out by blended learning where 50% of the total students carried out PTM (Face-to-Face Learning), while the rest carried out online learning using Google Classroom. The subjects in this study were class VII-F of SMP Negeri 8 Semarang.

The usage trial phase is divided into four stages, namely: (1) the preparation stage; (2) the pretest stage; (3) The stage of providing material; and (4) the posttest stage. Each of these stages will be described as follows.

At the preparatory stage, a test of mathematical creative thinking skills was carried out. The goal is to find out the questions that meet the criteria. The criteria in question are the results of the mathematical creative thinking ability test that meet the analysis of validity, reliability, discriminating power, and level of difficulty. The subject at this stage is class VIII-H of SMP Negeri 8 Semarang. The following is the result of the analysis of the mathematical creative thinking ability test.

Table 5. Results of the Test of Mathematical Creative Thinking Ability Test

Question Number	Validity	Reliability	Difficulty Level	Discriminating Power
1	Valid	Very High	Medium	Enough
2	Valid		Medium	Easy
3	Not Valid		Bad	Easy
4	Valid		Medium	Enough
5	Valid		Medium	Enough
6	Valid		Medium	Enough
7	Valid		Medium	Enough
8	Valid		Enough	Easy
9	Valid		Medium	Enough
10	Valid		Medium	Enough

Based on the results of the analysis of the mathematical creative thinking ability test, item numbers 1, 4, 6, and 9 were chosen for the pretest. While item number 2, 5, 7, and 10 are for the posttest. The items selected contain indicators of competency achievement and indicators of mathematical creative thinking skills.

In the pretest and posttest stages, 28 students from class VII-F of SMP Negeri 8 Semarang participated. While at the stage of giving the material, students are given soft files of teaching materials with STEM nuances for number material, as well as power points for number material. Learning takes place using an inquiry learning model with STEM nuances with blended learning implementation.

After the use trial phase is complete, the students' pretest and posttest results will be tested for normality as a prerequisite test and N-Gain test to determine the increase in students' creative thinking skills.

Normality Test

The normality test uses the SPSS 20 application with the hypothesis used is :

H_0 : Pretest and posttest data are normally distributed.

H_1: Pretest and posttest data are not normally distributed.

By using SPSS 20, the following results were obtained.

Table 6. Pretest and Posttest Normality Test Results

	Nilai $Asymp\ sig.(2-tailed)$	Criteria
Pretest	0.632	Normal Distribution
Posttest	0.746	Normal Distribution

Based on the table above, the value of Asymp sig.(2-tailed) in the pretest was 0.632, which means the value of Asymp sig.(2-tailed)>α=0.05 in the pretest result. So it can be concluded that the pretest data has a normal distribution. Meanwhile, in the posttest, the Asymp sig. (2-tailed) value was 0.746, which means the Asymp sig. (2-tailed) value> = 0.05 in the posttest results. So it can be concluded that the posttest data has a normal distribution. So the pretest and posttest of students are normally distributed.

N-Gain Test

The results of the Gain Normalization or N-Gain test are as follows.

Table 7. Results of N-Gain Test

Average		*N-Gain*	Criteria
Pretest	***Posttest***		
35.42	77.75	0.66	Medium

Based on the above obtained the value of N-Gain is 0.66. This means that there is an increase in the average value of the pretest to the posttest value of 0.66 with medium criteria. In addition, the value of N-Gain is calculated based on each indicator of mathematical creative thinking ability. The following is a picture of the average pretest and posttest scores of each indicator of students' mathematical creative thinking abilities.

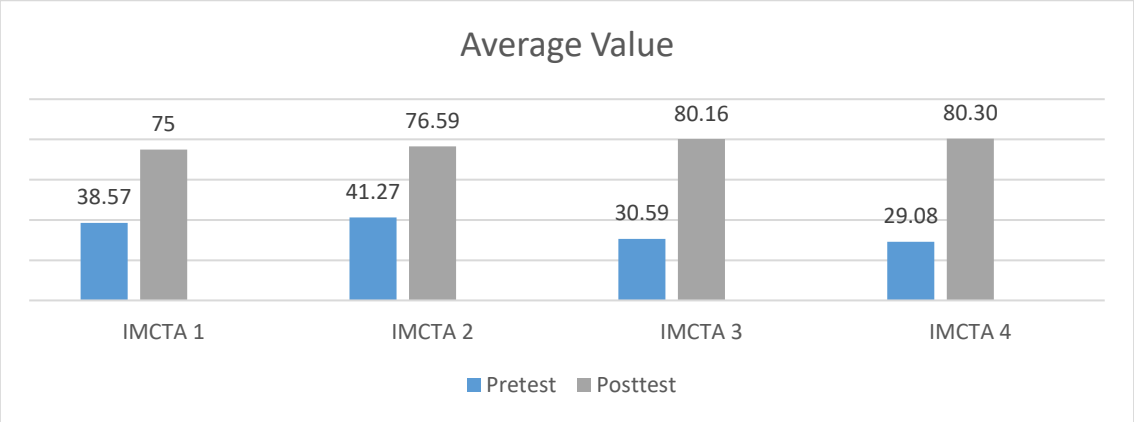


Figure 2. Average pretest and posttest scores on indicators of mathematical creative thinking ability (IMCTA)

Based on the picture above, it was found that every indicator of mathematical creative thinking ability from pretest to posttest increased. The amount of increase was analyzed using the N-Gain test. The N-Gain value for each indicator of mathematical creative thinking ability is shown as follows.

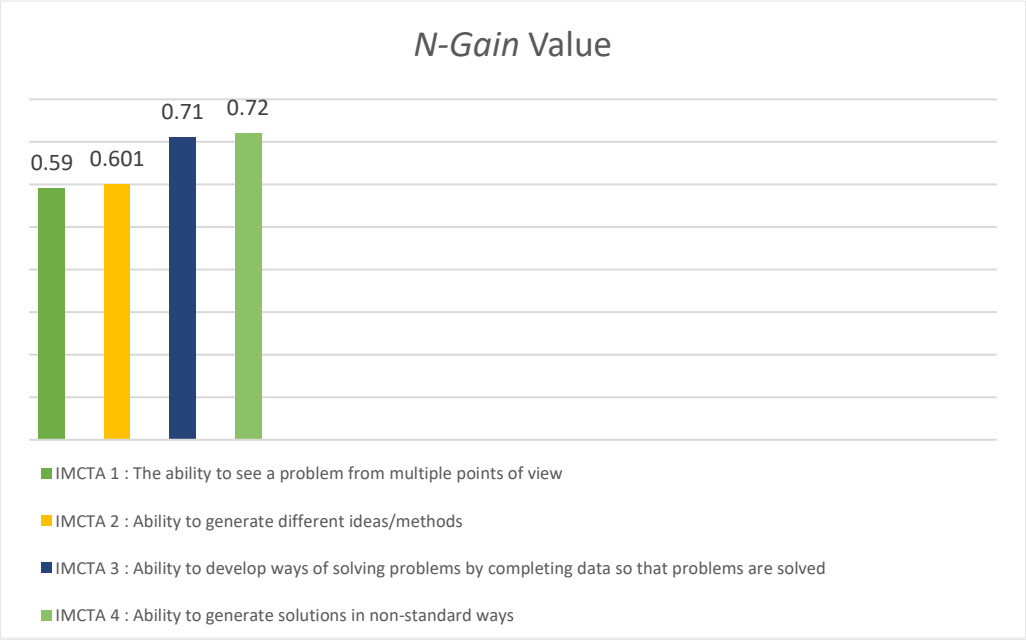


Figure 3. The N-Gain value of each indicator of mathematical creative thinking ability (IMCTA)

Based on the picture above, it is found that the ability of students to see a problem from various points of view has increased by 0.59 with a moderate improvement category. According to Sriraman quoted by Fatah, et al. (2016) stating that mathematical creativity is defined as the formulation of new questions and/or possibilities that allow an old problem to be regarded from a new angle. A new question or possibility from a new point of view is a mathematical creativity. In this study, before being given treatment, students were accustomed to seeing the problem from one point of view only, namely the point of view taught by the

teacher or the point of view listed in the textbook. After being given treatment, students can see new perspectives from various sides, where the problems presented are problems that can train students' creative abilities.

In the second indicator, namely the ability of students to generate various ideas or ways, it increased by 0.601 with a moderate increase category. This is because before being given treatment, students tend to solve problems according to the template on the book. After being given treatment, students can produce different ways of solving problems with the creativity of students but still in accordance with the concept of the correct number material. Ayllon, et al. (2016) in their research stated that they (teacher) actively stimulate the creativity of students since they oblige them to project their ideas generating original problems, thus encouraging the development of their creativity. requires students to project their ideas in solving problems.

Furthermore, the ability of students to develop ways of solving problems by completing data so that problems are solved differently has increased by 0.71 with a high improvement category. Kwon, et al. (2006) stated that an incomplete problem is a problem which does not define clearly what the question asks for, therefore allowing many possible solutions. This problem is also called an open-ended problem... the open-ended approach is a pedagogical strategy that aims to produce creative mathematics activities that stimulates the students' curiosity and cooperation in the course of tackling problems. A problem that has incomplete data is one of the open ended problems that allows it to have many answers, where the purpose of completing the question or problem is to produce creative mathematical activities so that it can stimulate the curiosity and cooperation of students in solving problems. In this study, before being given treatment, students are accustomed to solving problems that have complete data, without the need to think about other possibilities that can be solved from the problems given. After being given treatment, students can enter data with their respective creativity but still in accordance with the problem given. Each student will have a different answer to the same problem.

The fourth indicator, namely the ability of students to come up with various solutions in a non-standard way, increased by 0.72 with the category of high improvement. This is because before being given treatment, students often get closed problems that only have one correct answer, thus limiting the creative power of students. After being given treatment, students can solve an open-ended problem with various solutions using various ways that are still in accordance with the concept of the material. According to Titikusumawati, et al. (2019) "...when applied to solve open ended problems would encourage students' creative expression and influence their competencies in creative problem solving". creative problem solving by students.

Hershkowitz, et al. (2017) stated that inquiry-based classrooms, students tend to raise ideas and express their reasoning publicly. The explicitness of students' reasoning allows researchers to follow shared mathematical progress and shared constructing of new knowledge. Students reasoning may be imitative, in the sense that the students express previously learned algorithms, mathematical procedures or facts; however, students reasoning may also be creative, which means that by using the inquiry learning model, students can express their ideas. There are opinions of students who follow the concept of the material that has been studied, or express new ideas or opinions that are creative. So that using inquiry learning can help students to develop creative thinking patterns in the classroom. Sahin, et al. (2014) also concluded in his research that "...emphasized that STEM developed and practiced students communication and collaboration skills and creativity for lifelong learning" which means that learning using STEM will train and develop students' abilities to communicate, collaborate, and be creative throughout their lives. So that by using STEM nuanced learning tools with inquiry learning models, students can train and develop their creative abilities by expressing new ideas that they have creatively.

3.6. Final Product

The final product in this research is STEM nuanced learning tools in the form of STEM nuanced number teaching materials and STEM nuanced lesson plans with inquiry learning models. The learning tools in this study link STEM (Science, Technology, Engineering, and Mathematics), inquiry learning models, and mathematical creative thinking skills. In teaching materials with STEM nuances, contextual and factual problems are presented and related to STEM. While the RPP in this study presents the learning steps with the inquiry learning model in detail and is related to STEM.

4. Conclusion

Based on the results of research and discussion on the development of STEM nuanced learning tools to improve students' creative thinking skills through the inquiry learning model, the following conclusions were obtained that teaching materials with STEM nuances on number material have a suitable category for use in learning with an average percentage of eligibility that is 90.99%. While the learning implementation plan (RPP) with STEM nuances using the inquiry learning model on number material has a suitable category for use in the learning process with an average percentage of eligibility, which is 92.61%. So it was found that the development of STEM nuanced learning tools through the inquiry learning model with number material in this study had a feasible category. Meanwhile STEM nuanced learning tools using the inquiry learning model on number material can improve students' mathematical creative thinking skills. This can be seen from the results of the N-Gain test analysis which got a value of 0.66 with a moderate increase category. These results were obtained from the students' pretest and posttest scores.

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