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Development of LKS With a STEM Approach that Supports The Mathematical Communication Skills of SMP Students

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Abstract

The research was motivated by low mathematical communication skills of students and the lack of variety of teaching materials that can equip students to face the challenges of the 21st century including load activities to support mathematical communication skills. Based on these, this research aims to: (1) produce mathematics students worksheets (LKS) with STEM approach that supports mathematical communication skills of junior high school student and suitable for use in the mathematics learning. This development research was carried out by adopting the ADDIE Research & Development model. The results showed that: (1) Mathematics Student Worksheets with the STEM (Science, Technology and Engineering and Mathematics) Approach that Supported Junior High School Students Mathematical Communication Skills that were feasible were used in terms of validation test results by experts with a percentage of eligibility reaching 84.77% is at the interval $\bar{x} >$ 4.20 which is 4.23 with the category very good; and the quality of worksheets based on student and teacher responses shows the criteria of practical with a percentage value of them are 75% and 85%.

***Keywords**: Mathematical Communication Skills, Mathematics Student Worksheets, STEM*

Abstrak

Penelitian ini dilatarbelakangi oleh rendahnya keterampilan komunikasi matematika siswa dan kurangnya berbagai bahan ajar yang dapat membekali siswa untuk menghadapi tantangan abad ke-21 termasuk kegiatan untuk mendukung keterampilan komunikasi matematika. Penelitian ini bertujuan untuk: (1) menghasilkan Lembar Kerja Siswa matematika (LKS) dengan pendekatan STEM yang mendukung keterampilan komunikasi matematika siswa SMP dan cocok untuk digunakan dalam pembelajaran matematika. Penelitian pengembangan ini dilakukan dengan mengadopsi model penelitian dan pengembangan ADDIE. Hasil penelitian menunjukkan bahwa: (1) LKS Matematika dengan Pendekatan STEM (Sains, Teknologi dan Teknik dan Matematika) layak digunakan dengan hasil tes validasi oleh para ahli dengan persentase kelayakan mencapai 84,77% berada pada interval $\bar{x} >$ 4,20 yaitu 4,23 dengan kategori sangat baik; dan kualitas LKS berdasarkan respons siswa dan guru menunjukkan kriteria praktek dengan nilai persentase sebesar 75% dan 85%.

***Kata Kunci**: Keterampilan Komunikasi Matematika, LKS, STEM*

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INTRODUCTION

The development of science and technology requires the educational paradigm currently adopted is shifting from merely seeking knowledge (knowledge seeking) to creating and developing knowledge (knowledge creation and development). Kim et al., (2019) introduced four 21st Century competencies which are popularly known as the 4 Cs to support this paradigm, namely: critical thinking, communication, collaboration, and creative and innovate thinking. This competence can be instilled through educational programs in learning activities, including in mathematics learning.

One of the 21st Century competencies from the cognitive aspect that can be raised from learning mathematics is mathematical communication skills. Mathematical communication is a tool in the transmission of mathematical knowledge or as a foundation in building mathematical knowledge (Vahlia & Sudarman, 2015; Maulani et al., 2017) expressing mathematics in the form of mathematical models and images, and writing answers using their own words. This makes mathematical communication skills is very important to be improved. Mathematical communication needs to be the focus of attention in learning mathematics, because through communication, students can organize and consolidate their mathematical thinking, and explore mathematical ideas. In the learning and teaching process, it is very important between students and teachers to express thoughts and ideas through language so that there is an exchange of experiences and ideas between the two (Hendriana et al., 2017).

Even though it is very important, in fact mathematics learning still pays less attention to the development of mathematical communication skills. This is indicated by the lack of implementation of interactive learning and the lack of variety in math problems used in supporting the improvement of students' mathematical communication (Wardhana & Lutfianto, 2018). Based on the results of a survey by the Program for International Student Assessment (PISA) in 2018, Indonesia was ranked 72 out of 79 countries in mathematics achievement. Students' mathematical communication skills in expressing ideas in the form of data presentation into tables and diagrams are still low (Adesty et al., 2014). Responding to this, it is necessary to procure teaching materials that support the improvement of mathematical communication skills in student learning activities at school.

Student Worksheets (LKS) are one of the supporting components of student learning activities. A previous research, (Nopiyanti, 2016) revealed that the student worksheet (LKS) helps students to dare to express their thoughts and explore all their abilities, helps students construct their own knowledge and competence when proving a problem so as to help improve students' mathematical communication skills. Based on this, the use of student worksheets in mathematics learning can not only optimize the function of students' five senses in learning but can support students to develop their mathematical communication skills. Communication skills are critical in learning mathematics because it enables the students to express ideas and reflect their mathematics understanding to others (Utami et al., 2020).

However, the student worksheets used in schools mostly do not support students' mathematical communication skills. That's based on the results of observations of mathematics learning conducted by researchers in several junior high schools in Serang City, 4 out of 5

schools did not use LKS while others still had minimal variation and even only contained questions from the material that had been taught. Meanwhile, educational institutions need to give birth to a generation that is ready to face 21st century life, both in terms of understanding and development of science and technology. Therefore, the procurement of various student worksheets with an approach that suits current needs needs to be developed.

One of the learning approaches that can support 21st Century competencies is STEM. STEM (Science, Technology, Engineering, and Mathematics) is an important issue in education today (Dimmel & Herbst, 2017). STEM learning is an integration of science, technology, engineering and math learning suggested to help the success of 21st Century competencies (Beers, 2011). In many instances STEM has come to imply a deep integration of the disciplines within the acronym as well as art/design, language arts, and the social sciences. The STEM label is also often associated with integrated curriculum (Giamellaro & Siegel, 2018). STEM learning aims to produce students who, when they will enter the community, they are able to develop the competencies they have to apply them to various situations and problems they face in everyday life (Mayasari et al., 2014).

The application of the STEM approaches in learning today is very in line with the demands of 21st Century competencies and to answer the challenges of facing the industrial revolution 4.0, therefore a combination of knowledge (Science), skills in designing a work (Engineering) and compiling logically (Mathematic) can be used to answer problems in everyday life by utilizing current technological advances.

Even so, STEM is still a rare lesson in schools especially in the Tangerang district and Serang city both in terms of insight and implementation. Precident's Council of Advisors on Science and Technology (PCAST) stated that many obstacles were found in the procurement and implementation of STEM learning, including the lack of STEM teaching materials and the development of educational technology in their learning activities.

Based on the description above, integration of STEM in student's worksheet needs to be done because it is relevant to current educational needs including the development of students' mathematical communication skills. This paradigm is the background of the research on the development of Mathematics Student Worksheets (LKS) with STEM approaches that support the mathematical communication skills of junior high school students.

METHOD

The research conducted was an R & D (Research and Development) research with the ADDIE development model consisting of the stages of Analyze, Design, Development, Implementation and Evaluation. This model provides an opportunity to evaluate development activities at each stage to minimize the error rate or product shortage (Tegel et al., 2014). The evaluation used in this study consisted of formative evaluation research and summative evaluation. The formative evaluation consisted of self-evaluation, expert review, one to one and small group, while the summative evaluation was carried out at the end of the stage to determine the student's response to the product produced.

Table 2. Questionnaire Scale Score Interpretation Criteria

Criteria (%)	Classification	Information
$90 < \rho \leq 100$	Very good	No Revision Needed
$75 < \rho \leq 90$	Good	Little Revision
$65 < \rho \leq 75$	Enough	Revised Sufficiently
$55 < \rho \leq 65$	Less	Many Things Are Revised
$0 < \rho \leq 55$	Very less	Repeated Creating Products

Note: the number of KD based on School Curricula

The research procedure begins with analysing development needs which includes literature reviews, observation of learning activities and interviews with mathematics teachers at state junior high schools in Rajeg sub-district, and distributing questionnaires to mathematics teachers of junior high school level which is taken randomly refers to the calculation according on the number of correct answers or only positive values which are formulated as follows (Widoyoko, 2018):

$$\boldsymbol{S_k = B\ x\ 100\%} \quad \text{.....1}$$

Where: $\boldsymbol{S_k}$ is score obtained and B is the number of positive answers.

The conclusion from the needs analysis is based on the percentage acquisition according to the Likert Scale as follows Table 1.

Table 1. LKS Need Criteria

Score (%)	Information
$\boldsymbol{S_k} > 80$	Really need
$60 < \boldsymbol{S_k} \leq 80$	Need
$40 < \boldsymbol{S_k} \leq 60$	Less Need
$20 < \boldsymbol{S_k} \leq 40$	No need
$\boldsymbol{S_k} \leq 20$	Very Needless

Meanwhile, the evaluation carried out at this stage is in the form of self-evaluation by the developer. Based on the level of need obtained from the analysis stage, then the LKS design stage is carried out which includes media selection, preparation of LKS needs maps, preparation of LKS formats, collection of references, and preparation of data collection tools in the form of expert validation sheets. The evaluation carried out in this stage was in the form of a self-evaluation with supervisors 1 and 2 to be approved for its preparation.

The follow-up to the design that has been made is the development stage in the form of searching and collecting all sources and references needed for product development which consists of making worksheets in hardcopy, and compiling instruments.

The evaluation carried out at this stage through two stages, namely the self-evaluation carried out by the developer: then expert review with experts in related fields. Data processing is done with the following calculations:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad \text{.....2}$$

Where: $\bar{x}$ is average score obtained, $\sum_{i=1}^{n} x_i$ is total score obtained and n is the number of statements for each aspect of the assessment.

$$\rho = \frac{\text{raw score}}{\text{ideal score}} \times 100\% \quad \text{.....3}$$

Where: $\boldsymbol{\rho}$ is final presentation, raw score is score of respondents' answers, ideal score is highest answer score.

The conclusion obtained from these data is the feasibility level of the product used in learning which refers to the classification scale with the following qualifications (Widyastuti & Susiana, 2019). The Criteria shows in Table 2.

The final stage of the development research carried out was the implementation of worksheets that had been validated by experts in learning mathematics

in the classroom by conducting limited trials on the research targets, namely mathematics teachers and students with the small group method which aims to determine the responses of students and teachers to the student worksheets used in learning. as a measure of product practicality. Interpretation of the student response questionnaire is obtained based on the classification according to the scale which is classified as follows (Widoyoko, 2018) on Table 3.

Table 3. Efesience Criteria of worksheets

Practicality criteria	Classification
$p>80$	Very Efesience
$60 <p \leq 80$	Efesience
$40 <p \leq 60$	Quite Efesience
$20 <p \leq 40$	Less Efesience
$p \leq 20$	Very Less Efesience

The indicator of success in this research is the completion of a product in the form of developing Mathematics Student Worksheets (LKS) with a STEM approach that supports the Mathematical Communication Skills of junior high school students. The criteria for student worksheets are said to be good if the final percentage obtained from the results of expert test validation reaches at least 70% (Suparti, 2015) and getting a positive response from students and teachers, at least achieving practical clarification.

RESULTS AND DISCUSSION

Needs Analysis

The research was found in the analysis stage which includes five main points, namely the initial analysis as a general description of mathematics learning in schools as an initial analysis, where data is obtained from the results of observations of mathematics learning and interviews with mathematics teachers in schools; literature review on student characteristics; curriculum analysis; analysis of material concepts and specification of learning objectives.

Based on the analysis that has been done above, summarized the paradigm of developing Mathematics Student Worksheets (LKS) with the STEM approach which supports the mathematical communication skills of junior high school students that (1) students 'mathematical communication skills can be developed through student learning activities involving the functions of the five senses, the characteristics of students' emotional and social development, (2) mathematics learning activities by creating an innovation are able to construct the knowledge obtained by students. This can help students in achieving 21st century competence. These student activities can be supported through learning with students as the canter and teaching materials as supporting learning activities. One of the teaching materials needed to support student learning activities is Student Worksheets (LKS), (3) mathematics worksheets by integrating STEM into an innovative mathematics teaching material that can be used today. The level of need for Mathematics Worksheets with a STEM approach that supports mathematical communication skills is shown by the results of distributing questionnaires to 10 junior high school mathematics teachers who were taken randomly and found a positive response reaching Sk> 80%, namely 83.75% with a very need classification.

Product Concept

The product made in this development research is a math student worksheet with a

Table 4. Scientific and Engineering Design Practices

No	Practice	Scientific and Engineering
1	Make inquiries and determine problems	Students find most bridge designs in the form of right triangles, then ask why
2	Developing and using models	Use the analogy of distance and displacement Shown two replicas of the stairs with different angles that are formed
3	Plan and conduct investigations	Proves the truth of the Pythagorean theorem and the Pythagorean triples
4	Using mathematical and computational thinking patterns	Using the Pythagorean theorem and triple in solving problems
5	Build explanations and design solutions	Identify the strongest bridge design and the minimum cost / material
6	Engage in evidence-based arguments	Answering the reasons why many bridge designs are right triangles
7	Obtain, evaluate and communicate information	Share the advantages and disadvantages of the design of the bridge design made to friends in class

STEM approach that supports mathematical communication skills. There are three important components in product design, namely:

Mathematics Student Worksheet

Mathematics worksheets with a STEM approach are prepared based on the Glencoe process using the scientific method. The implementation process begins with making observations and theoretical studies, proposing hypotheses, compiling estimated answers, conducting experiments, and making conclusions.

STEM Approach

The general steps for the STEM approach (Moore-Russo et al., 2013; Fore et al., 2015; Gartmeier et al., 2016; Horvath et al., 2018) in the students' worksheet include stage the setting, exploration, key concepts, practice and application exercises that's follow: (1) Students will use reading, listening and observing skills to discuss, interpret and evaluate a mathematical idea at the stage of setting the stage (2) exploration. At this stage students identify the problem given then dig from various sources as a reference for problem solving. (3) the key concept is the stage when students can find concepts and ideas in the subject matter. Students' understanding of what they find can be measured when students are able to express these concepts and ideas by using vocabulary or language, intonation, and mathematical structures to express ideas, describe relationships and create models. (4) develop a basic understanding of mathematics, including the rules for defining mathematics, then become an indicator in the stages of practice and application of exercises as the core of the STEM learning process Based on this, math worksheets developed with the STEM approach become teaching materials that include activities to support the development of students' mathematical communication skills.

While the learning syntax in this LKS follows the stages which includes the stages of Reflection, Research, Discovery, Application, and Communicate (Vattøy, 2020). The implementation of these learning activities provides space for students to implement competency achievement indicators. which has been compiled by researchers. This is indicated by the provision of clue indicators for each activity carried out by students. To support capacity building through this STEM approach, at least three components are needed,

Table 5. Crosscutting Concept

No	Crosscutting concept	Activity
1	Pattern	Determine the sides that can form a Pythagorean triple
2	Scale, proportion and quantity	Scale comparison of the original bridge size with the design made. The number of straws used to design the bridge design.
3	System and system model	Test the strength of the bridge and calculate the materials used
4	Structure and function	The right triangle function and the Pythagorean theorem in bridge design

namely teachers foster supportive and caring relationships with and among students, teachers provide challenging learning activities with high expectations, authentic academic work, and clear feedback, teachers explain the relevance of activities and rules while soliciting input from students and respecting their opinions (Moore-Russo et al., 2013; Saxton et al., 2014; Dimmel & Herbst, 2017; Muntaner-Mas et al., 2017). The same as that statement, (Newton & Tonelli, 2020) stated important aspect of connecting content and pedagogy and the awareness of "expert blind spot" problem. For each STEM characteristic, teachers' attitudes are positively linked with instructional practices (Thibaut et al., 2018).

Student involvement in STEM learning is structured based on the development of science learning standards or known as NGSS (Next Generation Science Standards) which includes Scientific and Engineering Design Practices, Crosscutting Concepts, Disciplinary Core Ideas (DCI)

Scientific and Engineering Design Practices. This dimension is a learning standard that describes the behavior of a scientist when making observations and making models as well as the way an engineer makes models or systems in thisworksheets as follows as Table 4. **Crosscutting Concept.** This dimension contains standard learning concepts to communicate students' scientific thinking. This is presented in the Table 5. **Disciplinary Core Ideas (DCI).** DCI in this worksheet is the main idea of the engineering subject in the Pythagorean theorem. The DCI components in this LKS are as follows as Table 6.

Table 6. Disciplinary Core Ideas

Core and component idea	Activity
Describe and define engineering problems	Bridge design
Optimizing design solutions	Linking the impact of the project designed in economic and social aspects

Activities that Support Junior High School Students' Mathematical Communication Skill

Activities designed in this worksheet are structured in such a way as to support students in developing their mathematical communication skills both in writing and orally. This is stated in the development of competency achievement indicators based on expert literature reviews. The communication indicators used are as follows: (1) To represent real objects, pictures, or diagrams into a mathematical idea; (2) explain mathematical ideas, situations and relations orally or in writing using real objects, pictures, graphs or mathematical expressions; (3) interpret a mathematical idea in a paragraph or mathematical description.

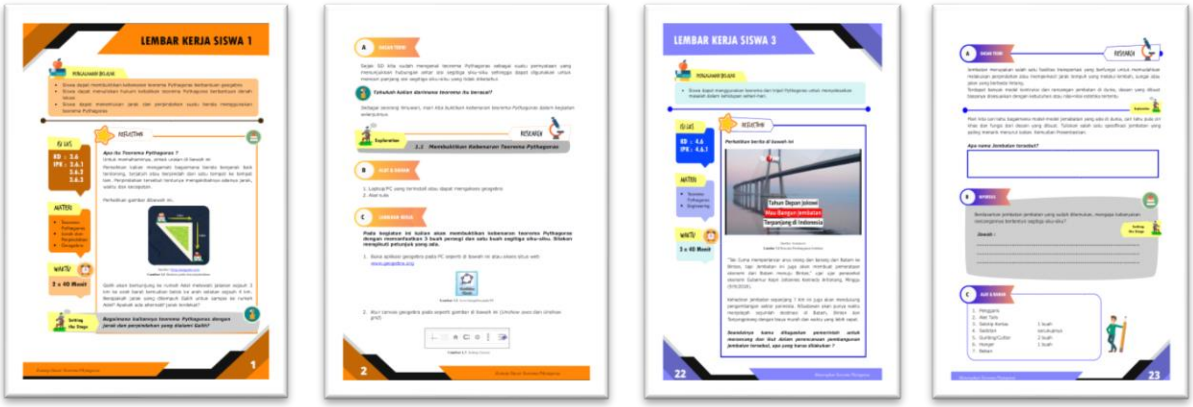

Figure 1. Preview of worksheets

Product Development

The Mathematics Student Worksheet with the STEM Approach that supports the mathematical communication abilities of junior high school students was developed by taking into account the three quality requirements of the student worksheets, namely from the didactic aspect, the construction aspect and the technical aspects (Darmojo & Jenny, 1993). Broadly speaking, the developed worksheets are presented in six parts, namely: (1) cover, (2) operational list of worksheets, (3) concept maps, (4) standard contents, (5) contents of worksheets, (6) competency tests.

At the development stage, three worksheets have been produced with details of LKS 1 containing the basic concepts of the Pythagorean theorem and LKS 2 containing the Pythagorean Triple concept. The two worksheets act as introductory worksheets and have met the basic competency number 3.6, namely students are able to explain and provide Pythagorean theorems and triples before using LKS 3 which is the application of the material that has been studied. The snippets of student worksheets that have passed the self-evaluation stage are as follows as Figure 1.

Learning Activities and Competency Testing

The extent to which the developed worksheets can become teaching materials containing supporting components of mathematical communication skills is outlined in the design of learning activities and competency tests which are the implementation of indicators of competency achievement and indicators of mathematical communication abilities. In writing, each part of the learning activity and competency test contains a clue of indicators of mathematical communication skills that have been compiled. The LKS competency test is prepared based on the indicators of mathematical communication skills contained in the content standard. The indicators are presented in the standard table of worksheet contents as follows as Table 7.

Table 7. Content Standards of Mathematics Worksheets

Indicator of Mathematical Communication Skills	Indicators of Competence Achievement
Representing real objects, pictures or diagrams to prove the truth of the Pythagorean theorem and triples	Formulate the Pythagorean theorem based on the written pattern of the sides of a right triangle Find the triple ythagorean pattern based on the written Pythagorean theorem formula Designing effective bridge designs based on the understanding of Pythagorean theories and triples
Explain the utility of the Pythagorean theorem and triples using real objects, pictures. Graph or mathematical expression	Formulate the distance and displacement of an object using the inverse law of the Pythagorean theorem Comparing the mechanical advantages of an inclined plane based on understanding the Pythagorean theorem and triples Shows the function of a right triangle in a building structure
Interpret the concept of the Pythagorean theorem in a mathematical description or paragraph	Applying the Pythagorean theorems and triples in everyday life

Validity Test

The validity test is an activity of product assessment by the validator to determine the feasibility of the student worksheet in learning. Based on the quantitative assessment that has been carried out by each of the 2 validators from the field of education, the material field, the field of evaluation and the field of media design, it is found that the Mathematics Worksheet with the STEM approach that supports mathematical communication skills is suitable for use in learning with revisions according to the suggestions given. According to one validator, the presentation of the worksheets makes it easy for users to find out the typical parts of STEM learning and from supporting activities for mathematical communication skills. In addition, the mathematics learning flow in the LKS is well designed so that it can add to the student learning experience.

The feasibility is shown based on the suitskills of the content contained in the worksheets with the assessment standards given the average percentage of eligibility of 84.77% exceeding the minimum score of success indicators, namely ρ > 70% (Suparti, 2015). While the nature of the category based on the average score obtained reaches the very good category, finding a score of 4.23 is in the category of 4.20 <ρ≤ 5.00 which means that the student worksheet is very well developed ((Widoyoko, 2018). The quantitative data from the recapitulation of the validity test are summarized in the following Table 8.

Table 8. Recapitulation of Product Validation

Validation	Percentage eligibility	Nature category
Education	85.25%	4.26
Theory	91%	4.53
Evaluation	78.42%	3.92
Media design	84.4%	4.22
Final score	84.77%	4.23

Based on the results of the validity test, then worksheets can be implemented in mathematics learning in class.

Limited Trial

The limited trial in question is a product trial for the research targets, namely students of class VIII and mathematics teachers. This limited trial was conducted at SMP Permata Islamic School class VIII-3. This stage aims to determine the practicality of the worksheets developed from the aspect of assistance in helping stu-

dents understand the material of the Pythagorean theorem, aspects of ease of use, as well as aspects of attractiveness of design both from visual appearance and learning variations.

In its implementation, students admit that it is difficult to work with their group friends to complete the project they have made, this is because students are accustomed to learning mathematics individually in class or in groups of their own choice. This actually results in the low enthusiasm of students in completing ongoing learning, it can even cause students not to find the essence of the learning that is given Even so students claim to be motivated by implementing Mathematics learning using Mathematics LKS with STEM approaches because it can add insights from simple things which are often forgotten but have had a big impact on major issues in various aspects of life such as economy and development.

Meanwhile, the teacher argues that the design made is very interesting and creates a new impression for students when they see it, but besides that there are still typo words in some parts. Although superior in terms of interest, the teacher said that he was still groping about the application of STEM in mathematics learning and the developer had not shown how the learning scenario was carried out with the LKS. Therefore, the developer designed the teacher's handbook of worksheets containing learning scenarios, teaching materials, answer keys and assessment rubrics as a reference and guidelines for implementing mathematics learning with the help of STEM worksheets that support the mathematical communication skills of the VIII grade junior high school students. The percentage of student and teacher responses is presented in the following Figure 2.

On this percentage, the evaluation of the implementation stage in the form of retrying the LKS was not carried out. Then math worksheets with the STEM approach that support mathematical communication skills are feasible to be widely used in mathematics learning in the classroom.

CONCLUSION

Worksheets for mathematics students with the STEM (Science, Technology, Engineering and Mathematics) approach have been produced as support for junior high school students' mathematical communication skills that are suitable for learning mathematics in the Pythagorean

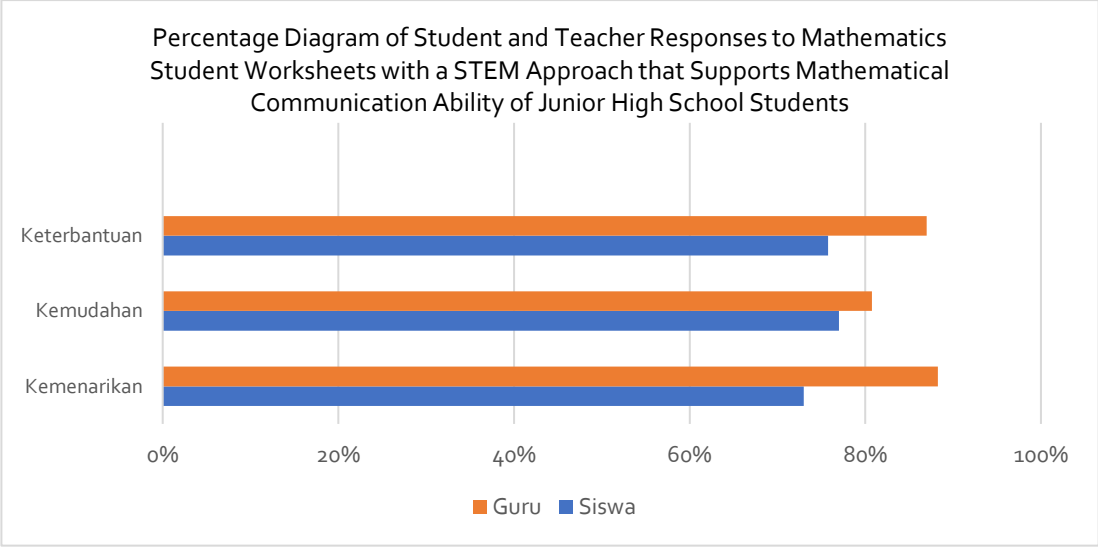

Figure 2. Percentage Diagram for Student and Teacher Response

theorem chapter VIII based on product validation with a final score of the eligibility percentage reaching 84.77% are at the interval > 4.20, namely 4.23 with the category "Very Good". Meanwhile, the user response to the Student Worksheet (Student Handbook) was obtained from distributing questionnaires to students with an overall score percentage of 75% and questionnaires to teachers with a score of 85%. Each response indicated that Mathematics Worksheets with STEM Approach that support mathematical communication skills are categorized as "Practical" and "Very Practical" in terms of attractiveness, ease of use and assistance for use in mathematics learning.

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