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Development of Realistic Mathematics Education (RME)-Based Student Worksheet to Improve Students' Mathematical Communication Skills

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Abstract

Improving mathematical communication skills is a key objective in mathematics education, particularly for problem-solving. At SMP Muhammadiyah 9 Yogyakarta, students' mathematical communication skills, as assessed through written tests, have been deemed to be at a low level. This study aims to enhance these skills by developing Learning Activity Sheets (worksheet) grounded in Realistic Mathematics Education principles. This research is an R&D research using the ADDIE model. The instruments used are validation instruments, student response questionnaires, and pretest and posttest questions. Validation tests revealed that the RME-based worksheet achieved high scores, indicating its quality both in terms of content (average score of 113) and as a teaching medium (average score of 83). Student feedback, gauged through questionnaires, indicated a positive reception with an average score of 54.38, suggesting practicality. Analyzing posttest scores from experimental and control groups demonstrated the effectiveness of the RME-based worksheet in enhancing students' mathematical communication skills.

Keywords: Worksheet; Realistic Mathematics Education; Mathematical Communication Skills

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INTRODUCTION

Mathematics education is an essential part of the curriculum, which must be given to students. The mathematics learning process aims for students to acquire mathematical skills that can be used in facing global challenges (La'ia & Harefa, 2021). Entering the 21st century, students are required to develop several skills, which are divided into four main aspects: problem-solving, critical thinking, creative thinking, and communication and collaboration, commonly known as 4C (Septikasari & Frasandy, 2018). One of the skills that is highly emphasized in the context of mathematics education is the ability to communicate mathematically (Ismayanti & Sofyan, 2021).

Developing communication skills is crucial for learners (Tong & Uyen, 2022). One of the main objectives of learning mathematics is to improve mathematical communication skills because these skills are very important for solving various mathematical (Fitriyana et al., 2021; NCTM, 2000). However, the fact is that there are still many students problems who struggle and do not master mathematical communication skills (Maulyda et al., 2023; Syamsir & Noviarni, 2018). Referring to observations made at SMP Muhammadiyah 9 Yogyakarta on April 28, 2023, significant information about students' mathematical communication skills was obtained. The results of teacher interviews show that students need help designing mathematical

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models based on story problems, experience obstacles in drawing conclusions from the problems, and need more courage to express their opinions. Field observations also reveal that students' mathematical communication skills still need to be improved. As seen from the test results given on May 25, 2023 in Figure 1.

Figure 1. Mathematical Communication Ability Test Results

Of the 28 students who took the mathematical communication ability test, 12 were in the low category, nine were in the medium category, and only seven met the high category. One of the triggers for students' low mathematical communication skills is that students still need help reflecting problems into mathematical models (Zaditania & Ruli, 2022).

One of the effective means to optimize communication skills is using teaching materials (Untayana & Harta, 2016). This is because teaching materials aim to help teachers convey information in the form of material or communicate to students (Irawan et al., 2018). Student worksheets are one of the teaching materials that can improve mathematical communication skills and positively affect student achievement (Untayana & Harta, 2016). Using worksheet in learning can improve students' mathematical communication skills (Nasri & Jamaan, 2022).

Apart from the use of teaching materials, other causes cause low mathematical communication skills, namely due to the less-than-optimal approach taken by the teacher in the classroom when learning takes place (Sitepu, 2024; Yulianti, 2021). The use of the Realistic Mathematics Education (RME) learning approach is a way to improve students' mathematical communication skills because it focuses on solving mathematical problems based on real-world situations (Chisara et al., 2018; Marja Van den Heuvel-Panhuizen, 2020). The RME approach also involves various activities that can help learners strengthen their communication skills, which are important for learners in the 21st century (Nguyen & Pham, 2023)

The results of several other studies show that Realistic Mathematics Education has the potential to improve mathematical communication skills. For example, research by Palinussa et al., (2021) and Putri et al., (2019) found that Realistic Mathematics Education (RME) has a great impact on students' mathematical reasoning and communication skills. Paroqi et al., (2020) research shows that learning using the RME (Realistic Mathematics Education) approach is more effective than conventional learning in improving students' mathematical communication skills. Regarding the existing problems, researchers are interested in developing a Realistic Mathematics Education (RME)-based Learner Worksheet (worksheet) to improve students' mathematical communication skills.

RESEARCH METHOD

This research is development research (R&D). Development research is used to design and test the level of effectiveness of a particular product (Sugiyono, 2017). The research design applied in this study is a mixed methods design, which combines qualitative and quantitative research in one study. Qualitative research aims to understand the validation process and practicality of worksheet. At the same time, quantitative research serves to obtain validation data, practicality data, and worksheet effectiveness. The product development model refers to the ADDIE model (Branch, 2009a). According to Branch, (2009) there are several processes in the ADDIE model: (1) Analysis, (2) Design, (3) Development, (4) Implementation, and (5) Evaluation. After the ADDIE stage is completed, the experimental stage is continued, which is used to test the effectiveness of the developed product. The method used is a Nonequivalent Control Group Design, which is part of a quasi-experimental design. At this stage, the control class used the worksheet commonly used by teachers, and the experimental class used the RME-based worksheet that the researcher had prepared. Both classes also received a pretest and posttest from the researcher who gave the treatment. Tables and Figures are presented center, as shown below and cited in the manuscript.

RESULTS AND DISCUSSION

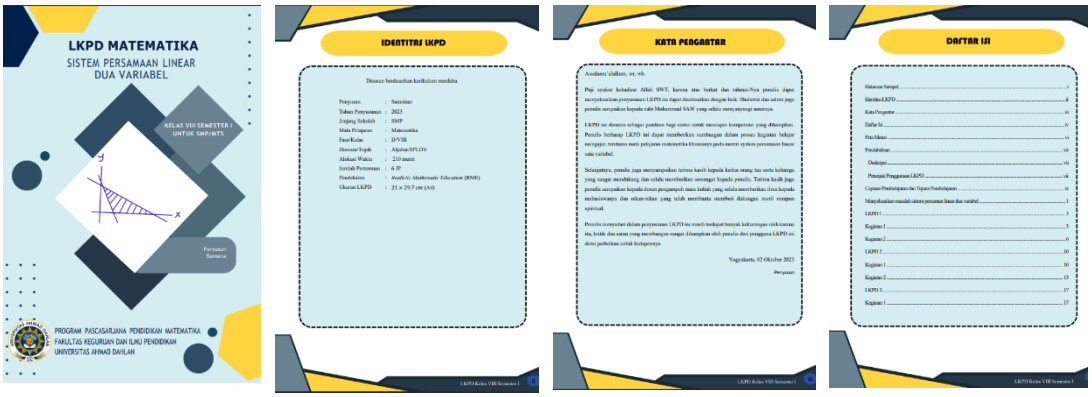
This section discusses the steps of development research that have been carried out using the ADDIE model, the results of experiments that have been carried out and discussions.

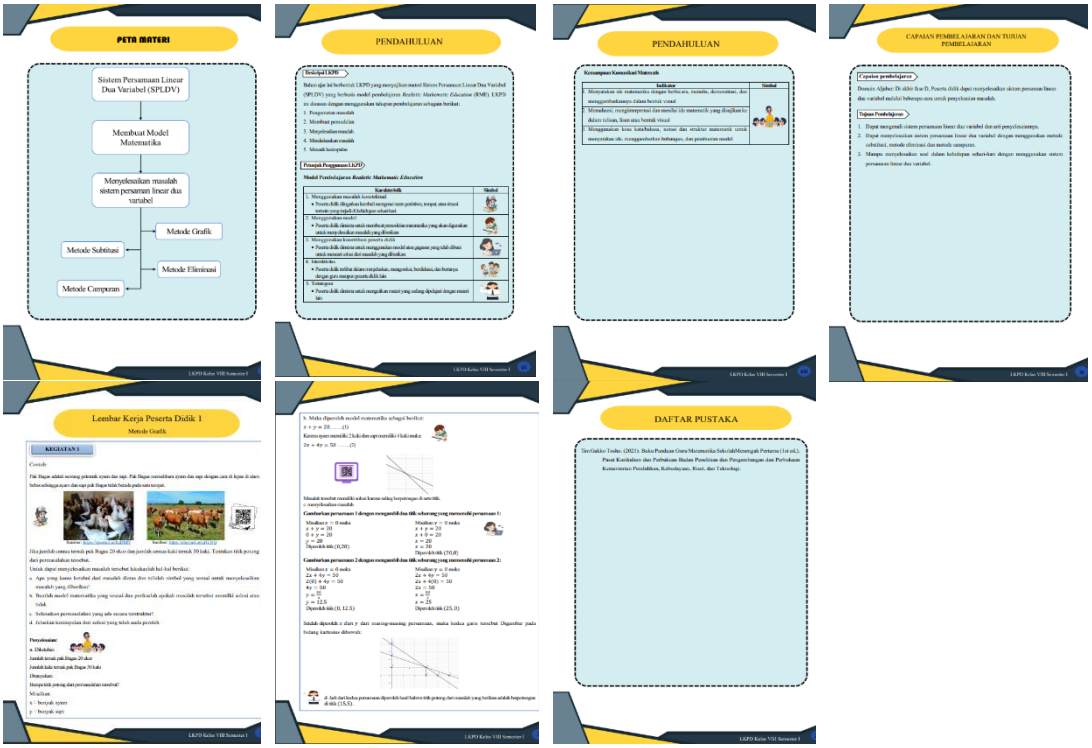
1. Analysis

Curriculum analysis was conducted by examining the curriculum applied at SMP Muhammadiyah 09 Yogyakarta, namely the independent curriculum. Based on the material analysis results, information was obtained that the material considered difficult for students was SPLDV. At the same time, the teaching materials students need based on the needs analysis questionnaire are worksheet. The process of assessing the characteristics of students involves giving tests that include mathematical communication indicators to evaluate their communication skills; it can be seen if the students' mathematical communication skills still need improvement.

2. Design

The following is the initial design of the worksheet developed:





3. Development

At the WORKSHEET development stage, it is designed based on the initial design that has been prepared. This worksheet was compiled using Canva and Microsoft Word 2021. This worksheet is supported by several additional features, namely Geogebra, Google Forms, and YouTube. The worksheet that has been designed is then validated by material experts and media experts to evaluate its feasibility. The instrument used to validate the WORKSHEET has undergone revision and review of instruments by experts. The results of the product validation process carried out by media and material experts are described in Table 1.

Table 1. Validation Results of Material Experts and Media Experts

Validator	Material Expert	Media Expert
Validator 1	105	78
Validator 2	121	88
Validator 3	113	-
Total Score	339	166
Average	113	83
Category	Good	Good

Some significant changes after the validation process are as follows:

4. Implementation

After the worksheet developed by the researcher is declared feasible to use or meets the validity criteria, the worksheet is implemented in a small class or small class practicality test and then continued learning activities using RME-based worksheet in a larger class to test the practicality of the product. This large class trial was conducted for two meetings with 6 JP lesson hours. Researchers and 21 students used worksheet as the main media for learning activities during implementation. Every learning activity carried out by students is centered on WORKSHEET. The results of the implementation stage in small and large classes based on the learner response questionnaire can be seen in the following table.

Table 2. Data on Small and Large Class Learner Response Questionnaires

Respondent	Total score	Average	Category
10 8th grade students of SMP Muhammadiyah 9 Yogyakarta	496	49,6	Good

21 8th grade students of SMP Muhammadiyah 9 Yogyakarta	1.142	54,38	Good

5. Evaluation

The evaluation process is the last step in a research series using the ADDIE model. At the evaluation stage, researchers identify the shortcomings of the previous processes and then make continuous improvements. At this stage, there is an evaluation consisting of formative and summative evaluations. Formative evaluation is carried out at each stage of ADDIE. At the design stage, formative evaluation involves revising the test and non-test instruments used in this research's next stage. Expert lecturers reviewed this process and made revisions based on the feedback.

Furthermore, in the media development process, revisions were made based on the material and media experts' feedback. The results of the development stage concluded that the developed media was valid regarding material and media. In the implementation stage, small-class and large-class trials were conducted. Based on students' responses in the trial, this media is practical to use and get an assessment in a good category.

Meanwhile, summative evaluation is carried out at the final stage by conducting tests as essay questions. In evaluating the use of WORKSHEET products developed, students are given a pretest before the implementation stage or the provision of worksheet. In addition to giving a pretest, the researcher also gave a posttest to students who were the objects of the worksheet trial. After learning activities, the posttest was given to determine students' mathematical communication skills.

After the product is declared valid and practical, experiments are conducted to determine its effectiveness. The results of this experimental research must fulfill prerequisite tests such as normality and homogeneity tests.

Table 3. Results of Normality Test of Pretest and Posttest Values of Students' Mathematical Communication Ability

Assessment	***Sig.***	**Information**
Experimental Class Pretest	0,001	Abnormal
Control Class Pretest	0,297	Normal
Experimental Class Posttest	0,138	Normal
Control Class Posttest	0,216	Normal

According to Table 3, the pretest data in the experimental class deviates from normal distribution as indicated by the significance value of < 0.05. However, the posttest data in the experimental class exhibits a normal distribution. Conversely, both pretest and posttest data in the control class are normally distributed, as shown by the significance value of > 0.05. Additionally, a homogeneity test was conducted.

Table 4. Homogeneity Test Results of Pretest and Posttest Values of Mathematical Communication Ability of Students

Test Type	***Levene Statistic***	$\mathbf{df_1}$	$\mathbf{df_2}$	**Sig.**	**Information**
Pretest	3,856	1	40	0,057	Homogeneous
Posttest	1,146	1	40	0,291	Homogeneous

Table 4 shows that the Levene Statistic value for the pretest is 3.856, with a significance of 0.057. Thus, H_0 is accepted ($0.057 > 0.05$), this means that the pretest data of the experimental and control classes are homogeneous. In the posttest, the Levene Statistic value is 1.146, with a significance of 0.291. Thus, H_0 is accepted. This means that posttest data in both control and experimental classes are homogeneous.

Since the posttest data of students in the experimental class follows a normal distribution, testing the average posttest score of the experimental class and control class to determine the product's effectiveness uses an independent sample t-test with the help of SPSS 25.

$H_0 : \mu_1 \leq \mu_2$ (there is no significant difference)

$H_a : \mu_1 > \mu_2$ (there is a significant difference)

The hypothesis test results are described in Table 5.

Table 5. Hypothesis Test Results of Mathematical Communication Ability of Students

Data	Test result	
	t	***Sig. 2 tailed***
Posttest results for experimental class and control class	3,096	0,004

Table 5 indicates that the significance (two-tailed) is $0.004 < 0.05$. Consequently, H_0 is rejected. In simpler terms, there exists a notable discrepancy in students' mathematical communication skills between the experimental and control classes. Thus, employing RME-based worksheet proves to be more efficacious compared to teacher-led worksheet.

In this study, the N-gain test was utilized to evaluate the enhancement of mathematical communication skills by comparing students' pretest and posttest scores in both the experimental and control classes. Table 6 illustrates the outcomes of the N-Gain test regarding mathematical communication proficiency.

Table 6. N-Gain Results of Mathematical Communication Ability

No	Student Name	Experimental Class		N-Gain Value	Control Class		N-Gain Value
		Pretest	***Posttest***		***Pretest***	***Posttest***	
1	PD1	68,75	93,75	0,80	56,25	58,33	0,05
2	PD2	25	81,25	0,75	35,42	72,92	0,58
3	PD3	25	75	0,67	12,50	64,58	0,60
4	PD4	70,83	87,5	0,57	25,00	77,08	0,69
5	PD5	31,25	75	0,64	35,42	37,50	0,03
6	PD6	31,25	75	0,64	25,00	41,67	0,22
7	PD7	12,5	66,67	0,62	25,00	54,17	0,39
8	PD8	12,5	50	0,43	20,83	45,83	0,32
9	PD9	12,5	75	0,71	47,92	70,83	0,44
10	PD10	70,83	93,75	0,79	41,67	75,00	0,57
11	PD11	12,5	75	0,71	35,42	47,92	0,19
12	PD12	12,5	54,12	0,48	8,33	70,83	0,68
13	PD13	12,5	62,5	0,57	41,67	66,67	0,43
14	PD14	58,33	87,5	0,70	20,83	60,42	0,50
15	PD15	12,5	50	0,43	27,08	47,92	0,29
16	PD16	6,25	50	0,47	12,50	39,58	0,31

17	PD17	12,5	60,42	0,55	12,50	39,58	0,31
18	PD18	35,42	75	0,61	27,08	35,42	0,11
19	PD19	47,92	81,25	0,64	47,92	87,50	0,76
20	PD20	41,67	87,5	0,79	8,33	45,83	0,41
21	PD21	12,5	66,67	0,62	47,92	81,25	0,64
Average N-Gain value				**0,63**			**0,41**

The experimental class achieved an average N-Gain score of 0.63, categorizing it as medium, while the control class attained a score of 0.41, also in the medium range. These N-Gain results indicate that employing RME-based worksheet is more effective in enhancing students' mathematical communication skills compared to teacher-led WORKSHEET. Put differently, the experimental class exhibited a greater increase in scores compared to the control class. The graphical representation below illustrates the average increase in pretest and posttest scores.

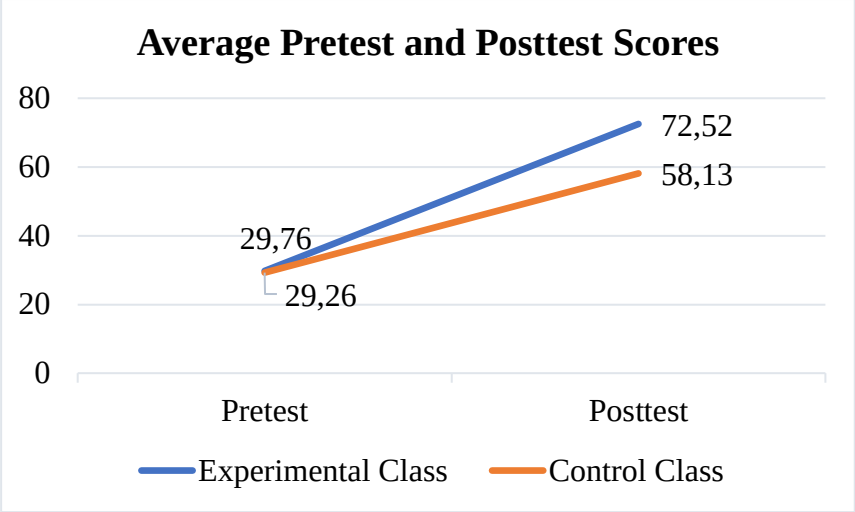


Figure 2. Increase in Pretest Average and Posttest Average

From the study results, it is known that the worksheet produced has contained eligibility requirements in terms of material and media. This shows that the WORKSHEET developed by the researcher has met the requirements of Depdiknas, (2008) regarding the feasibility of language, content, presentation, and graphics. The feasibility of RME-based worksheet also shows that the resulting worksheet is eligible for use by students with low mathematical communication skills. This can be seen from the development of worksheet, which contains the characteristics of the RME approach, namely the use of models to assist students in overcoming their limited ability to use language, notation, and mathematical structures to display ideas, illustrate linkages, and model through modeling activities in worksheet. This is in line with research conducted by Risfalidah et al., (2019) where the results showed that the ability of students to formulate mathematical models or develop mathematical ideas from contextual problems was still limited.

Worksheet that have been developed, when assessed in terms of validity, have met the standards as teaching materials that students in learning will use. The validation results carried out in the validation of material and media experts are in the "Good" category, with a score of 83 for material experts and 113 for media experts, respectively. Meanwhile, concerning practicality, the worksheet that has been made is already in the practical category for students with an average score of 49.6 and with

"good" criteria. For large classes, the average score is 54.38 with "good" criteria. Along with the view of Widoyoko, (2017), the validity of teaching material is considered adequate if it reaches the good category, and the practicality of teaching materials can be assessed based on the response questionnaire of students who at least reach the good category. Therefore, the WORKSHEET that was prepared met the validity criteria from the perspective of material experts and media experts, as well as practical ones based on students' responses.

Apart from being revi iewed in terms of practicality and validity, the developed worksheet is also seen in terms of its effectiveness. The effectiveness of an worksheet can be observed from the achievement of students' scores. Based on the effectiveness test results using the independent t-test at a significant level of 5%, the significance value (2-tailed) $0.004 < 0.05$ was obtained. This suggests a notable disparity in mathematical communication abilities between students in the experimental and control classes.

In addition to testing the effectiveness using an independent t-test, the effectiveness of worksheet is also seen based on the average posttest in the experimental class, experiencing an average increase of 42.76 from the results of the pretest work that has been given previously. Meanwhile, the control class experienced an increase of 28.87. Based on the posttest results, the WORKSHEET developed can be categorized as an effective worksheet. This is supported by research conducted by (Kurniawati, 2022; Nur & Fitri, 2023; Pamungkas & Rokhima, 2023; Sitepu, 2024) where the results of RME-based worksheet can improve students' mathematical communication skills.

The effectiveness test outcomes indicate variations in mathematical communication skills before and after instruction between the experimental and control cohorts. The group utilizing RME-based worksheet demonstrated a more substantial enhancement compared to the group employing teacher-led WORKSHEET. Moreover, the average N-Gain data in the experimental class further corroborates this, showcasing a superior increase compared to the control class. However, both are in the medium category and indicate that the developed worksheet is effective. This finding implies that the RME-based WORKSHEET that has been developed meets the standards of validity, practicality, and effectiveness, so it is worth implementing. This study implies that the application of RME-based worksheet can positively contribute to improving students' mathematical communication skills. This conclusion is supported by the results of previous research conducted by (Pamungkas & Rokhima, 2023; Risfalidah et al., 2019; Sitepu, 2024; Wirevenska et al., 2021), all of which show the effect of RME-based worksheet in improving students' mathematical communication skills.

CONCLUSION

Based on the results and discussion, it can be concluded that:

1. The development of RME-based worksheet to improve mathematical communication skills is carried out with the ADDIE model, namely:
   a. Analysis
      Needs analysis encompasses the evaluation of curriculum, materials, teaching resources, and learner attributes.
   b. Design

Based on the conducted analysis, the design of Learning Activity Sheets (worksheet) is tailored accordingly. During the design phase, researchers utilize a framework centered on selecting materials that align with students' characteristics, along with the chosen learning methods and evaluation techniques.

c. Development
In the development process, researchers translated the design details from the design stage into physical form, producing a prototype of development products in the form of RME-based worksheet. Material and media experts have validated this prototype to ensure quality and effectiveness in improving students' mathematical communication skills.

d. Implementation
Implementation is the stage where researchers conduct trials of s that have been developed. In this step, researchers tested it with 21 students of class VIII A.

e. Evaluation

f. In the evaluation stage, researchers identified the shortcomings of the previous processes and then made continuous improvements. At this stage, the evaluation consists of formative and summative evaluations.

2. The RME-based worksheet that was created fulfills the validity standards. This is evidenced by the evaluation from the content expert, scoring 113 and categorized as good, and from the media expert, scoring 83 and categorized as very good.
3. The RME-based worksheet meets the practical criteria based on the assessment of the student response questionnaire, which is indicated by the assessment results of 54.38 in the good category.
4. RME-based meets the effective criteria for improving students' mathematical communication skills. This is based on the significance results (2-tailed) $0.004 < 0.05$, which means that H_0 is rejected. Put differently, there exists a notable contrast in students' mathematical communication abilities between the experimental and control groups. This is further evidenced by the greater average score improvement in the experimental class compared to the control class. Moreover, this discrepancy is reinforced by the higher average N-Gain in the experimental class compared to the control class.

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DECLARATION

Author Contribution

All authors contribute in the research process, such as collecting the data, analyzing the data, and writing the manuscript. All authors approved the final manuscript.

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This research did not receive any funding.

Conflict of Interest

Both authors declare that they have no competing interests.

Ethics Declaration

We as authors acknowledge that this work has been written based on ethical research that conforms with the regulations of our institutions and that we have obtained the permission from the relevant institutes when collecting data. We support the International Journal on Emerging Mathematics Education (IJEME) in maintaining high standards of personal conduct, practicing honesty in all our professional practices and endeavors.

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