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Development of Mathematical Communication Skill through Worksheets Integrated Problem Based Learning using ADDIE Model

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Abstract

Mathematical communication is one of the skills that everyone needs to have to succeed in studying and working, especially in the 21st century era and the industrial revolution 4.0. Mathematical communication skills are very important for students to present arguments in presentations and discussions. These skills can be developed through problem-based learning model. However, student worksheets to support these models have not been extensively created. Therefore, this study aims to develop student worksheets to support problem-based learning models. In student worksheets, mathematical communication skills were integrated into activities. Furthermore, it uses a study and development model including Analysis, Design, Development, Implementation, and Evaluation (ADDIE). The subjects were 50 8th-grade students and 2 mathematics teachers at a Junior High School in Yogyakarta, Indonesia. Here, the teacher is an expert in judging. Collection of data was conducted through observation techniques, interviews, documentation and testing. The result showed that a valid, practical, and effective student worksheets should be able to support the problem-based learning model by integrating students' mathematical communication skills. It can be used by teachers when the teaching and learning process are conducted through a problem-based model. Its substantial contribution is the integration of mathematical communication skills into worksheets. Therefore, students using the worksheets will understand the subject matter and master communication skills simultaneously.

Keywords: *Addie Model, Mathematical Communication Skill, Problem Based Learning, Student Worksheets*

INTRODUCTION

In the era of the industrial revolution 4.0, students are expected to be equipped with 21st-century skills. Mastery of this century skills is essential for students to succeed in life, and one of them is communication (Reeve, 2016). A real illustration that mathematical communication is important for students now and in the future is that mathematical communication skills are needed to express mathematical ideas correctly. The mathematical communication has been studied by authors from various countries, for example Zeybek & Açıl (2018), Sánchez Paredes & Vargas D'Uniam (2016), and Lee (2015). In Zeybek & Açıl (2018), investigations of students' mathematical communication skills included definition, use of mathematical concepts, and mathematical language skills. In (Sánchez Paredes & Vargas D'Uniam, 2016), four aspects are investigated: organization of mathematical thinking through communication, communication of mathematical thinking, analysis and evaluation of the strategies and mathematical thinking of others, and expression of mathematical ideas using the language of mathematics. Mathematical communication is an important tool that allows students to demonstrate their thinking and understanding (Lee, 2015). Therefore, the teachers are expected to be genuinely trained to improve their mathematical communication skills through a learning model.

Several studies by Meiriyanti et al (2018), John (2006), and Tawfik & Trueman (2015) were conducted related to the use of learning models to improve the mathematical communication skills. The results showed that the mathematical communication skills achieved through problem-based learning (PBL) were significantly better than direct learning process (Meiriyanti et al., 2018). One of the PBL syntax is developing and presenting work. This component in PBL can develop students' mathematical communication. In addition, PBL helps students develop thinking and problem-solving skills, learn adult roles and practice, and apply knowledge to obtain solutions to specified problems (John R., 2006). In Indonesia, this learning model is also listed in the Ministry of Education and Culture Regulation No. 22/2016. Therefore, PBL is recommended as a model to be used in Indonesian schools.

The implementation of the PBL model effectively improves students' mathematical communication skills when supported by appropriate worksheets. Several studies have conducted related to the development of student worksheets, for example: Akma & Suparman (2018), Zulyadaini (2017), and Merdekawati & Lestari (2011). They are one of the teaching materials consisting of summaries and independent work guides directed to the basic competencies to be achieved (Merdekawati & Lestari, 2011). In the worksheets, students are more active in solving the problems presented. This is because it can impart their mathematical concepts, and improve their achievement Zulyadaini (2017). In Akma & Suparman (2018), learners' worksheets that fit the PBL model are designed to improve problem-solving. Searching for the term mathematical communication using Vosviewer sourced on Google Scholar data base from 2018 to 2022 presented in Figure 1. Searching for 250 documents with the minimum number of terms is 5, Vosviewer found 918 terms. Of the 918 conditions, there were 55 which filled the threshold.

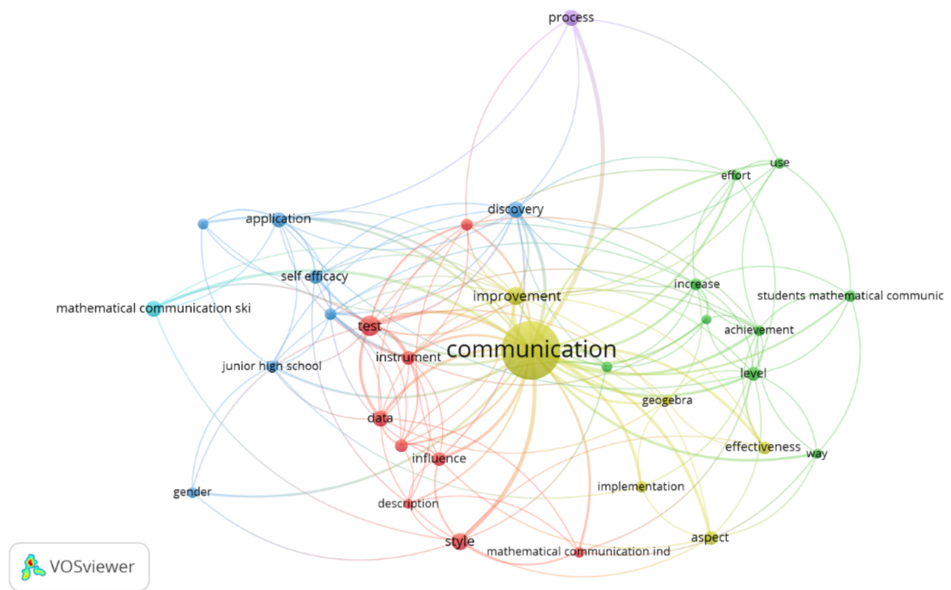


Figure 1 Search for mathematical communication terms

However, research linking mathematical communication with problem based learning has not been widely studied. Likewise, the relationship between mathematical communication and student worksheets.

This study aims to develop student worksheets to support the PBL model with the target of integrating mathematical communication skills. The student worksheet focuses on the Pythagorean material, which is taught to Junior High School students in grade 8 odd semesters. Pythagorean material was chosen because it can be applied to solve various problems and the Pythagorean material are still considered difficult by students compared to other materials.

LITERATURE STUDY

1. Mathematical Communication

Mathematical Communication Skills can be seen in the following 4 indicators (Rohid & Rusmawati, 2019). First, students' ability to structure and relate their mathematical thinking through communication. Second, students' ability to communicate logical and clear mathematical thinking to friends, teachers, and others. Third, students' ability to analyze and assess mathematical thinking and strategies used by others. Fourth, students' ability to use mathematical language to express mathematical ideas correctly. While other authors use the following 3 indicators (Asmarawati et al., 2019). The three indicators used are written text, drawing, and mathematical expression. Students' mathematical communication skills can be developed through several strategies, for example the application of learning models (Surya et al., 2018) and digital module design (Setiyani et al., 2020).

2. Problem based Learning

The PBL learning model can be a better option than traditional lecture-based classes in teaching hyperthyroidism during an endocrinology internship (Hu et al., 2019). Problem-based learning (PBL) is an effective model in developing the professional communication competence of nursing students and nurses (Li et al., 2019).

The PBL approach gave very positive results both in terms of laboratory techniques and critical thinking skills (Costantino & Barlocco, 2019). PBL combined with case-based learning is an effective method to improve the performance of medical students and improve their clinical skills (Zhao et al., 2020). Students have the perception that PBL provides a higher ability for intellectual stimulation (Oderinu et al., 2020).

3. Students' Worksheet

Studies show graduate students find worksheets to be effective in helping develop research questions (Byrd & Camba, 2020). The study which aims to determine the effectiveness of worksheets shows that student worksheets with PhET simulation using scaffolding question prompts are effective in improving student learning outcomes (Mahtari et al., 2020).

METHODOLOGY

This study uses development research. In this study, the product developed is the worksheet of students. One of the development models used to develop learning tools is the ADDIE model, for example: (Latif & Nor, 2020), (Zhang, 2020), (Jalil et al., 2020), and (Andriani & Suparman, 2019). In this study, the development of the student worksheet used the ADDIE. Research procedures include analysis, design, development, implementation, and evaluation.

The subjects were 50 students of grade 8 and 2 mathematics teachers at a junior high school in Yogyakarta. They were selected by purposive sampling and the types of data taken were qualitative and quantitative. Data collection was conducted using observation, interview, and test techniques. The instruments used include observation and interview guidelines as well as test questions. Furthermore, construct validity was conducted before the instruments were used. In construct validity, the validity test is based on expert judgment. For data collection, direct observations and interviews were made during the study of mathematics and with various college students in 8th grade respectively. During the interview, there were several questions to find out students' mathematical communication in the learning process in class. Furthermore, tests were conducted to measure the increase in communication skills both before and after using the worksheets.

Data analysis used Interactive Model with several stages including collection, reduction, presentation, and drawing conclusions or verification (Susanti et al., 2018). Data analysis was conducted through the following stages: (1) recording all findings of the phenomenon using observation and interviews. This was carried out to determine the needs of learning media and to stimulate students mathematical communication, (2) after collection then reviewing the observations and separating data that are considered important and unimportant. This work was repeated to check the possibility of classification errors, (3) description of the classified data with due observation to the focus and research objectives, and (4) make a final analysis in the form of a report.

RESULTS AND DISCUSSION

1. Results

In the analysis phase, there are several outcomes at this stage: (1) students' mathematical communication still needs to be improved, (2) teaching materials in schools are not consistent with the syntax of the learning model, (3) mathematics subjects in Pythagorean material are still considered difficult.

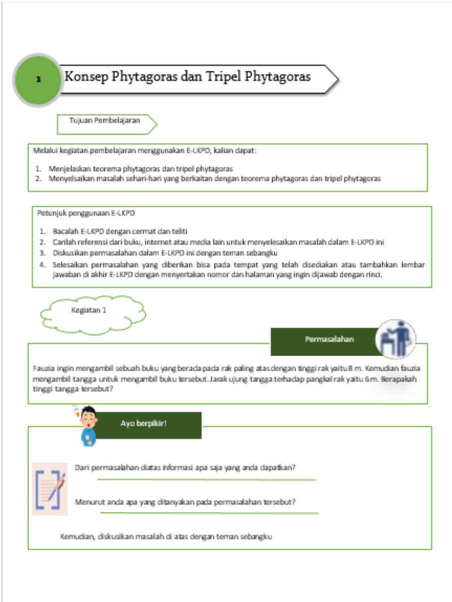
In the design phase, there are several results at this point since student's worksheets are based on the PBL model. The material presented for Junior High School grade 8 odd semesters is Pythagoras. The next step is introduction, which contains student support worksheets. One part is the introductory part. Instructions for use contain procedures for using worksheets to achieve material objectives. The table of contents is presented. List the contents of this worksheet to make it easier to find the topics they want to learn. The next content is the section, which contains concept maps and competencies. The summary in the worksheet presents Pythagorean material and it is concise and clearly presented.

The integration of PBL syntax in the worksheets as follows. The syntax of the model includes: (a) students' orientation to the problem, (b) organizing students to learn, (c) guiding investigations, (d) developing and presenting work, (e) analyzing and evaluating the problem-solving process (Arends, 2008). The implementation of PBL syntax in the worksheets can be seen in Figure 2.

The practice sheet contains test questions to measure students' mathematical communication skills in the Pythagorean material. Similar to (Asmarawati et al., 2019), the indicators used are written text, drawing, and mathematical expression. Furthermore, mathematical communication skills are measured through students' answers in working on the questions. The exercise sheet is presented in Figure 3.

In the development stage, the student worksheets were validated by 2 material and 2 media experts following the aspects of the eligibility of content, language, activities/observations of students, appearance, and presentation. Based on this, the students' worksheets were revised and this is presented in Table 1.

Figure 2 Design of learning materials according to PBL syntax



1 Konsep Phytagoras dan Tripel Phytagoras

Tujuan Pembelajaran

Melalui kegiatan pembelajaran menggunakan E-LKPD, kalian dapat:

1. Menjelaskan teorema phytagoras dan tripel phytagoras
2. Menyelsaikan masalah sehari-hari yang berkaitan dengan teorema phytagoras dan tripel phytagoras

Petunjuk penggunaan E-LKPD

1. Bacalah E-LKPD dengan cermat dan teliti
2. Carilah referensi dari buku, internet atau media lain untuk menyelesaikan masalah dalam E-LKPD ini
3. Diskusikan permasalahan dalam E-LKPD ini dengan teman sebangku
4. Selesaikan permasalahan yang diberikan bisa pada tempat yang telah disediakan atau tambahkan lembar jawaban di akhir E-LKPD dengan menyertakan nomor dan halaman yang ingin dijawab dengan rinci.

Kegiatan 1

Permasalahan

Fauzia ingin mengambil sebuah buku yang berada pada rak paling atas dengan tinggi rak yaitu 8 m. Kemudian fauzia mengambil tangga untuk mengambil buku tersebut. Jarak ujung tangga terhadap pangkal rak yaitu 6 m. Berapakah tinggi tangga tersebut?

Ayo berpikir!

Dari permasalahan diatas informasi apa saja yang anda dapatkan?

Menurut anda apa yang ditanyakan pada permasalahan tersebut?

Kemudian, diskusikan masalah di atas dengan teman sebangku

Figure 3 Exercise sheet

Table 1 Suggestions and input from the validators

Suggestions / Comments from Validators	Follow-up from the Author
The cover appearance should be simple and attractive	The cover appearance has been revised
Fixing practice questions	The questions have been revised
Adding more complete instructions on how to use student worksheets	Instructions have been added

Furthermore, the validators also provided material and media assessments. The value was compared with the material eligibility criteria for a product as presented in Table 2.

Table 2 Product eligibility criteria in terms of material (Widoyoko, 2016)

Score Range	Qualitative Criteria
$\bar{X} > 71.34$	Very Good
$57.78 < \bar{X} \leq 71.34$	Good
$44,22 < \bar{X} \leq 57.78$	Good Enough
$30,66 < \bar{X} \leq 44.22$	Bad
$\bar{X} \leq 30.66$	Very Poor

A student worksheet is said to be valid when the average validator score in terms of minimum material is in the "Good" category. Where $\bar{X}$ is the average score of the validator in terms of material and the values regarding the eligibility of the material are shown in Table 3.

Table 3 Student worksheets in terms of material

Validator	Score
V1	58
V2	64
Total Score	122
Average Score	61

In the same way, the value of the validator in terms of media is also compared with the eligibility criteria for the media, as presented in Table 4. Students' worksheets are said to be valid when the average score of the validator in terms of media is at least in the "Good" category.

Table 4 Product eligibility criteria in terms of media (Widoyoko, 2016)

Score Range	Qualitative Criteria
$\bar{Y} > 79.81$	Very good
$64{,}6 < \bar{Y} \leq 79.81$	Good
$49{,}4 < \bar{Y} \leq 64.6$	Good Enough
$34{,}19 < \bar{Y} \leq 49.4$	Bad
$\bar{Y} \leq 34.19$	Very Poor

Where $\bar{Y}$ is the average score of the validator in terms of media. The scores regarding the eligibility of the media are shown in Table 5.

Table 5 Student Worksheets in terms of media

Validator	Score
V1	75
V2	82
Total score	157
Average score	78.5

In the implementation phase, small groups consisted of 10 students and the product practicality data were obtained from 10 student response questionnaires. The responses of small class students are shown in Table 6.

Table 6 Small class student response scores

Student Code	Score
PS-1	60
PS-2	61
PS-3	54
PS-4	68
PS-5	59
PS-6	70
PS-7	63
PS-8	66
PS-9	72
PS-10	58
Total Score	631
Average Score	63.1

Here, the value of the small class student response scores is compared with the eligibility criteria for the student response, as presented in Table 7. Students' worksheets are said to be practical for use in small class trials when the average score of the small class student response is at least in the "Good" category.

Table 7 Ideal assessment criteria for student response (Widoyoko, 2016)

Score Range	Qualitative Criteria
$\bar{Z} > 63$	Very good
$51 < \bar{Z} \leq 63$	Good
$39 < \bar{Z} \leq 51$	Good Enough
$27 < \bar{Z} \leq 39$	Bad
$\bar{Z} \leq 27$	Very Poor

Where $\bar{Z}$ is the average response score of students. Therefore, student worksheets are practical for use in large class trials, which consist of 30 students. The responses of small class are presented in Table 8.

Table 8 Large class student response scores

Student Code	Score
PB-1	58
PB-2	70
PB-3	62
PB-4	59
PB-5	65
PB-6	68
PB-7	67
PB-8	62
PB-9	56
PB-10	50
PB-11	72
PB-12	66
PB-13	69
PB-14	63
PB-15	64
PB-16	55
PB-17	64
PB-18	54
PB-19	69
PB-20	67
PB-21	50
PB-22	61
PB-23	52
PB-24	55
PB-25	67
PB-26	53
PB-27	60
PB-28	68
PB-29	66
PB-30	65
Total score	1857
Average score	61.9

Finally, the value of the large class student response scores is also compared with the eligibility criteria for the student response, as presented in Table 7. Students' worksheets are said to be practical for use in large class trials when the average score of the large class student response is at least in the "Good" category.

2. Discussion

The analysis phase involves analyzing the need to detect or identify problems under development to conduct a study. This is part of the context for the development of teaching materials. This stage contains the analysis of student learning needs in PBL to improve mathematical communication skills, analyze their characteristics, material that is deemed difficult, support facilities, and solutions for implementing PBL on the media to be made.

The design phase is achieved by designing the student worksheets based on the results of the analysis. Student worksheets consist of cover, introduction, table of contents, basic competencies, material summary, and exercises. The activity steps are in line with Problem Based Learning. In the worksheets, there are activities conducted in groups, which provide opportunities for students to understand the concept of learning.

The development phase is conducted by writing a draft of student worksheets, developing assessment instruments, as well as validating and revising student worksheets. Table 3 shows that the average score is 61 and according to the criteria in Table 2, this is included in the “Good” category. Therefore, the student worksheets developed are valid in terms of material. The table 5 shows that the average score was 78.5. According to the criteria in Table 4, it is included in the "Good" category. Therefore, the student worksheets developed are valid in terms of the media. It can be concluded that the students' worksheets have fulfilled the validity of both the material and the media. Therefore, it can be used to improve their mathematical communication skills.

In the implementation phase, after the student worksheet was declared valid or eligible from the material and media aspects, it was tried out on the students for small and large classes. After using the worksheet, they were asked to fill out a questionnaire on responses to the worksheet. Table 6 shows that the average response score of small class is 63.1. To obtain the practicality of the participant's worksheets, this score is compared with the ideal assessment criteria for responses in Table 7. Students' worksheets are said to be practical when the average response score is at least in the "Good" category. Table 6 shows that the average response score of small class students was 63.1 and based on Table 7, it is included in the "very good" category. Table 8 shows that the average response score of large class students is 61.9. To obtain the practicality of the participant worksheets, this score was compared with the ideal assessment criteria for students' responses in Table 7. Furthermore, table 8 shows that the average response score of small class students is 61.9. Based on Table 7, this score is also in the “very good” classification. Therefore, students' worksheets are also said to be practical, both for small and large classes as well as can be used for real classroom learning.

In the evaluation phase, the worksheets are applied to learning in a classroom with 17 students. They were given a pretest to determine the initial conditions and posttest to determine the final condition. For each student, the posttest score was higher than pretest score. Based on the interview, it was obtain that the average pretest score was low because the students did not study the material tested. To determine the effectiveness of the worksheet, the average posttest score was compared with the minimum completeness criteria (KKM) and classical learning completeness. The KKM set by the school is 74. Students' worksheets are said to be effective when the average posttest score is above the KKM. The average posttest score was also greater than the KKM and this implies that the worksheets are effective in improving students' abilities in mathematical communication on Pythagorean material.

Several previous studies have designed worksheets with the target of increasing mathematical communication as conducted by (Wardani & Suparman, 2019) and (Supriyanto et al., 2020). According to (Wardani & Suparman, 2019), the students' worksheets are designed following the Team Achievement Divisions (STAD) learning model on the material for two-variable linear equation systems. Whereas (Supriyanto et al., 2020) designed it following the Realistic Mathematics Education (RME) learning model on Arithmetic Sequences material. In (Zeybek & Açıl, 2018), mathematical communication is associated with student academic achievement on standards Geometry. Therefore, this study complements previous studies.

CONCLUSION

This study uses the ADDIE model to produce math student worksheets that are developed based on needs analysis. Student worksheets are designed on the basis of the PBL model and are oriented towards mathematical communication. Furthermore, it is developed based on input and suggestions from material and media validators and this process produces valid worksheets. The worksheet was then tried out on several students and revised according to the input and this process resulted in practical student worksheets. Students that use the worksheet get a score above the Minimum Completeness Criteria (KKM). Therefore, this process produces student worksheets that are effective in instilling their mathematical communication skills.

The developed student worksheets have advantages in improving mathematical communication skills from the Pythagorean material at the grade 8 junior high school level. The presented material contains indicators of mathematical communication skills which are integrated into the questions.

Furthermore, the worksheets were developed according to the syntax of the PBL learning model. Therefore, the results of the study can be used in the learning process when the teacher taught using the PBL model. This study has implications for improving learning outcomes and the ability of students to communicate mathematically. Also, practice on alternative learning resources in accordance with the model. Further study can be conducted by comparing the effectiveness of this student worksheet with others through experiment.

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DATA AVAILABILITY

Data will be made available on request.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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