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Development of Problem Based e-Worksheet to Enhance Mathematics' Communication Skill in Cartesian Coordinates

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Abstract: The importance of mathematics communication as one skill in the mathematics learning process standard doesn't necessarily make learning oriented towards achieving this skill. This study aims to develop a problem-based e-worksheet and determine its validity, practicality, and effectiveness in enhancing the mathematics communication skill in the cartesian coordinate topics. This study is a Research and development using the ADDIE model containing stages of analysis, design, development, implementation, and evaluation. The results showed that the e-worksheet was declared feasible. The validity of the e-worksheet is indicated by the average score of the material and media validators which is a very good criterion. The response questionnaire average value also shows the practicality of this e-worksheet. While the effectiveness is shown by increasing students' mathematics communication skills after being given an e-worksheet. Several features of the e-worksheet and the loaded Problem-Based Learning model syntax support the effectiveness of the e-worksheet.

Keywords: mathematics communication, e-worksheet, problem based learning.

Abstrak: *Pentingnya komunikasi matematika sebagai salah satu keterampilan dalam standar proses pembelajaran matematika tidak serta merta menjadikan pembelajaran berorientasi pada pencapaian keterampilan tersebut. Penelitian ini bertujuan untuk mengembangkan e-lembar kerja (e-LKPD) berbasis masalah dan menentukan validitas, kepraktisan, dan keefektifannya dalam meningkatkan keterampilan komunikasi matematis siswa pada topik koordinat kartesius. Penelitian ini merupakan penelitian dan pengembangan dengan menggunakan model ADDIE yang berisi tahapan analisis, perancangan, pengembangan, implementasi, dan evaluasi. Hasil penelitian menunjukkan bahwa e-LKPD dinyatakan layak. Validitas e-LKPD ditunjukkan dengan nilai rata-rata dari validator materi dan media yang termasuk dalam kriteria sangat baik. Nilai rata-rata angket respon juga menunjukkan kepraktisan e-LKPD tersebut. Sedangkan keefektifan e-LKPD ditunjukkan dengan adanya peningkatan kemampuan komunikasi matematis siswa setelah diberikan e-LKPD. Beberapa fitur yang terdapat pada e-LKPD dan muatan sintaks model Pembelajaran Berbasis Masalah juga mendukung efektivitas e-LKPD tersebut.*

Kata kunci: *komunikasi matematis, lembar kerja, pembelajaran berbasis masalah.*

▪ INTRODUCTION

During this Covid-19 pandemic, the implementation of various activities such as health, economy, tourism, and education including learning activities must be carried out from home (Sintema, 2020; Donthu & Gustafsson, 2020; Chertoff et al., 2020; Flores & Swennen, 2020). In school learning activities must be transformed through a face-to-face learning system by utilizing online and internet communication technology. This is in accordance with the circular letter of the Ministry of Education and Culture of the Republic of Indonesia Number 4 of 2020 concerning the implementation of education policies in the emergency period of the spread of Covid-19 so that the

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learning process is carried out from home through distance learning. Implementation of various learning platforms and applications that are used to support learning from home including mathematics (Atsani, 2020; Mustakim, 2020) .

According to Atsani (2020), problems during online learning during this pandemic are related to the unpreparedness of all components involved in the learning process, both in terms of standards and the quality of learning outcomes. In addition, it was also found that students' boredom towards online learning, considerable anxiety to buy internet quota during online learning, especially students whose parents have low income, as well as changes in students' moods due to too many assignments from the teacher (Irawan, et al., 2020; Magdalena et al., 2020; Noviansyah & Mujiono, 2021). The complexity of the implementation of the mathematics learning process during the pandemic has become quite an interesting material to highlight because in its implementation it requires the accuracy of material delivery and the development of mathematical abilities. As a science that has an abstract and hierarchical object of study, the acquisition of mathematical knowledge requires the provision of direct learning experiences so that learning becomes more meaningful and not difficult for students to understand. One of the mathematical materials that students find difficult to learn even though its application is found in everyday life and has a great chance for students to know is the Cartesian coordinate material. Whereas, at the primary and secondary levels students aren't only required to understand concepts, but also can communicate ideas, strategies, and problem-solving both orally and in writing, including in mathematics (Manouchehri & Goodman, 2010; Vale & Barbosa, 2017; Ariawan & Nufus, 2017; Hartini, Maharani, & Rahman, 2016). This is also supported by Fachrudin, et al. (2014), that students learn to hone their communication skills while still learning mathematics.

According to NCTM (2000), mathematical communication skills are one of the standard processes contained in the principles of learning mathematics. In addition, mathematical communication is also the goal of learning mathematics (Sinaga & Manik, 2019). In learning mathematics, students are directed to be able to communicate and interpret mathematical ideas orally and in writing, in the form of diagrams, mathematical symbols, so as to clarify the information contained in the problems they face (Paruntu, et al., 2018). In line with this, according to Sari (2017) one of the 21st century skills that students need is mathematics communication. Mathematics communication is also one of the higher-order thinking skills (HOTS) (Madu, 2017; Tambunan, 2018; Tambunan, 2019). This ability is needed by students to communicate, inform or explain the ideas they have with other students (Deswita et al., 2018). Therefore, the achievement of mathematical communication in learning can create a more communicative and fun atmosphere through problem solving discussion activities (Deswita et al., 2018; Perwitasari & Surya, 2017). This shows the importance of mathematical communication for students to share ideas and clarify understanding, in order to obtain a picture of the internal representation, improvement and development of students' ideas (Madio, 2016).

In learning the Cartesian coordinate material, students have difficulty in solving contextual problems, which are related to present of coordinates on pictures and contrarily. Students also have difficulty in explaining the point position of an object that is contained in a contextual problem if it is presented in the cartesian system of coordinates both orally and in writing. This difficulty certainly creates its own obstacles when they are asked to mathematically model the contextual problem. Another difficulty is that students are constrained in translating and solving contextual problems that contain images.

The difficulties experienced by students are increasing with the trend of inequality in mathematics learning opportunities during Emergency Distance Teaching (Lambert & Schuck, 2021). Moreover the fact that there are still many parents who are unable to provide learning assistance according to the needs of students. This is supported by the results of Adler's research (2014) which shows that almost 10% of parents of children have low motivation to get involved online, thus hindering their child's learning. Several studies have found a decrease in student engagement during online learning in general education (Anderson et al., 2001). As a result, students tend to memorize the concept of Cartesian coordinates rather than understanding it. Meanwhile, both online and offline learning conditions on a limited scale are currently also not possible to provide direct experience to students. Whereas in the Letter of the Minister of Education and Culture Number 4 of 2020, online learning must still provide a meaningful learning experience for students. This meaningful learning can be achieved by learning that is oriented towards providing direct experience related to the problems of everyday life. Therefore, appropriate mathematics learning strategies and methods are needed so that students can have an understanding and ability to apply mathematics in everyday life problems (Kamsurya, 2020).

To choose the right learning method, teachers need to consider limitations, interest in learning, and whether the teaching materials used are interactive or not. Problem Based Learning (PBL) is one of the learning models that is oriented towards providing problems related to real or actual life (Ejin 2016; Sucipto 2017). PBL is also one of the innovative problem-based learning models where the teacher presents real-world problems so that students can be active during the learning process and can pour their ideas into the problems presented (Nurbaiti et al., 2016; Yanti, 2017). With PBL it is possible for students to discuss and exchange ideas to express their opinions, so that it has implications for the results of the mathematics communication of students themselves (Hafely et al., 2018).

In addition to learning models, several research results indicate the need for teaching materials to support learning models during a pandemic where learning time is increasingly limited. So far, teachers only use student worksheet that aren’t made by the teacher themselves as book companions and these worksheet don’t train students in solving contextual problems or in everyday life. This worksheet only contains a summary and a collection of questions to be solved with formulas.Whereas student worksheet as one of the teaching materials should be able to guide students in understanding the process skills and concepts of the material being and will be studied (Nurfadhillah et al., 2018). Considering that teaching materials are used by teachers in carrying out teaching and learning activities in the classroom (Ramdani, 2012), teaching materials must be able to facilitate the needs and accommodate the unique characteristics of students (Yanti, 2018). Furthermore, according to Munifah et al. (2019) to facilitate the needs and to enhance the achievement of students' mathematics communication skills, the existing student worksheet must be integrated with the PBL model. Considering the limited learning time and the use of textual teaching materials which are deemed to be less supportive of students' mathematics communication achievements, students need teaching materials that accommodate students' mathematical communication achievements and are oriented towards contextual problems with more flexible accessibility, wherever and whenever.

Based on the problems experienced by students in learning cartesian coordinates above, it is necessary and important to develop interactive teaching material that can support cartesian coordinate learning in improving students' mathematical communication skills during the pandemic, but the teaching material is quota-friendly so it does not cause student anxiety. The interactive learning teaching material developed in this study is a problem based learning teaching material that is included in everyday life. Therefore, the aim of this research is to develop of electronic student worksheet based on Problem Based Learning (PBL) and determine the validity, practicality, and effectiveness of it to enhance mathematics communication skill of cartesian coordinate material

▪ METHOD

The type of research conducted is research and development (R & D) with the ADDIE model, consisting of five stages: analysis, design, development, implementation, and evaluation (Branch, 2009). The population in this study were seventh-grade students from SMP Muhammadiyah 2 Minggir. Furthermore, the selected research sample was 20 students of class VII A from the school, which would later be used as a trial class, using purposive sampling because only class VII A had almost 98% of students using a smartphone. The research instruments used here include: material and media validation questionnaire sheets whose indicators refer to aspects of product feasibility according to the Ministry of National Education (2008), student response questionnaires, observation guidelines and interview guidelines that have all been validated both in terms of content and constructs by two people. evaluation expert. In the initial research stage, the researcher conducted a literature study from previous studies, then analyzed the problems and needs in learning. Researchers design a product, learning tools, instruments, and the prototype of the worksheet product. This electronic student worksheet was previously designed on the Flip PDF Corporate Edition, then underwent additional functions by creating book configs using the FAPA book extender application. This application runs on the Nougat android platform from version 7.0 to version 11.0. An electronic student worksheet was used in learning for three meetings.

The finished electronic student worksheet was validated by material experts and media experts to determine the validity of the products that have been developed in this study. To validate the electronic worksheets, the researchers developed material validation instruments and media validation. The material validation instrument consists of four indicators: the appropriateness of the content represented by four questions; language represented by six questions; the feasibility of presentation; and conformity with the PBL model represented by five questions. The media validation instrument also consists of four indicators: the size of the electronic worksheet represented by two questions; the layout represented by seven questions; the design of the electronic worksheet represented by sixteen questions; and illustrations represented by three questions.

After the product is declared valid, at the implementation stage the product is used in learning for three meetings. During the implementation phase, students use their own smartphones that have an electronic worksheet application installed. The teacher in its implementation is only a facilitator in the construction of student knowledge. The teacher begins learning by orienting students through the problems shown in the video on their electronic worksheet, then continues with the activity of organizing students in their study groups. Furthermore, the teacher guides the investigation of the student group in finding solutions to the problem. The results of the investigation and discussion with the group will be presented in front of other groups and the teacher so that feedback from problem-solving presented by each group can be given in turn. Finally, the teacher and students jointly evaluate the problem-solving process of each group. After the implementation of the worksheet product was carried out, the researcher gave a response questionnaire to the students to find out the practicality of the worksheet during learning. Furthermore, at the evaluation stage, the researcher gave posttest questions to determine the effectiveness of the electronic worksheet that had been implemented to compare with the results of the pretests that the researchers had given to students.

Answers from the validator and students indicate their level of agreement with a series of questions posed in the questionnaire. Approval on the questionnaires was arranged in stages using a Likert scale consisting of 5 choices, as attached in Appendix 2 and Appendix 3. The score for each expert or student choice answer in a row is: 1) score 'Not Good' = 1; 2) score 'Less Good' = 2; 3) score 'Good Enough'=3; 4) score 'Good'=4; and score 'Very Good'=5 of the five answer choice scores, the highest score was 5, and the lowest score was 1.

The calculation of the average results of the expert assessment questionnaires and student response questionnaires is called the actual average score. Then, this average score is converted into qualitative criteria that refer to the criteria by Widoyoko (2018) as presented in Table 1.

Tabel 1. Average score and its associated category (Widoyoko, 2018)

Score Intervals	**Category**
$X_{bar}>X_i+1.8Std_i$	Very Good
$X_i+0.6Std_i<X_{bar}\leq X_i+1.8Std_i$	Good
$X_i-0.6Std_i<X_{bar}\leq X_i+0.6Std_i$	Enough
$X_i-1.8Std_i<X_{bar}\leq X_i-0.6Std_i$	Deficient
$X_{bar}\leq X_i-1.8Std_i$	Very Deficient

Description:
Xbar = the actual mean Xi = ideal mean = ½ (ideal maximum score + ideal minimum score)
Stdi = the ideal standard deviation = 1/6 (ideal maximum score–ideal minimum score)
The ideal maximum score = number of questions × highest score
The ideal minimum score = number of questions × lowest score

Based on those criteria, the electronic student worksheet is considered valid if the average actual score obtained from the results of the expert's assessment is in the minimum category of 'Good.' Likewise, with practical criteria, it is assessed if the actual average score obtained from the results of the student response questionnaire is in the minimum category of 'Good'. Furthermore, to find out whether the use of electronic student worksheet is said to be effective, the researchers calculated the difference between the pretest and posttest scores (Gain score) using the N-Gain formula as a determinant of the category of improving students' mathematics communication (Hake, 1999). The researcher also considered the mean posttest and pretest values of students which stated that the increase in the mean of students' mathematics communication from before to after being given the worksheet occurred if the mean posttest value>mean pretest value. The calculation of N-Gain and consideration of the pretest and posttest scores were used to base the conclusion that the use of PBL-based electronic student worksheet can be said to be effective in improving students' mathematics communication skills.

▪ RESULT AND DISSCUSSION

Stage of Analysis

At this first stage, the researchers analyze the problems and needs experienced in the cartesian coordinate learning and students' initial mathematics communication skill. Researchers obtained initial data through interviews and observations with mathematics teachers and students at SMP Muhammadiyah 2 Minggir. Interviews were conducted to determine how the mathematics learning process was carried out at SMP Muhammadiyah 2 Minggir, which included the media used, the application of technology in learning, the learning model, etc. Based on the interviews, it is known that teachers have never implemented electronic student worksheet. Teachers only use teaching materials in textual printed books, word or pdf materials, and learning videos sourced from YouTube during the pandemic era.

From the interviews, it is known that mathematics teachers still use conventional approaches to learning. They conduct direct learning through the lecture method, then ask students to apply the formula content/material that the teacher has conveyed to the practice questions given by the teacher. In this case, students have difficulty solving contextual problems related to Cartesian coordinates.

The teacher never gives contextual problems at the beginning of learning, so students are unusual in dealing with these contextual problems. Directly giving material makes students only receive information/knowledge from the teacher. Students aren't allowed to collaborate or discuss with other students. Students also don't get teacher guidance in conducting investigations to obtain information related to contextual problems. To support learning with limited time and place, students need electronic teaching material containing tasks oriented to problem-solving activities during learning. Therefore we need teaching material in electronic student worksheet, such as the results of interviews and observations of researchers to mathematics teachers and students.

Based on the results of observations through observation sheets shared with students via Google Forms, it was found that 87% of students enjoyed learning mathematics using Android than textbooks. Therefore, it can be concluded that class VIII students are very close to technology, especially in the use of Android and laptops. Hence, in this research, the researchers developed PBL-based electronic worksheet to enhance students' mathematics communication skills based on the above analysis.

Stage of Desain

Researchers designed the research instruments and the initial prototype design of the electronic student worksheet at this stage. This electronic student worksheet contains

Cartesian coordinates material oriented to the achievement of indicators of students' mathematics communication skills and has PBL syntax. In addition, researchers also developed learning tools in the form of a syllabus and lesson plan. The presentation of the material is based on the PBL syntax stages, namely orienting problems through giving problems at the beginning of learning, organizing students, guiding investigations, developing and presenting problem-solving results, also analyzing and evaluating the process of student problem-solving results. The PBL syntaxes are used as a strategy for researchers to align the material with the achievement of students' mathematics communication skills. Therefore, at this design stage, the researcher designs symbols to represent each stage in the PBL syntax and indicators of mathematics communication skills. The presentation of PBL syntax symbols and mathematics communication indicators is presented as shown in Figure 1 below.

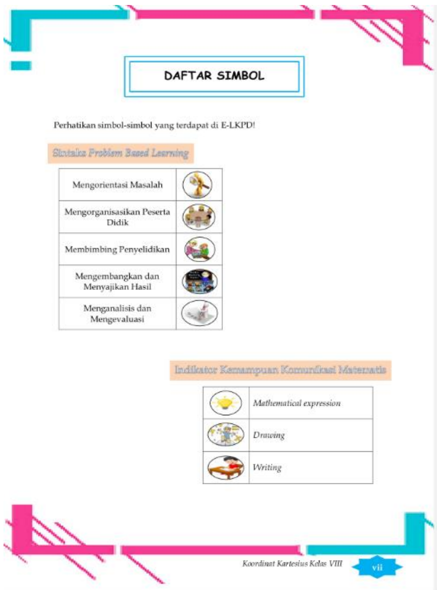


Figure 1. Symbols of PBL syntax and mathematics communication indicators

The initial design format for this electronic student worksheet refers to the student worksheet format compiled by Prastowo (2012), namely the cover, study instructions, competencies to be achieved, supporting information, tasks and work stage, and assessment.

Stage of Development

The researchers developed an electronic student worksheet in PDF format at this stage. Then, the worksheet would be imported into the Flip PDF Corporate Edition application, while the video was made using the Filmora application. The researchers add supporting features to this electronic worksheet to adjust the characteristics and functions of interactive electronic student worksheets oriented to students' mathematical communication skills. Therefore, researchers use the FAPA book extender application to expand the functionality of Flip PDF Corporate Edition on android devices. The FAPA book extender application will read the Flip PDF Corporate Edition publication results, so researchers must make book configs that are tailored to the needs of electronic student worksheets that can be accessed online and offline.

Furthermore, the researcher validated the electronic student worksheet developed by media experts and material experts, each consisting of 2 (two) lecturers and 1 (one) mathematics teacher. The validation of student worksheets based on the assessment of material experts and media experts can be seen in Table 1 and Table 2 below.

Table 1. e-Worksheet validation results by material experts

Validator	Total Score	Category
Validator-1	79	Good
Validatar-2	93	Very Good
Validator-3	87	Very Good
The total score of 3 validators	259	
Average	**86.33**	
Validity criteria		**Very Good**

Table 2. e-Worksheet validation by media experts

Validator	Total Score	Category
Validator-1	135	Good
Validatar-2	117	Very Good
Validator-3	129	Very Good
The total score of 3 validators	381	
Average	**127**	
Validity criteria		**Very Good**

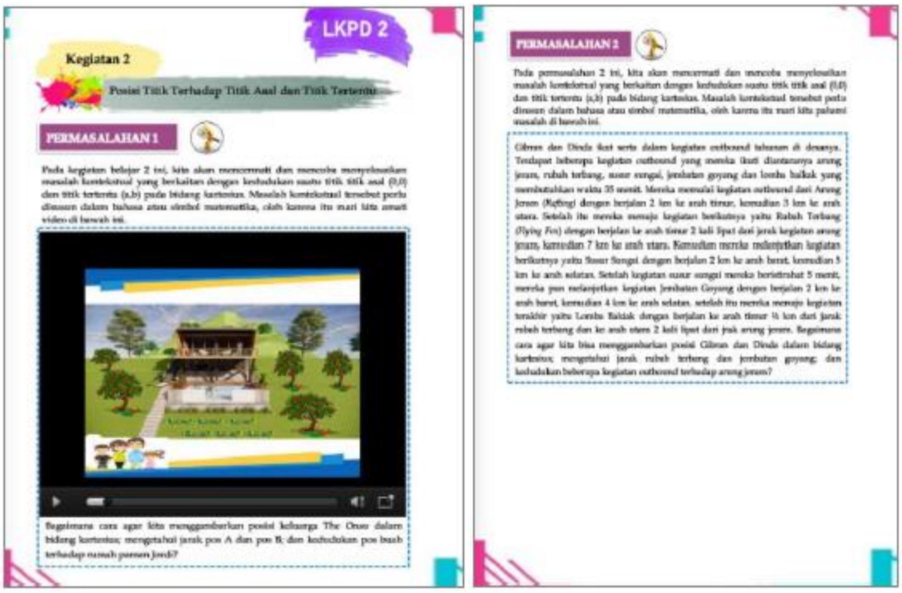
In Table 2, it is known that the average score of the three material expert validators is 86,33, and the average value of the three media expert media validators in Table 3 is 127. These results indicate that the electronic student worksheet product developed in this study has met the very valid criteria in terms of content construction of the material and media. Hence, it is feasible to be used as teaching material. This condition is in line with what was conveyed by Nieveen (1999), which states that research and development products are said to be feasible if the product meets the aspects of content and construct validity. Content validity means that the worksheet has current needs and conditions. Construct validity means that all components of the worksheet are consistent and interconnected. There are some suggestions from the validator regarding some of the writing and spelling of the wrong words, also the size of the letters presented. The results of this product revision will later be used in field trials to measure the practicality and effectiveness of the product.

Stage of Implementation

Electronic student worksheets that have been valid and declared suitable for use by the validator are then tested in the learning class three times. The implementation of the activity sheet for learning Cartesian coordinate material begins with learning stages that are adapted to the PBL syntax as follows:

Orienting Stage

At this stage, learning begins with giving contextual problems presented through video or text. Students are asked to observe the problem, and essential information is contained in the video or text shown on the worksheet. Presentation of contextual problems in videos or text in electronic student worksheets can be seen in Figures 2 (a)-(b) below.



(a) (b)

Organization Stage

At this stage, the teacher directs students to make small groups, and then students define their encountered problems. In this case, students are assigned to write down what is known and asked questions after discussion to solve contextual problems. The task of the organization stage that students must do on the electronic worksheet can be seen in Figure 3 below.

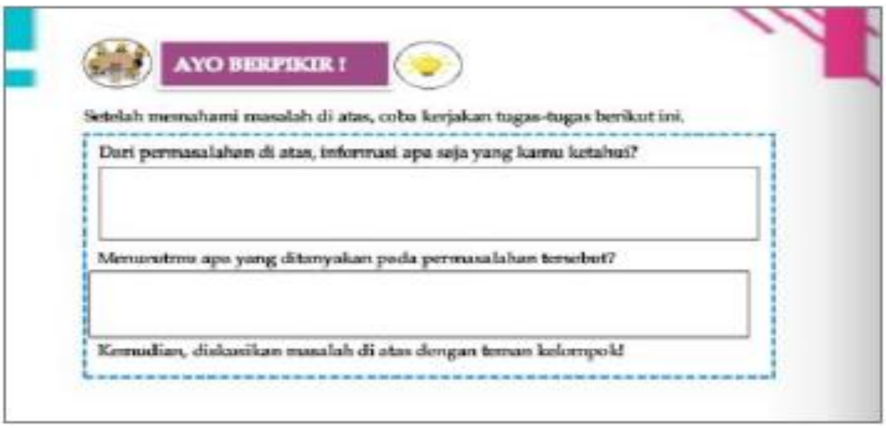


Figure 3. Student assignments at the stage of organizing

Guiding Investigation Stage

At this stage, students are asked to write their plans through mathematical modeling from the information known in the problems above. The investigation stage task that students must do on the electronic worksheet can be seen in Figure 4 below.

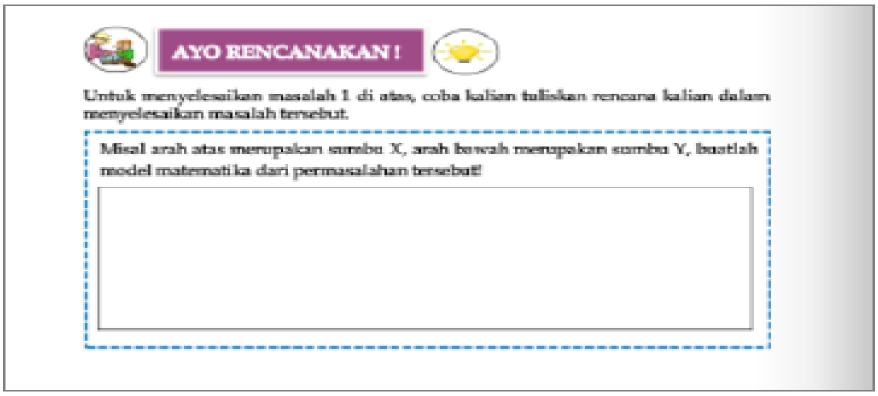


Figure 4. Student assignments at the stage of guiding investigation

Developing and presenting problem-solving results

At this stage, the teacher guides students to plan, prepare the results of their discussions and present them. The first activity begins with students' activity to solve problems with friends in one group and then show their results for meeting with other groups. In this activity, students realize the plans they have written in the previous stage by drawing their work on a Cartesian coordinate. The presentation stage contains tasks that students must do student in worksheets, as shown in Figure 5 below.

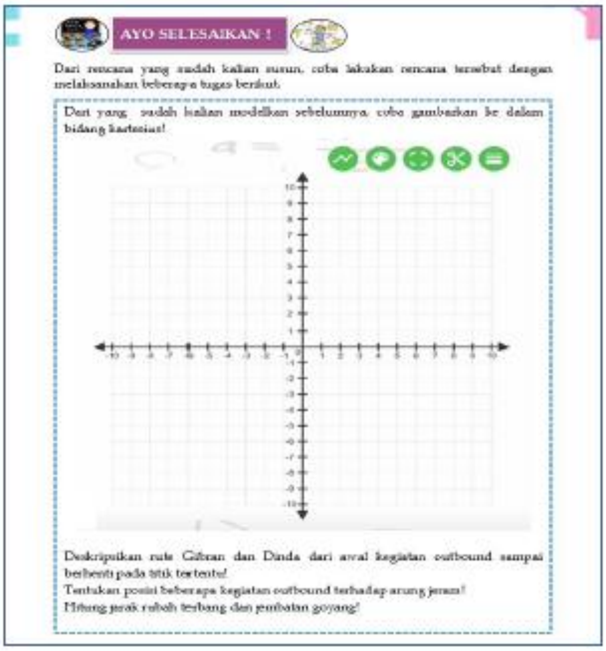


Figure 5. Student assignments at the stage of developing dan presenting problem-solving

Evaluating the process Stage

At this stage, the teacher directs students to reflect on the problem-solving process used by students. Students are asked to write conclusions from what they have learned to present after it. The task of the evaluation stage that students must do on the worksheet can be seen in Figure 6 below.

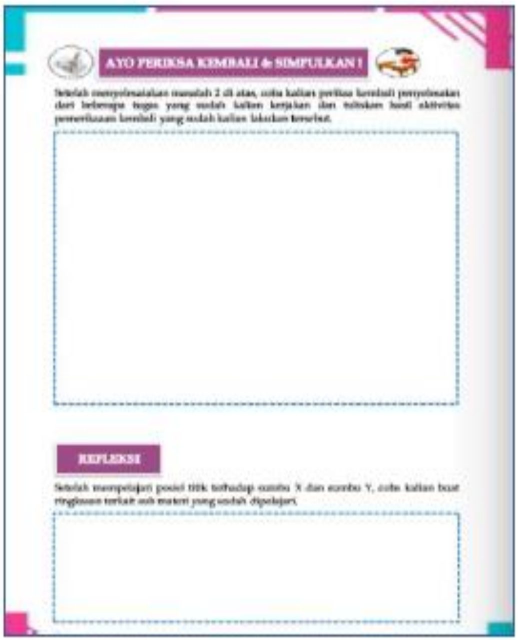


Figure 6. Student assignments at the stage of evaluating

After class implementation was carried out, the researchers gave a student response questionnaire to students as users of the electronic worksheet to measure its practicality. The student's response questionnaire results obtained can be seen in Table 3 below.

Table 3. The result of electronic worksheet practicality

Responden	Total Score	Category
PD-1	118	Good
PD-2	121	Very Good
PD-3	125	Very Good
PD-4	112	Good
PD-5	116	Good
PD-6	117	Good
PD-7	113	Very Good
PD-8	116	Good
PD-9	120	Very Good
PD-10	113	Good
PD-11	119	Very Good
PD-12	115	Good
PD-13	114	Good
PD-14	118	Very Good

PD-15	119	Very Good
PD-16	110	Good
PD-17	128	Very Good
PD-18	114	Good
PD-19	118	Very Good
PD-20	123	Very Good
The total score of 20 responden	2312	
Average	**115,6**	
Criteria		**Good**

Based on Table 3, it is known that the average score of students who students' worksheet users are 115.6, which is included in the criteria 'good'. So with the practical value of the electronic worksheet of 115.6, that can be said that the electronic worksheet is practical to be applied used by students or teachers in learning mathematics.

Stage of Evaluation

At this stage, the researchers gave a post-test related to students' mathematics communication skills after receiving an electronic worksheet. The post-test result would then be compared with the result of the pretest that had been carried out before the analysis stage was carried out. A comparison of the results of the pretest and post-test of the students was carried out to assess the effectiveness of the electronic worksheet by using the test questions on mathematics communication. Before testing the two test results, the researchers tested the normality of the data using the Shapiro Wilk test. From the results of testing the normality data for the pretest, a significance value (p-value) = 0,404. For the post-test data, it is obtained a significance value (p-value) = 0,167. Because the p-value of the second test is > 0.05, the data meets the requirements for normality of the distribution data. Then, paired data test was performed using paired sample t-test with SPSS software.

The paired sample t-test shows that the significance value (p-value) = 0.000. Because p-value < 0.05 then H0 is rejected. In other words, there is a significant difference between students' mathematics communication before and after using electronic worksheets. Next, the researchers calculated the N-Gain value of the students showing the results of the calculation of 0.69, which means the increase in students' mathematics communication skills is in the moderate category. In other words, the electronic worksheet in this research effectively increases mathematics communication skills.

Improving students' mathematics communication skills by selecting PBL models and the use of electronic worksheets in Cartesian coordinate learning shows the importance of learning designs that can provide meaningful learning experiences to stimulate students' mathematics communication skills, as presented by Mahmudi (2006). According to Mahmudi (2006), teachers will provide learning experiences to students through various opportunities to communicate ideas mathematically with the right learning design. The learning design itself can be in the form of learning tools, one of which is in the form of worksheets so that learning takes place in a fun, efficient manner and optimizes all students' skills according to their psychological development (Andriyani, 2020). So, this worksheet can be an alternative teaching material that teachers can use to meet the needs of fun interactive teaching materials during online learning in the pandemic era and towards the era of society 5.0. Because in that era, almost all sectors, including education, must be able to adapt and transform through a learning system that optimizes the use of online and internet communication technology (Buliali et al., 2022).

▪ CONCLUSION

The type of research is research and development (R&D). The development model of the electronic student worksheet based on PBL developed in this study can be said to meet the criteria of practicality and effectiveness based on the results of the product development feasibility test. The validity of the electronic student worksheets is indicated by the fulfillment of the very good criteria in terms of the material with an average validation score of 86.33 and the very good criteria in terms of the media with an average validation score of 127. The practicality of the learning media is indicated by the fulfillment of the very good criteria in terms of student responses, with an average score of 115.6. The effectiveness of electronic student worksheets is shown by the difference between pretest and post-test scores on students' mathematical communication skills. Finally, the average post-test score was more significant than the average pretest score, which can also be seen in the moderate category's increase between pretest and post-test scores. Therefore, the electronic student worksheet used has proven to be a solution to the problem of the low level of mathematical communication of students in learning Cartesian coordinates.

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