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Development of Mathematics Didactic Design with Integration of Peer Instruction Regarding Representational Ability of High School Students

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Mathematical Representation Ability.

ABSTRACT

This study focuses on the ability of representation with the integration of peer instruction which was developed through didactic design development research. The purpose of this research is to develop a didactic design in the form of learning tools, which are referred to in this study, namely: Lesson Plans, Teaching materials in the form of Student Worksheet in the form of student guides containing material information, sample questions, and practice questions. According to the problems experienced by students related to the ability of representation. The process of developing learning tools using Didactical Design Research (DDR), consists of didactic situation analysis, metapedadidactic analysis, and retrospective analysis. The didactic design developed was validated by 3 experts, namely 1 mathematics education lecturer and 2 high school mathematics teachers. The results showed that the learning plans were obtained in the form of a didactic design in the form of lesson plans that integrated peer instruction and worksheets for 8 meetings with the overall results of each aspect of the learning device being analyzed descriptively by revising the didactic design based on input and notes from the validator. Mathematics didactic design in high school to minimize learning obstacles related to students' representational abilities, includes 1) The material begins with the introduction of problems that are suitable for the situation and even related to the context of daily life, providing an overview of the benefits of the material to be studied, 2) Strengthening the material prerequisites presented at the first meeting, 3) Integrating peer instruction in the implementation of mathematics learning, 4) Providing scaffolding at the time of learning, 5) Student work and assignments are corrected and confirmed directly. In addition, the process of strengthening the visual representation process, modeling or mathematical expression, and the process of making written words presented on the worksheets is also carried out. Thus, the mathematical didactic design with the integration of peer instruction has provided appropriate learning activities; the purpose, depth and accuracy of the concepts and materials presented are traceable, communicative, the clarity of the images and spelling is appropriate, there is no correction given by the validator, so it can be implemented with the aim of developing students' mathematical representation abilities.

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A. INTRODUCTION

Mathematics learning in high school is oriented not only to achieving goals in obtaining mathematical knowledge but being trained on how to develop thinking skills to solve problems related to problems in everyday life through various activities that are adapted to intellectual development to produce the abilities to be achieved in the future high school level.

One of the goals of high school mathematics learning is to communicate ideas and compile mathematical proofs by using complete sentences, symbols, tables, diagrams, or other medians to clarify the situation or problem (Permendikbud Nomor 59 Tahun 2014). In high school mathematics learning, one of the competencies that students must have is the ability to communicate mathematical ideas clearly and effectively (Permendikbud Nomor 21 Tahun 2016). The ability to interpret or communicate mathematical ideas or thoughts in an external form is a representational ability.

Mathematical representation ability is one of the objectives of learning mathematics in schools (NCTM, 2000). Which is used as a tool to communicate ideas and find solutions to mathematical problems. Students still have difficulty in performing mathematical representation skills. Lack of prerequisite knowledge, lack of representation ability (Khasanah, 2015). Therefore, how to communicate problems using representations must be owned by all students, not only high-ability students.

There have been many studies that have examined the ability of mathematical representation in Indonesia, including Yusnita et al., (2016), Arnidha (2016), Kholiqowati et al. (2016), Rezeki (2017), Putra (2018), Wilujeng (2019), but all of the research carried out mostly uses learning models to develop students' mathematical representations, without the help of didactic designs that are tailored to the needs-based on learning obstacles that occur. students and do not pay attention to the interaction between students and the learning resources used. Research that examines the ability of mathematical representation internationally, among others, is Bruner & Kenney (2014) understand how mathematics learning from the type of symbolizing representation can occur, for students using learning media, some aspects occur that affect their learning, namely the role of construction, use of notation, different and varied places, characters, or insights. Kilic (2015), examines that the process of making a pattern in mathematics is an activity that needs to use many types of representations such as physical material, verbal, numbers or symbolic rules and, images, the results of the study reveal that the use of different types of representation and translation among representation is very important and can improve students' algebraic thinking skills and students' level of creativity.

The reasons for developing a didactic design include producing new didactic designs with interventions and situations that are in accordance with the needs of students by using certain theoretical frameworks based on the reality of students' understanding of representational abilities based on didactic situations and learning paths that have been carried out previously.

Based on the fact that the lesson plans prepared by the teacher only pay attention to interactions between students, students, and teachers but there has not been any interaction between students and the material. In line with (Yunarti, 2014) the lesson plan prepared by the teacher only pays attention to interactions between teachers and students and between students, while student interactions with the material tend to be ignored. So the teacher often repeats the basic concepts or prerequisite materials that have been studied and should have been mastered by students. Not all teachers can help students' learning process by teaching, designing information to be more meaningful and more relevant to the needs of their students.

One of the efforts that teachers can do is to prepare a good mathematics learning design, namely by making more detailed learning plans and designed with alternative strategies to anticipate student problems and various possible student responses that occur during the learning process or the diversity of learning trajectories (Hypothetical Learning Trajectory). HLT becomes the Anticipation of Pedagogic Didactics (ADP), namely the synthesis of the results of the teacher's thinking based on various possibilities that are predicted to occur in learning events (Suryadi, 2010).

The didactic design in mathematics learning is the design of teaching materials made by the teacher with the condition of paying attention to student responses, where before the learning process takes place the teacher makes learning so that the sequence of activities and didactic situations can be pursued in accordance with what has been planned regarding material in mathematics learning to facilitate the learning process regarding mathematical knowledge, in this case, the ability of representation.

Based on the background that has been described previously, the purpose of this research is to develop a didactic design for integrating peer instruction mathematics in the form of lesson plans and worksheets related to the ability of students' representation in high school mathematics learning.

B. METHODS

The type of research used in this study is Didactical Design Research (DDR), formal steps in DDR (Suryadi, 2010), namely didactic situation analysis, metapedadidactic analysis, and retrospective analysis. The data collection technique in this didactical design development research used a questionnaire. To analyze the expert validation data, a descriptive analysis will be used by revising the didactic design based on input and notes from the validator, which was carried out by 1 mathematics education lecturer and 2 high school mathematics teachers.. The aspects assessed consist of: a) Subject identity; b) The suitability of basic competencies and learning objectives; c) the suitability of the formulation of the subject matter; d) Preparation of opening activities; e) Preparation of core activities; f) Preparation of closing activities. The design that the researcher arranged was also assessed in terms of the feasibility of the material concept to see the practicality and effectiveness of teaching materials, the aspects of the assessment consisted of: a) The purpose of the material; b) Depth of material; c) Concept accuracy. Descriptive analysis is used to revise teaching materials based on input and notes from the validator

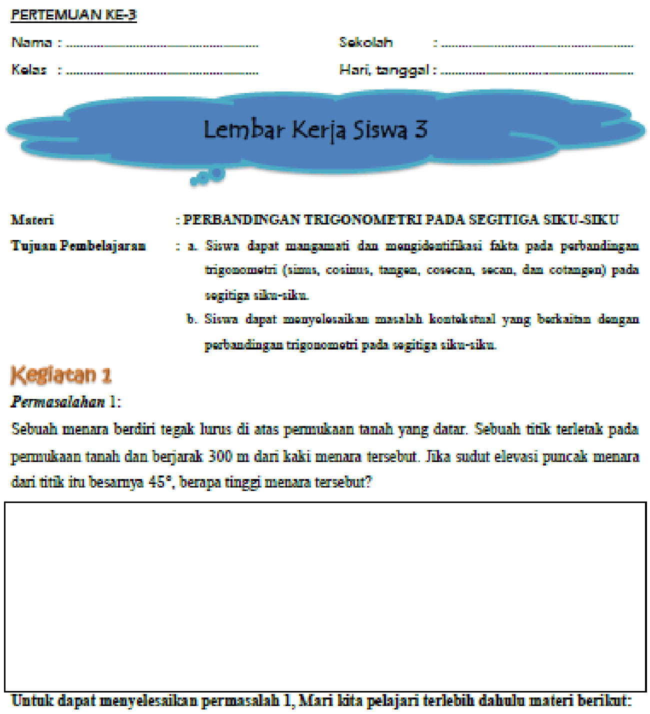
C. RESULT AND DISCUSSION

The result of this research is the development of a mathematical didactic design in the form of lesson plans and worksheets related to mathematical representation abilities that integrate peer instruction and worksheets in 8 meetings. This research and development are carried out using development procedures.

In the early stages of the research carried out was to identify learning obstacles that occurred in students' representational abilities based on literature studies conducted and preliminary research that had been carried out by researchers which resulted in learning obstacles consisting of 3 types according to Broussaeu (Suryadi, 2019), namely: 1) ontogenically learning obstacles , namely learning barriers based on psychology, where students have learning difficulties because of the mental readiness factor for student learning, in this case, the way of thinking of students who have not entered because of age, students' limitations in self-development; 2) Didactical learning obstacles, namely obstacles that arise based on the sequence and stages of the curriculum including its presentation in class (Suryadi, 2018), including the method or approach used. 3) Epistemological learning obstacles, namely obstacles that occur due to the limitations of the context used in the didactic design (Suryadi, 2018), obstacles regarding the knowledge possessed by students in certain contexts that are incomplete.

Then the researchers determined the learning objectives, in this study the chosen mathematical concept was learning on trigonometry material. Because the trigonometry material is one of the topics that exist at the high school level and is included in the compulsory subject group and is a requirement for further mathematics material. Trigonometry material has a very close relationship with algebra, geometry, and functions (Solikin, 2016; Price & Van Jaarsveld, 2017). Comparison of trigonometry is one example of a material that is considered quite difficult by some high school students in class X. But in fact, trigonometry is one of the difficult subjects to understand in high school mathematics and is not liked by most students (Gerhana et al., 2017; Kamber & Takaci, 2018), even though the concept of trigonometry is used as prerequisite material for other materials such as three dimensions, limits, integrals, and others.

The didactic situation analysis before learning (prospective analysis) focuses on the relationship between teacher, student, and material so that it can be a direction in the implementation of learning in the form of a Hypothetical Learning Trajectory. According to (Simon, 1995), HLT consists of three: learning objectives, learning activities, and teaching-learning situation hypotheses. So that HLT can serve as a guide in designing teaching materials that focus on students' mathematical representation abilities. In this study, HLT includes Didactic and Pedagogical Anticipation (ADP), consisting of 1) The main teaching materials are designed in the form of Student Worksheets (material and problem guides) that direct each student to go through the process or indicators of mathematical representation ability; 2) Learning activities are carried out in a variety of ways, consisting of independent, group work, intergroup work, and class discussions, this makes it possible for each student to learn meaningfully; 3) Using scaffolding techniques that are possible can change the existing didactic situation so that the respondent's thinking process becomes more focused.


PERTEMUAN KE-3

Nama : .... Sekolah : ....

Kelas : .... Hari, tanggal : ....

Lembar Kerja Siswa 3

Materi : **PERBANDINGAN TRIGONOMETRI PADA SEGITIGA SIKU-SIKU**

Tujuan Pembelajaran :
a. Siswa dapat mangamati dan mengidentifikasi fakta pada perbandingan trigonometri (sinus, cosinus, tangen, cosecan, secan, dan cotangen) pada segitiga siku-siku.
b. Siswa dapat menyelesaikan masalah kontekstual yang berkaitan dengan perbandingan trigonometri pada segitiga siku-siku.

Kegiatan 1

Permasalahan 1:

Sebuah menara berdiri tegak lurus di atas permukaan tanah yang datar. Sebuah titik terletak pada permukaan tanah dan berjarak 300 m dari kaki menara tersebut. Jika sudut elevasi puncak menara dari titik itu besarnya 45°, berapa tinggi menara tersebut?

Untuk dapat menyelesaikan permasalah 1, Mari kita pelajari terlebih dahulu materi berikut:

Figure 1. Example of Activity 1 on Student Worksheet Meeting 3

After obtaining a learning device in the form of a mathematical didactic design in high school to minimize learning obstacles, namely, 1) the material begins with the introduction of problems that are suitable for the situation and even related to the context of daily life, providing an overview of the benefits of the material to be studied, which can be seen in

Picture. 2) strengthening the prerequisite material presented at the first meeting. 3) Integrating peer instruction in the implementation of mathematics learning. The learning steps using modified peer instruction (Crouch & Mazur, 2001) are integrated into the worksheet, as follows: individually students consider or work on the problems presented; students work in small groups (3-4) students to discuss each other's answers to arrive at the correct answer decision, students are asked to answer the question a second time individually; and class discussions led by the teacher based on the findings from the group and clarifying them. 4) Provide scaffolding at the time of learning. Scaffolding techniques can be used in addition to directing the thinking process (Shabani, 2016; Hebe, 2017), scaffolding is prepared by the teacher not to change the nature or level of difficulty of the task but allows students to successfully complete the task (Suryadi, 2019). 5) student work and assignments are corrected directly.

Mathematics didactic design in high school is to minimize learning obstacles that occur in students related to the representation ability process, namely by strengthening the visual representation process, strengthening the process of making mathematical equations or expressions, and strengthening the process of making written words. So that the activities presented in the lesson plan consist of 1) in the preliminary activity designing learning by presenting problems related to concepts related to the real world whose solutions are using; 2) In the core activity, a worksheet is made that allows students to get used to visualizing the material; 3) In the core activity, a worksheet is made that allows students to get used to the use of formulas, patterns or symbols that have been obtained previously with the material being studied in the calculation and proof process; 4) In the core activity, worksheets are made that allow students to get used to making arguments or conclusions not only in the form of oral but in the form of written words; 5) Practice questions are presented at each meeting that is adjusted to the ability of mathematical representation, for example, presented in Figure 2; 6) Learning integration of peer instruction.

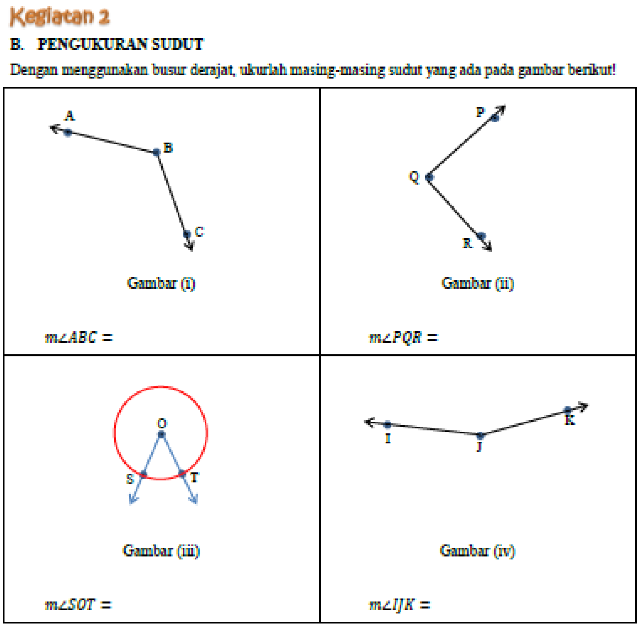


Figure 2. Example of Activity 2 on Student Worksheets

The didactic design developed also pays attention to three didactic processes (Brousseau & Warfield, 2020), 1) Situation of Devolution, the teacher arranges students to accept challenges boldly and confidently from a given mathematical situation and is instructed what to do without the help of the teacher and done by the teacher. students themselves with full responsibility. This happens when the worksheet is given by giving problems related to the material to be studied in certain situations or situations in real context problems with peer instruction integration; 2) Situation of Mathematical, the teacher directs to find material and solve problems by making the representation ability process presented on the worksheets that are done individually or in groups, discussing answers and problems and communicating the results of the work; 3) Situation of Institutionalization, Clarifying the results of the material and solving the questions presented by students, strengthening the material, making conclusions and informing the next material.

In the metapedadidactic analysis process, developing actions so as to create didactic and pedagogical situations, recontextualizing, personalizing according to student needs, identifying and analyzing student responses as a result of didactic and pedagogical actions taken. Then take further didactic and pedagogical actions based on the results of the analysis of student responses towards the achievement of learning targets.

Table 1. Example of a Didactic Situation Analysis, Response, and Anticipation of a Pedagogical Didactic Meeting 3

No	Didactic Situation	Response	Pedagogical Didactic Anticipation
1	Students are asked to solve problem 2, in the form of story questions whose answers are made in cartesian coordinates, and students are asked to fill in questions related to the problem	Students can solve problems	a. Students confirm the answers that have been made. b. The teacher does scaffolding by asking questions related to other ways or different ways of solving problems
		Students cannot solve the problem	a. The teacher guides students to determine what they already know, then asks to illustrate in catesian coordinates b. Teachers and students who can solve problems do scaffolding
2	Students are asked to solve problem 3, in the form of questions presented in the form of a right triangle image and students are asked to fill in questions related to problems in the form of trigonometric comparisons	Students can solve problems	a. Students confirm the answers that have been made. b. The teacher does scaffolding by asking questions related to other ways or different ways of solving problems
		Students cannot solve the problem	a. The teacher guides students to determine what they already know from the picture of a right triangle, then fill it in to the points in the question. b. Teachers and students who can solve problems do scaffolding
3	The teacher confirms and gives conclusions about trigonometric comparisons in the form of power point	students understand the subject matter	Students are guided to fill in the practice questions in the next section
		students do not understand the subject matter	Teachers or students who already understand explain the material they do not understand
4	Students work on evaluations in the form of practice questions and solve problems 1	Students can answer	a. Students confirm the answers that have been made. b. The teacher does scaffolding by asking questions related to other ways or different ways of solving problems
		Student cannot answer	Teachers and students who can answer, guide students and do scaffolding

Design validation is a step to assess whether the product development design made is feasible or not to be used in SMA. After the product design is complete, then an assessment is carried out by experts. The readability test aims to determine the validity of the material, as well as the ease or difficulty of students when understanding the teaching materials used in learning mathematics. Based on 1 mathematics education lecturer and 2 mathematics teachers, they have understood all the material and can follow every step of the learning carried out. According to them, the material presented is traceable, communicative, the clarity of the image and the spelling are appropriate. Furthermore, by revising the product based on the input from the validator, in this study the revision stage was the last stage, but no correction was given. The revised didactic design will become a learning material that meets the standards of attractiveness of learning materials in terms of material, educational practitioners, and language. So that the resulting didactic design of teaching materials (modules) for trigonometry material in Mathematics learning is expected to develop the representation ability of high school students. But not until the product trial. This activity will be carried out as a continuation of the research that will be carried out by researchers. Based on the results of the validation carried out by the validator, so that the reference is used to see that the didactic design and teaching materials produced are feasible and can be implemented with the aim of developing students' mathematical representation abilities.

D. CONCLUSION AND SUGGESTIONS

The didactic design was developed based on the results of the preliminary analysis conducted to see the learning constraints and theoretical analysis. Based on the results of the analysis, it produces a Hypothetical Learning Trajectory which is developed into a hypothetical didactic design that considers devolution situations, mathematical situations, and institutionalization situations. The design of mathematics didactics in high school to minimize learning barriers related to students' representational abilities, includes 1) The material begins with the introduction of problems that are appropriate to the situation and even related to the context of daily life, providing an overview of the benefits of the material to be studied, 2) Strengthening the prerequisites of the material presented at the first meeting, 3) Integrating peer instruction in the implementation of mathematics learning, 4) Providing scaffolding during learning, 5) Student work and assignments are corrected and confirmed directly. In addition, the process of strengthening the visual representation process, mathematical modeling or expression, and the process of making written words presented on worksheets are also carried out. The mathematical didactic design with integrated peer instruction developed by the researcher is suitable for use in accordance with the results of the validator, which has presented appropriate learning activities; the purpose, depth and accuracy of the concepts and materials presented are traceable, communicative, the clarity of the images and spelling is appropriate, there is no correction provided by the validator, so that it can help students to learn more independently and comfortably in the learning process and students are very interested in teaching materials . After that, the didactic design was modified from a hypothetical didactic design based on the results of a retrospective analysis of students' representational abilities in high school which could be implemented with the aim of developing students' mathematical representation skills.

Suggestions for the next researchers are to continue research to the implementation or experiment stage of this module to see the quality of this module itself. Hopefully, this research can be useful and become a source of reference or reference for further research or the basis for implementing learning with the didactic design that has been developed.

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