Development of learning instructions on mathematics learning based on M-APOS to improve problem-solving ability of grade VII students of middle school / MTs

Yerizon, Armiati, L Fadhilah and N Afifah Rusyda
Universitas Negeri Padang
Email: yerizon@fmipa.unp.ac.id

Abstract. This study discusses the development of mathematical learning instructions based on the M-APOS theory. It aims to produce a mathematical learning instruction based on the M-APOS theory for students on grade VII of SMP / MTs of the second semester which is valid, practical, and improve students' mathematical problem-solving abilities. The type of research is research and development which develops lesson plans and worksheets. The Plomp model was used in this study consisted the preliminary analysis phase, the prototype development stage, and the assessment stage. In the preliminary stage, a needs analysis, curriculum analysis, concept analysis and analysis of students is carried out. At the prototype development stage, a formative evaluation was carried out consisting of self-evaluation, one-to-one evaluation, expert review, small group evaluation, and field test. The subjects of this study were VII grade students of SMP Negeri 2 Pasaman. Based on the field test, learning instructions, the RPP and LKPD based on M-APOS mathematics for class VII SMP in the second semester, are valid, practical and effective. Valid is from aspects of content, presentation, language, and graphics. Practical is in terms of implementation, time, ease of use. And effective is in terms of its potential impact on students' mathematical problem-solving abilities.

Keywords: Learning Instructions, M-APOS Theory, Problem Solving, worksheet.

1. Introduction
Mathematics is a subject that has important roles and functions for students. According to Cornelius (in [1]) there are five important reasons for learning mathematics; (1) the means of thinking clearly and logically, (2) the means to solve the problems of daily life, (3) the means of recognizing patterns of relationships and generalizing experiences, (4) the means to develop creativity, and (5) the means to improve awareness of cultural development.

Problem solving ability is one of the goals of mathematics learning at school. According to Hudojo [2] problem solving has an important function in mathematics teaching and learning activities. Through problem solving students can practice and integrate concepts, theorems and skills that have been learned. But in fact, the students’ problem solving skills is low. This can be seen from several previous studies. Fauzan and Tasman [3] in West Sumatra Province concluded that students' problem solving abilities were low where the percentage of 40.957% of students scored low, 34.574% got a moderate score, and 24.468% obtained high scores. Furthermore, the research conducted by Sari et al [4] in SMP Negeri 1 Padang, 23 students who took the test of problem solving ability were only 9 students who were able to understand the given problems and 14 students did not understand those
problems. These results were also found from the results of the problem-solving ability test in several SMP / MTs in Kab. West Pasaman. The test results can be seen in Table 1.

| School Name          | Numbers of Students | Excellent (%) | Good (%) | Enough (%) | Low (%) | Very Low (%) |
|----------------------|---------------------|---------------|----------|------------|---------|--------------|
| SMP N 2 Pasaman      | 22                  | 13.63         | 9.09     | -          | 13.63   | 63.64        |
| MTs S Darussalam     | 31                  | 16.13         | 9.67     | 6.45       | 9.67    | 58.064       |

The low level of mathematical problem solving abilities of students is caused by several factors. One of the factors is the learning resources used by teachers in learning, namely worksheets (LKPD). The LKPD used so far has not been able to make students have good problem solving skills. For this reason, it needs to be corrected and added to the LKPD so that students become active in constructing their understanding to find a mathematical concept. In addition, the problems given in the LKPD do not lead to contextual problems or issues of daily life that are close to students. Things like this can cause students to be unable to solve mathematical problems in daily life so that the goals of mathematics learning will be difficult to reach.

Therefore, the used LKPD needs to be added activities for constructing and finding students’ understanding. Because students are directly involved in learning, the concepts learned will stay longer in the minds of students [5]. The problems presented in the LKPD should be in the form of contextual problems so that students are accustomed to solving mathematical problems in their daily lives so that the mathematical abilities of students can be increased, and the goals of mathematics learning can be obtained by students. To guide the implementation of the LKPD it is necessary to design a lesson plan (RPP) with the M-APOS approach in accordance with the 2013 curriculum. M-APOS is a modification of APOS (Action, Processes, Objects and Schemes) ([6], [7]).

Modifications were carried out in the activity phase, where activities in the computer laboratory in the APOS model were replaced by giving recitation assignments given before the learning was carried out. Recitation assignments are presented in the form of student activity sheets that guide students in reviewing concepts or solving mathematical problems.

M-APOS is considered able to improve students' problem-solving abilities, because solving a problem will certainly involve a high level of thinking process. In this thought process, an idea cannot suddenly appear in the mind. Ideas occur after a variety of actions and processes. The activities of M will go through several stages of mental construction, namely: (1) Action, at this stage is done by giving step-by-step instructions on how to do the operation, (2) Process, which is a mental construction that occurs internally when students take action repeatedly, (3) Objects, can be interpreted as something that results from mental construction that has been done at the process stage, and (4) Scheme, namely a collection of actions, processes, and objects that are summarized into a scheme [8].

2. Methods

This research is research and development. In this study, learning instructions in the form of Mathematics RPP and LKPD will be made for students of VII grade SMP / MTs in second semester. Products that have been developed are tested the validity, practicality and effectiveness.

The development model used in this study is the Plomp model which consists of 3 stages. They are the preliminary research phase, development or prototyping phase, and the assessment phase [9].

The procedure of product development is focused on three phases. Each of these phases is briefly shown in Table 2:
Table 2. Phase in Product Development

| Phase in Product Development | Emphasis on content validity | Problem analysis and literature studies. The results of this phase are a form of initial prototype design |
|-----------------------------|-----------------------------|-----------------------------------------------------------------------------------------------|
| Preliminary Research        | Focus on consistency (construct validity) and practicality. Furthermore, prioritizing practicality and gradually towards effectiveness. | Development of prototypes that will be piloted in stages and revised based on the formative evaluation phase |
| Prototyping Stage           | Practicality and effectiveness | Assess whether the user can use the product with practicality (practicality) and effective and willing to apply it |

2.1. Preliminary Research Stage

In general, the details of the activities carried out at the Preliminary Research stage are presented in Table 3.

Table 3. Details of Preliminary Research

| Research Activities       | Method of collecting data | Instrument | Goal | Result |
|---------------------------|---------------------------|------------|------|--------|
| Needs Analysis            | Teacher interviews, student questionnaires, observations and tests | Interview guidelines, observation sheets, initial tests of problem-solving skills and questionnaires | Knowing the problems found in mathematics learning and their causes and seeing the implementation of learning and the use of learning tools and also to find out more detailed problem-solving abilities of students | The type of product that is suitable to be developed. |
| Curriculum Analysis       | Documentation              | Documentation of teaching materials | Studying basic competencies to develop indicators of achievement of learning outcomes | Indicators of achievement of learning outcomes |
| Analysis of students      | Questionnaire              | A list of questions | To find out the characteristics of students, the age of students, the learning methods preferred by students, the presentation of LKPD that students like | The type of product that matches the characteristics of students |
| Concept Analysis          | Documentation              | Concept documentation | To study the design of material organizing, time allocation, the design of appropriate devices is based on the M-APOS theory | Material organizing units and time allocation, draft RPP and LKPD based on M-APOS theory |

2.2. Development or Prototyping Phase
Based on the results of the analysis at the preliminary stage, RPP and LKPD based on M-APOS were prepared for all material in the seventh semester of SMP / MTs. Designing lesson plans in accordance with the format contained in Permendikbud Number 65 of 2013 concerning Basic and Secondary Education Process Standards, Permendikbud Number 81A in 2013. Designing LKPDs in accordance with the Guidelines for Development of Teaching Materials issued by the Ministry of National Education in 2008 taking into account the feasibility of content, language, presentation, and graphics. At this design stage, a framework is based on the components of the LKPD.

The design results at this stage produced a prototype I mathematics learning instruction. Then the prototype is evaluated by referring to formative evaluation. Formative evaluation has several steps illustrated in Figure 3.

![Figure 1](image_url)

**Figure 1.** Formative Evaluation of Plomp Development Model [9]

Based on Figure 3, the activities carried out in formative evaluation in this study consisted of self-evaluation, expert validation, individual evaluation, small group evaluation, and field test.

2.3. Assessment Phase

After a one-to-one evaluation and small group evaluation, a limited trial (large group trial) was carried out in one class. At this stage it aims to determine the extent of the practicality and effectiveness of the mathematics learning tools developed in the implementation of learning. Based on the results of one class trial, the results of the trial data were analyzed and the mathematics learning instruction was revised again. Trials and revisions can be done repeatedly until a practical and effective prototype of a mathematics learning instruction is obtained.

Learning tools that are valid are tested on a limited basis in one junior high school in West Pasaman Regency. Limited testing is done to measure the practicality of the devices developed, so that it can be known how far the ease of use of this instruction. Data was collected through the implementation observation plan RPP, student response questionnaire and teacher response questionnaire. The procedure for development trials is summarized in Figure 4.
The subjects of trial of the development of M-APOS-based learning instruction were students of SMPN 2 Pasaman. The types of data taken from this study are qualitative data and quantitative data. Qualitative data was obtained from the results of interviews during the trial, in the form of input, comments, criticisms and suggestions, while the quantitative data were obtained from the results of questionnaires, observation sheets and problem-solving ability tests.

3. Results and Discussion

3.1. Validity of M-APOS Based Learning Instructions
The validity test of M-APOS-based learning instructions is carried out by 5 experts. Experts who become validators come from 3 fields of expertise namely Mathematics, Educational Technology and Indonesian Language. RPP validation is carried out by 4 experts, consisting of 3 Mathematics experts and 1 Indonesian Language expert. Aspects assessed in RPP are aspects of presentation / didactic, content aspects, and linguistic aspects. The M-APOS-based LKPD validation was conducted by 5 experts, namely 3 mathematics lecturers, 1 language lecturer, and 1 education technology lecturer. The observed aspects are didactic aspects / presentation, content, language and graphics.

The following is a summary of the results of the RPP and LKPD based on M-APOS validation.

Table 4. Test Results for the Validity of Learning Instructions

| No. | Learning Instructions | Average Rating | Category   |
|-----|-----------------------|----------------|------------|
| 1   | RPP                   | 3.60           | Very Valid |
| 2   | LKPD                  | 3.69           | Very Valid |
|     | Average Overall Rating| 3.64           | Very Valid |

Table 4 shows that the developed learning instruction has an average value of 3.64 in the very valid category. In addition, based on the validator's assessment of the learning instructions based on M-APOS, it can be concluded that these instructions are valid [10].

During the validation stage of the RPP and LKPD there were several revisions made based on suggestions from the validator. For example, the font size is not suitable, the sentence is unclear, the problem is poorly understood, instructions are unclear.
3.2. Practicality of Learning Instruction based on M-APOS

Learning Instruction based on M-APOS is said to be practical because it meets the criteria of ease of use, interesting, easy to understand, time efficiency, and equivalence. In addition, based on the teacher's response questionnaire and students' response questionnaire, it shows that the developed learning instruction is interesting and easy to use, so it can be concluded that the learning instructions based on M-APOS is practical.

3.3. Effectiveness of Learning Instruction based on M-APOS

In this study the effectiveness of learning instruction is seen from students' problem-solving abilities. Tests of problem solving abilities of students are carried out before learning and after learning using learning instructions based on M-APOS. There is an increase in the results of problem-solving ability tests before and after the application of learning instruction.

The effectiveness test of learning instruction aims to determine the impact that occurs on students after using learning instruction based on M-APOS. The potential impact tested in the study is the students' problem solving abilities, so that the potential impact of learning instruction based on M-APOS is measured through initial tests and final tests of students' problem solving abilities. After obtaining the results of the initial test and the final test of students' problem solving abilities, the data regarding the value can be seen in Table 5.

Table 5. Descriptive Statistics Scores of Initial Test and Final Test

|          | N   | Mean | S    | Max Value | Min Value |
|----------|-----|------|------|-----------|-----------|
| Initial Test | 29  | 43.99| 24.17| 84.85     | 0         |
| Final Test  | 29  | 81.50| 11.23| 93.94     | 51.52     |

From Table 5 it can be seen that the average final test results are higher than the results of the initial test of mathematical solving abilities of students. The difference between the average initial test and the final test is 37.51. Meanwhile, the variance of the initial test results was higher than the last test. This shows that the results of students' problem-solving abilities after following the study using learning instruction based on M-APOS are better and more uniform than before using it.

For more accurate results, a statistical test of the results of the initial test and final test is carried out. Based on the results of the normality test on the data from the initial test results obtained $L = 0.0823$ and $L_{table} = 0.187$ with $N = 29$. Because $L = 0.0823 < L_{table}$, it can be concluded that the distribution of initial test data values is normally distributed. Furthermore, from the normality test of the data the final test results obtained $L = 0.1759$ and $L_{table} = 0.187$ with $N = 29$. Because $L = 0.1759 < L_{table}$, it can be concluded that the distribution of data is normally distributed.

From the normality test of the results of the initial test and the final test, the students are normally distributed. The statistical test used for the hypothesis test is the parametric test, namely the $t$ test for paired observations. Based on the results of the analysis of the initial test and the final test it was found that $t = -6.835$ and $t_{table} = 1.701$ with free degrees $(df) = 28$. Because $-6.835 < -1.701$ or $t < t_{table}$, it can be concluded that the average final test results ability students 'mathematical problem solving is higher than the average results of the initial test of students' mathematical problem-solving abilities.

Besides using parametric statistical tests, the following will also describe the increase in the percentage value of each indicator of students' problem-solving abilities before and after using learning instructions based on M-APOS. The results of increasing the percentage value for each indicator of problem-solving ability can be seen in Table 6.
Table 6. Percentage of Value for Each Problem-Solving Indicator

|           | Percentage for Each Indicator |
|-----------|-------------------------------|
|           | 1    | 2    | 3    | 4    |
| Initial Test | 75.33 | 41.67 | 44.67 | 25.33 |
| Final Test  | 98.67 | 87.33 | 83.00 | 62.67 |
| Improvement | 23.34 | 45.66 | 38.33 | 37.34 |

From Table 6, it can be seen that the percentage value of each indicator of problem solving ability in the final test is higher than the results of the initial test, meaning that there is an increase in the percentage value for each indicator of mathematical problem solving ability after learning using learning instructions based on M-APOS.

Based on the results of parametric statistical tests and description of the increase in percentage values for each indicator of problem solving ability of students, it can be concluded that the learning tools in the form of RPP and LKPD have a positive impact on students' problem solving abilities or it can be said that learning instructions based on M-APOS are effective.

This is also supported by several previous studies. Lestari [7] reported that the improvement of mathematical problem-solving abilities of students whose learning uses the M-APOS learning model is better than students whose learning uses conventional learning models that use expository methods. This can be seen from the results of the analysis of index data from the two classes which showed that the improvement of the mathematical problem-solving ability of the experimental class was better than the control class.

Arnawa et al [11] reported that APOS activities were able to improve the ability of students to understand the system of linear equations. Yerizon et al [8] also found that the M-APOS approach can improve the mathematical communication skills of middle school students. Based on the things that have been stated above, it can be concluded that the learning instructions based on M-APOS theory is able to improve the mathematical problem-solving abilities of Grade VII students of SMP / MTs.

4. Conclusion

Based on the results of the research and discussion it can be concluded that the learning instructions based on M-APOS developed has been valid for every aspect of the assessment, has met the practical criteria both from the aspect of implementation, ease and time required. This learning tool has been effective, it can be seen from the average final test results of students 'problem solving abilities higher than the average results of the initial test of students' problem solving abilities.

References

[1] Abdurrahman M 2012 Anak berkesulitan belajar: Teori, diagnosis, dan remediasinya (Rineka Cipta: Jakarta)
[2] Hudojo H 2005 Pengembangan Kurikulum dan Pembelajaran Matematika (Malang: Universitas Negeri Malang)
[3] Fauzan A and Tasman F 2012 Analisis Literasi Matematis Siswa SM di Sumatera Barat (Padang)
[4] Sari S, et al 2014 Pengaruh pendekatan Pembelajaran Berbasis Masalah Terhadap kemampuan pemecahan masalah Matematika siswa kelas VIII SMP Negeri 1 Padang Jurnal Pendidikan Matematika 3 54-9
[5] Nitiaroza, Arnawa I M and Yerizon 2018 Practicality of Mathematics Learning Tools Based on Discovery Learning for Topic Sequence and Series,” Int. J. Sci. Technol. Res. 7 236–41
[6] Yerizon 2011 Peningkatan Kemampuan Pembuktian dan Kemandirian Belajar Matematik Mahasiswa Melalui Pendekatan M-APOS Doctor Dissertation
[7] Lestari K E 2015 Penerapan model pembelajaran M-APOS untuk meningkatkan kemampuan pemecahan masalah matematis siswa SMP Jurnal Pendidikan Uniska 3 45-52
[8] Yerizon, Armiati, Tasman F and Abdullah B 2019 Development of student worksheets based on m-apos approach with mind mapping to improve mathematical communication ability of grade VII students of middle school *Int. J. Sci. Technol. Res.* **8** 352-6

[9] Plomp T and N Nieveen 2013 *Educational Design Research* (Enshede: Netherlands Institute For Curriculum Development)

[10] Fadhilah L, Yerizon and Armiati 2018 Validity of Mathematics Learning Devices Based on M-APOS Theory to Improve The Problem Solving Ability of Students Class VII Junior High School *Proceedings of the 2nd International Conference on Mathematics and Mathematics Education 2018 (ICM2E 2018) Series: Advances in Social Science, Education and Humanities Research*

[11] Arnawa I M, Yerizon, Nita S and Putra R T 2019 Development of students’ worksheet based on apos theory approach to improve student achievement in learning system of linear equations *Int. J. Sci. Technol. Res.* **8** 287-92