Development Of Student Worksheets Based On M-APOS Approach With Mind Mapping To Improve Mathematical Communication Ability Of Grade VII Students Of Middle School

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Abstract: The purpose of this study is to produce valid, practical and effective M-APOS-based SMP / MTs math worksheets. Its effectiveness is seen from students' mathematical communication skills. This research is a development research with Plomp model with three stages, namely preliminary research, Development or Prototyping Phase, and assessment phase. The subjects of this study were Grade VII students of SMP Negeri 1, Kapur District IX. The research instruments were validation sheets, teacher and student response questionnaires, observation sheets, and tests. This research has produced a valid, practical and effective worksheet. Teachers and students gave a good response to these worksheets because it helps them in the learning process. Learning becomes efficient and students can understand easily the mathematical concepts that they learned. These worksheets also generate students' interest in learning and it can improve students' mathematical communication skills.

Index Terms: M-APOS Approach, Mind Mapping, mathematical communication skills, worksheet, middle school, valid, practical.

1 INTRODUCTION

Mathematics learning requires students to have mathematical communication skills. Mathematical communication skills in the following matters: (1) State situations, images, diagrams or real objects in the language of symbols, mathematical ideas or models; (2) Explain ideas, situations, and mathematical relations in verbal or in writing; (3) Hearing, discussing and writing about mathematics; (4) Reading with an understanding of a written mathematical representation; and (5) Revealing a description or mathematical paragraph in its own language [1]. Arends states that teachers must teach their students how to communicate mathematically [2]. According to NCTM [3] essential communication is part of mathematics and mathematics education. Mathematical communication skills can make students understand and identify existing problems, plan solutions, implement completion plans, and draw conclusions about the solutions to the problems. However, students' mathematical communication skills are still low [4], [5]. According to Armiati [4], mathematical communication skills are still the weak points of students in mathematics learning. Teachers tend to be active so that students are lack in communicating mathematics [5]. Mathematical communication skills need to be developed in the learning process that takes place at school. One of the factors used to assist students in the learning process is a worksheet. However, the existing worksheets still need to be developed to improve students' mathematical communication skills [6], [7]. Some aspects that need to be improved are (1) presenting material that is close to the daily lives of students, (2) the appearance and color are not yet interesting, (3) the appearance of the image / diagram / graph is not good. (4) The writing of mathematical symbols is unclear [8]. Sanjaya [9] said that learning resources that can be utilized by teachers in the learning process in the classroom are human resources, teaching tools and materials, various activities as well as the environment. One source of learning is a worksheet. A worksheet is a sheet containing tasks that must be done by students [10]. Worksheets can be used to convey concepts to students that aim to improve understanding of concepts [11], [12]. Worksheets designed must help students in learning and make it easy to understand a concept [13]. The solution that is expected to be used is the development of worksheets with the M-APOS approach assisted by mind mapping. The APOS theory is about how the possibility of learning a mathematical concept or principle continues. APOS theory assumes that mathematical knowledge is the result of interaction with others. These mental constructions called action [14], [15]. The Action Phase will help students to improve connecting real objects, images, diagrams and tebel in mathematical ideas based on the given stimulus from external learners [16]. Objects help in improving using ideas, situations and expressing solutions to problems. The process increases in expressing events or problems expressed in a language or mathematical symbol. Schema improves in the work of the brain processing information, storing information, conveying information, connecting between materials and reminding students about what they have learned. APOS learning consists of three components, namely ACE: (A) activities, (C) class discussion, and (E) exercises performed outside the classroom [17]. The M-APOS approach is a modification of APOS by replacing the action activities using a computer with a worksheet. APOS theory helps students construct their own knowledge. The role of the teacher is to guide students through the activities on the worksheet to understand the concept. Students must take action so that it becomes their own experience. Schema formation in students can be done through making mind mapping in the learning process. Mind mapping shows how the brain processes information. This information is conveyed in the form of communication. Students ability to connect the materials that exist with one another and improve the formation of schemes in the brain of students and remind them of what they have learned, activate their entire brain to classify concepts, transfer information from short-term memory to long-term memory. Porter [18], argues that mind mapping uses the whole brain by using visual images and other graphic feelings to form an impression. Buzan [19] says that mind mapping is the easiest way to put information into the brain and to extract information from the brain. The purpose of this study is to produce a junior high school math worksheet with the M-APOS approach assisted by mind mapping to improve students' mathematical communication skills which are valid, practical and effective.

2 RESEARCH METHODS

2.1 Review Stage

The type of this research is the design research Plomp model [20] which consists of three stages, namely preliminary research, development or prototyping phase, and assessment phase. An evaluation of product design is carried out in each phase. The development phase is shown in Table 1.

Phase	Activity Description
Preliminary research	Need analysis, curriculum analysis, student analysis, concept analysis
Development/ Prototyping Phase	Evaluation of prototypes in terms of validity, which is done through Self-Evaluation and Expert Review. After being revised, it continued with practical assessment through One-to-one Evaluation and Small Group Evaluation.
Assessment Phase	Assess whether the product has been practical and effective through a Field Test

This phase uses formative evaluation. According to Tesmer in [20] there are four stages of the formative evaluation process, namely, 1) expert review, 2) one-to-one, 3) small group, and 4) field test.

3 RESEARCH RESULTS AND DISCUSSION

3.1 Design Results

The results of the analysis found that students had difficulty to understand the problem of stories, mathematical symbols, and the language used by teaching materials. Students are not used to reading and they do not want to present their work. They involved rarely in solving problems that are given by the teacher. They agree to learn by using a worksheet because the worksheet can guide students in understanding mathematics subject matter. They easily follow all the commands on the worksheet which is made with an attractive appearance with supporting illustrations of the subject matter. Students want their worksheet in colour blue, green, yellow, red and black with interesting writing and pictures. Worksheets based on the M-APOS approach with mind mapping are sheets containing activities and problems that must be resolved that contain APOS components. This worksheet contains covers, introductory words, drafting team, table of contents, conceptual material discussed, answer key of worksheets and conclusions, practice questions and mind mapping sheets. There are three aspects that are considered in designing worksheets, namely: didactic and material, linguistic, and graphic. The following are the results of the worksheet design based on the M-APOS approach with mind mapping. The action stage begins with giving illustrations that contain problems in students' daily life that inspire them to be more enthusiastic and more eager to solve the given problems together. The worksheet includes images that are relevant to the problem. The students expected to read and to observe the problems given, to ask questions, to gather information by understanding the given problems and by processing the information that has been collected. After students feel that they can understand the concept that being learned, they are given a second problem which is characterized by the problem 1, but, this second problem will be solved independently by them by using the concept that they had learned. At this stage, the teacher only monitors work of the students, teacher can find out who of her students that really understand the concepts given. Afterward the students conclude the concepts that they have obtained on the conclusion sheet in the worksheet, as a result of the action and process activities that have been carried out before the students will get new concepts that are being studied on that day. If an individual is able to apply or imagine applying to a process it is said that the process has been encapsulated into an object. Object activities are carried out by students on the conclusion sheet which also contains keywords. Students must know the key words or important points of the mathematical concepts. Writing keywords and conclusions on the object will make it easier for students to follow the next stage called scheme. The keywords and conclusions that have been made can be used by students to create a scheme in the form of mind mapping [21]. The last activity is a schema in which students try to connect the concepts that they have been obtained in the mind mapping sheet in the worksheet. Learners can make connections between the concepts on that day and the concepts that have been studied before. So that the scheme stage is the final stage of M-APOS learning, students who have arrived at the scheme stage are considered students to be able to construct their own knowledge of the mathematical concepts that have been learned.

Expert Review Results

The validity of the worksheet was carried out by five experts who are 3 mathematics education experts, 1 Indonesian language expert and 1 education technology expert. The validity criteria for the worksheet are assessed from several aspects, namely didactic and material, linguistic and graphic. The validation results can be seen in Table 2.

Table 2. *Validity of Worksheet*

No.	Aspects of Validation	Validity Indeks	Category
1	Didactic and Material	89,13	Very Valid
2	Linguistic	95,43	Very Valid
3	Graphic	75	Valid
Average		86,52	Very Valid

Suggestions from the expert to improve the worksheet are: the cover of the worksheet has not been arranged neatly; the pictures that have not been related to the contents and logo of the 2013 curriculum are too large. The conclusion page has too many images, so there is less space for writing conclusions. The statement for questions does not connect with the problem given, so the researcher changes the editorial language of the question so that it can be easily understood by the students and it is clear what the students will do to solve the problem given. Unclear steps to be taken by students. The researcher revised according to what was suggested by the expert so that good results were obtained. After validating process of didactic and material aspects get 89.13% which are categorized as very valid. From the didactic and material aspects of the criteria it can be concluded that the worksheet already contains instructions for using the worksheet, involving students actively discovering mathematical concepts, motivating students to ask questions, motivating students to learn more about mathematical concepts.

3.2 Results One to One Evaluation and Small Group Evaluation

Worksheets were tested to three students with high, medium and low abilities. The students are asked to try to understand the instructions on the worksheet. They were asked to give suggestion about the concepts, problems, images, illustrations, orders, and questions that exist. Information is collected by making observations as long as students work on the worksheet. Students find some typos and dubious words. After conducting an individual evaluation, revisions are made according to the errors found by students during the individual evaluation process. Then the evaluation is continued with small group evaluation by practicing learning tools that have been designed for a group of students. Evaluation was carried out on 6 students with heterogeneous abilities. At this stage students are divided into 3 groups, namely groups of students with low, medium and high abilities. Small group evaluations were carried out in 5 meetings. At the first meeting students are not accustomed to using worksheets and are still hesitant to write answers to existing worksheets. They have difficulty in answering questions and drawing conclusions about the definition of data, datum, types of data and how to collect data. At the second meeting the students were still not right in carrying out the questioning activities, the questions that student made seemed rigid and less related to the learning objectives. When working on the exercises, students are still guided by the teacher in interpreting the given questions, here also shows that the mathematical communication skills of students are still low, but after explaining the purpose of the problem students are able to work independently. In the third meeting, students discussed material about processing and presenting data in the form of bar charts. Learners can follow the teacher's explanation about problems related to processing and presenting data in the form of bar charts in daily life very well. For example processing and presenting data on the number of teachers and subjects taught in schools in the form of bar charts. In the fourth meeting, students discussed material about processing and presenting data in the form of line diagrams. The teacher does not guide and not give direction too much to them. There are no obstacles faced by students. Students can also convey the results of the discussion in front of the class. Practice questions on worksheets can also be completed by students according to the time given. Students have begun to understand how to solve mathematical communication skills questions. Students have been able to make their own keywords and conclusions and make them into mind mapping well. In the fifth meeting, students discussed material about processing and presenting data in pie charts. The Equipment is again becomes a problem, because many students do not carry the protractor and bow as a tool for making pie charts. Many of the students who have not been able to describe the circle diagram in accordance with the data obtained, to overcome the obstacles that occur researchers guide students to understand the concepts being studied in the action activities and then students can already do it independently. After revision of individual assessment and evaluation of small groups, the worksheet was tested to class VII.1 SMPN 1 Kec. Kapur IX. The trial is conducted in 5 meetings. Practical data is obtained from student and teacher response questionnaires and observations. The results of the practical questionnaire from student responses can be seen in Table 3 and Table 4.

Table 3. *Students' Response of Small Group Stage Participants*

No.	Aspect	Average	Persentage	Category
1.	Ease of Use	3,51	88	Very practical
2.	Time efficiency	3,00	75	Practical
3.	Benefits of a worksheet	3,67	92	Very practical
Average		**3,50**	**88**	**Very practical**

The average level of practicality of worksheets according to student responses is 88%, so it can be concluded that worksheets are very practical according to student responses. Students feel helped to understand the concept with the activity on the worksheet. They have no difficulty in following the instructions. Practical questionnaires are given to the teacher after all worksheets have been completed in the learning process. The result of the teacher response questionnaire is presented in Table 5.

Table 4. *Students' Response in the Field Test*

No.	Aspect	Average	Persentage	Category
1.	Ease of Use	3,51	88	Very practical
2.	Time efficiency	3,23	81	Practical
3.	Benefits of a worksheet	3,67	92	Very practical
Average		**3,50**	**88**	**Very practical**

Table 5. *Teacher Responses to Worksheets*

No.	Aspect	Average	Persentage	Category
1.	Attractiveness	3,75	94	Very practical
2.	Process of Use	4	100	Very practical
3.	Ease of Use	3,5	88	Very practical
4.	Time	3,17	79	Practical
5.	Equivalence	3,67	92	Very practical
Average		**3,62**	**91**	**Very practical**

Table 5 shows that the result of the teacher's questionnaire responses is 91% which is categorized as very practical. The teacher does not experience difficulties in teaching using a worksheet. Students have begun to be interested in learning by using existing instructions [22].

3.3 Effectiveness Results (Field Test)

The effectiveness of mathematics learning instruction can be seen from the results of the mathematical communication ability test of students. Worksheets are said to be effective if they are able to improve students' mathematical communication skills. The effectiveness of worksheets can be seen from the test scores of students' mathematical communication skills by determining completeness as shown in Table 6.

Table 6. *Analysis of Small Group Mathematical Tests*

Students Grup	Percentage of Completeness	
	Complete	Incomplete
High Ability	95,83	4,17
Medium Ability	83,33	16,67
Low Ability	70,83	29,17
Average	**83,33**	**16,67**

It can be seen from Table 6 that students who took the test, high-ability students achieved completeness scores of 95.83%, moderate ability students with 83.33% completeness scores and low-ability students with 70,83% completeness scores. Overall, the test results of small group class is 83.33% which is categorized as completed. The effectiveness of worksheets is also seen from the acquisition of percentage comparisons of each indicator of mathematical communication skills in the sample class that can be seen in Table 7.

Table 7. *Percentage Comparison of Each Sample Class Mathematical Communication Capability Indicator.*

Mathematical Communication Ability Indicator	Ideal Score	
	Eksperiment Class	Control Class
Connect real objects, pictures, diagrams and tables in mathematical ideas.	76,79	42,86
Use ideas, situations, and determine solutions to problems using images, charts, tables, and algebraically.	78,57	62,50
Declare the events expressed in a language or mathematical symbol.	61,61	39,29

The results show that the percentage of achievement of the three indicators of mathematical communication skills of experimental class students is better than the control class. Thus, the mathematical communication skills of students who learn by using worksheets based on the mind mapping M-APOS approach are better than students who do not use them. The results of the study are in line with the research of Mudrikah [23] that APOS learning activities can be used to stimulate reflective abstraction of students. Reflective abstracts as a method of building knowledge on APOS theory. This activity can encourage students to create process formation in the form of generalization, interiorization, encapsulation, coordination and reversal. APOS theory can also provide a reasonable explanation of various facts relating to facts for mathematicians and philosophers and lead to being a culture for students in learning mathematics [24].

4 Conclution

Based on the process and results of the research that has been carried out, the conclusion from this study is that a worksheet based on the M-APOS approach assisted by mind mapping:

1. Valid in terms contents and constructs.
2. Practical in aspect of implementation, ease and time required.
3. Effective in improving students' mathematical communication skills.

References

[1] Sumarmo, Utari. (2014). Asesmen Soft Skill dan Hard Skill Matematik Siswa dalam Kurikulum 2013, (Paper in Seminar Pendidikan Matematika at STAIN Batusangkar 14 September 2014)

[2] Trianto. (2009). Mendesain Model Pembelajaran Inovatif-Progresif.Jakarta: Kencana Persada Media Group

[3] NCTM. (2000). Principles and Standars for School Mathematics. Reston, VA: NCTM

[4] Armiati. (2011). Meningkatkan Kemampuan Penalaran, Komunikasi Matematis dan Kecerdasan Emosional Mahasiswa melalui Pembelajaran Berbasis Masalah. (Not Publised), Bandung: Doktor at SPS Universitas Pendidikan Indonesia Bandung

[5] Darkasyi, et al (2014). Peningkatan Kemampuan Komunikasi Matematis dan Motivasi Siswa dengan Pembelajaran Pendekatan Quantum Learning pada Siswa SMP Negeri 5 Lhokseumawe. Jurnal Didaktik Matematika, Vol. 1, No. 1, ISSN: 2355-4185

[6] Nitiaroza, Arnawa, I M, Yerizon. 2018) Practicality Of Mathematics Learning Tools Based On Discovery Learning For Topic Sequence And Series, International Journal Of Scientific & Technology Research, Volume : 7 Issue : 5 ISSN : 2277-8616

[7] Yerizon, Musdi E, Ardeliza J (2018) Development Of Worksheets Based On Contextual Approach To Increase Student's Mathematical Problem Solving Ability, International Journal of Progressive Sciences and Technologies (IJPSAT) Vol. 9 No. 2 July 2018, pp. 313-319 ISSN: 2509-0119.

[8] Yerizon, Putra, AA, Subhan, M. (2018). Mathematics Learning Instructional Development based on Discovery Learning for Students with Intrapersonal and Interpersonal Intelligence (Preliminary Research Stage), International Electronic Journal of Mathematics volume 13 issu 3 (ISSN: **1306-3030**)

[9] Sanjaya , W (2008). Perencanaan dan desain sistem pembelajaran. Jakarta: Kencana Prenada Media Group

[10] Majid, A. (2014). Implementasi Kurikulum 2013. Bandung: Interes Media.

[11] Prayitno, E dan Mahmudi, A. (2003) Media Pembelajaran Matematika.Yogyakarta: UNY

[12] Prastowo, A. (2012). Panduan Kreatif Membuat Bahan Ajar Inovatif. Yogyakarta: Diva Press.

[13] Sudjana, N dan Ahmad R. (2003). Teknologi Pengajaran.Bandung: Sinar Baru Algensindo

[14] Arnawa, M, et al. (2007). Applying the apos theory To improve students ability To prove in elementary Abstract algebra. Journal. Indonesian Mathematics Sociaty (MIHMI) Vol. 13, No. 1 (2007), pp. 133-148.

[15] Vahid, B and Michael. Gr. Voskoglou. (2016). Applying the APOS Theory to Study the Student Understanding of Polar Coordinates. American Journal of Educational Research. Vol 4 No. 16, 1149 – 1156.

[16] Makonye, J P. (2014). Teaching Functions Using a Realistic Mathematics Education Approach: A Theoritical Perspective. International Journal Education Science . 7(3). 653-662

[17] Asiala, M. et al. (1996). The development of students' graphical understanding of the derivative. Journal of Mathematical Behavior, 16(4), 399-431

[18] Porter, Bobbi De. (2009). Quantum Note-Taker (Jadikan Penuh Makna, Jadikan Tak Terlupakan). Bandung: Kaifa.

[19] Buzan, T. (2008). Mind Map untuk Meningkatkan Kreatifitas.Jakarta: Gramedia Pustaka Utama
[20] Plomp, T and Nieveen, N. (2013). An Introduction toEducational Design Research. Enschede: Netherland Institute for Curriculum Development (SLO)
[21] Hartati, S J. (2014). Design of Learning Model of Logic and Algorithms Based on APOS Theory, International Journal of Evaluation and Research in Education (IJERE) Vol.3, No.2, June 2014, pp. 109~118 ISSN: 2252-8822
[22] Abdullah, B, Yerizon, Armiati (2018) Learning Practices Learning Based Approach M-APOS to Improve Communication Capability Mathematic Participants Grade VII of Junior High School, Proceeding The 2nd International Conference On Mathematics And Mathematics Education Mathematics 2018 (Advances in Social Science, Education and Humanities Research (ASSEHR)), volume 285
[23] Mudrikah, Achmad. 2016. Problem Based Learning Asssociated by Action-Process-Object-Schema (APOS) Theory to Enhance Student's High Order Mathematical Thingking Ability. Nusantara Islamic University. IJRES. ISSN: 2148-9955 Vol.2 issue 1
[24] Ed Dubinsky et al (2005). "Some Historical Issues and Paradoxes Regarding The Concept of Infinity: An APOS Analysis: Part 2" Educational Studies in Mathematics 60: 253–266 DOI: 10.1007/s10649-005-0473-0