The Development of Test Instruments to Measure Students’ Mathematical Communication Skills

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Abstract. This study aimed to determine the procedures and quality of developing test instruments to measure student mathematical communication skills of SMP Negeri 17 Makassar. The research type used research and development with the Plomp model through 4 stages: preliminary investigation, design, realization/construction, test, evaluation, and revision. The results showed that the developed test instrument was valid with a high interpretation from the value of CVR and CVI is 1. The instrument test was reliable on 0.71 with a very high interpretation while in terms of the level there was 1 item in the difficult category, 7 items in the medium category and 1 item in the easy category. In terms of distinguishing power, there were 2 items at sufficient categories, 3 items in the good category, 2 items in very good categories and 2 items in the poor category. Therefore, the test instruments that met the quality of the criteria from the good test instruments consists of 5 items of description questions.

Moreover, based on the results of the trial, it is known that from 32 students there were 4 students categorized who had a very good level of mathematical communication skills, 9 students included in the good level of mathematical communication skills, 17 students under sufficient level of mathematical communication skills, and 2 students in the less level of mathematical communication skills.

Keywords: Development, Test Instruments, Mathematical Communication.

1. Introduction
Mathematics is a tool that assists in the application of other sciences, which also has an important role in developing mathematics itself as well as other sciences and technology [1]. In the era of competitive reasoning and decision making, it is a must for students to master mathematical material which is now increasingly competitive in school learning that tends to be textbook oriented makes student achievement in mathematics not so satisfying yet. Therefore the results of learning mathematics in Indonesia are still in the low category [2]. Mathematics is a compulsory subject taught from elementary, junior high school and senior high school/MA, even college level. According to Nursalam, mathematics is a science arranged systematically and structured that can support people to carry out an activity through generative, dynamic, and active processes [3]. However, mathematics is considered difficult by students, this proven in every mathematical test results in the form of daily tests, block exams even to the national mathematics exam tend to have lower grades than other subjects so that many of them are avoiding to learn about it [4]. Mathematics is very important included as a basic subject found in all levels of education. In achieving a good mathematics learning
achievement, students are needed to improve their knowledge in thinking logically, rationally, critically, and efficiently [5].

Allowing students to think logically, analytically, critically and creatively and be able to work well together in solving problems systematically are the goals of learning mathematics [6]. Students who can understand should also be able to have strong mathematical communication with the result that what they have got can be conveyed and figured out well by others [7]. By expressing his mathematical ideas to others, the student can improve his mathematical comprehension [8].

Communication is considered to be an essential part of human life in connecting ideas to one another. In this context, it certainly plays a significant role in mathematics education. According to Ramdani, mathematical communication skills is the skill to share both verbally and non-verbal communication which is obtained through listening and analyzing the words in the process of discussion or presentation and writing obtained in the writing process [9]. Through communication, a student can convey ideas or messages, understandings and his opinions to teachers, peers, groups or the whole class [10]. Therefore, mathematical communication skills are very important both in daily life days and learning process because it helps people to understand and respond to others through the good and right communication. According to Baroody there are two important reasons of communication in learning mathematics at school that needs to be developed; first, mathematics is a tool for thinking in finding solutions and solving every problem, and also a tool for communicating ideas clearly, precisely and concisely, second, mathematics as teacher and student communication tools indeed as an interaction between students by making mathematics as a social activity in the learning-teaching process at school [11]. These two things become important reasons for communication in mathematics; communication cannot be separated from mathematics because without its existence, one cannot explain everything about symbols, graphics, etc. in learning mathematics.

In the field of reality emphasizes that mathematical communication skills are still low and students have not been able to solve mathematical communication problems even though this ability is one of the abilities that must be possessed by students. This is shown by research Istiqoma, Rohaeti, and Qohar which states the low mathematical communication skills of students both verbally or in writing [12]. The unfamiliarity of students in expressing their various ideas and opinions in the process of learning mathematics in class because of the obstacles they have faced as well as they are not allowed to convey mathematical thoughts thus they find it difficult to get a solution to the given problems. The Program for International Student Assessment (PISA) conducted a survey toward students in 65 countries in 2012 found that Indonesia was ranked 64th in mathematics, ranked 60th with Argentina in reading, and ranked 64th in science (OECD). Specifically, in the field of mathematics, a survey conducted by PISA aimed to assess students' ability to solve problems, reason, and communicate. It can be seen from the results of a survey in the field of mathematics, illustrated that the three abilities of students in Indonesia cannot be said to be satisfactory. Based on the survey, it can be said that the average student in Indonesia still has low mathematical communication skills [13].

Moreover, a good instrumental tool is purposed to measure mathematical communication skills indeed to have standard questions that must be achieved so that students can think critically and creatively [14]. Having valid criteria, high reliability and distinguishing power and sufficient levels of difficulty are the requirements should be owned by the test instrument for mathematics education research or in other meaning these four things must be met to obtain a good instrument. Therefore, researchers want to develop test instruments to measure students' mathematical communication skills with the aim that this test can develop other competencies in the mathematics curriculum.

2. Methodology
This research type is research and development with aims to develop test instruments to measure the students' mathematical communication skills that are valid and reliable in learning mathematics. The development model used in this study is the Plomp development model.
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Figure 1. The Development Stages of Plomp Model

Explanation:

- The direction of reciprocal activity that has taken place so far between the development stage and the implementation of the learning model.
- The way of the development phase activities,
- The line of activity is back to the previous development steps.

The research procedure is a stage that must be carried out to obtain a test instrument following the objectives of the study. Briefly, the design of the trial-test product as follows:

Figure 2. The Steps of Test Instrument Development

The trial subjects used in this study were junior high school students (SMP Negeri 17 Makassar) from the odd semester of the 2016/2017 school year. Data collection techniques and instruments used in this study were the tests and the questionnaires.

3. Result and Discussion
3.1 Procedure for Developing Test Instruments of Communication Skills
The development of test instruments to measure mathematical communication skills has passed through a series of the development phases of formative research types ranging from preliminary investigation, design, realization/construction until test, evaluation and revision stages to produce a product. The intended product is a test instrument to measure mathematical communication skills. The preliminary investigation stage was the initial or preliminary stage of the development process. This phase started by collecting several references related to this research, namely research development, test instruments, and mathematical communication skills. At this step, an analysis of the curriculum, material, and students was also carried out. The next stage was the design stage where the researchers have designed the test instruments of mathematical communication skill based on what was identified at the preliminary investigation stage. The test questions were created based on the material that has
been analyzed and also based on an indicator of mathematical communication ability called the initial design. The test instruments have designed consists of a grid, test questions in the form of a description, test answer sheets, answer criteria, and assessment/scoring guidelines. The further stage was the realization/construction where the main design based on the initial design which examined and reconstructed about the suitability of the test components, the adequacy of the theories and also the suitability of the 3 prototype characteristics that refer to the construct, content and language accordingly so that it was ready to be tested for validity by experts from a rational angle theoretical and consistent construction.

The next stages were the test, evaluation and revision which involved a very mature consideration of the product quality that will be developed to make a decision. At these points carried out (1) validation activities to experts in the field of test instrument development and mathematics material experts, (2) field trials, where the test instruments that have been developed were tested on research subjects, namely IX\textsubscript{9} class of SMP Negeri 17 Makassar. Furthermore, the obtained data measure the content validity of the questions, questionnaire of student responses, reliability, level of difficulty, and distinguishing power and to find out the results of higher-order thinking skills.

### 3.2 The Instrument Test Quality of Mathematical Communication Skills

The test of content validity conducted is Content Validity Ratio (CVR) where its objective of the content analysis focused on knowing the material suitability of every question items on the measured topic based on the experts' opinion. The content validation results showed that the 9 items examined by 3 validators have shown that these items support test validity. Also, from the CVR results in the CVI (Content Validity Index) value obtained which was the average of CVI for all items in the amount of 1 meaning "very appropriate" questions with the topic to be analyzed. Thus, the stated prototype was valid.

### 3.3 Analysis of Student Responses

The questionnaire of student responses is used to determine the readability of the questions on the test instrument of mathematical communication skills. This questionnaire is given to students so that they can conduct it on the limited trials outside of the test subject. The results of questionnaire test instruments for mathematical communication skills, namely:

| Statement | Scale Alternative | Percentage | Total Percentage | Description |
|-----------|-------------------|------------|------------------|-------------|
|           | 4                 | 3          | 2               | 1           | +          | -          |
| 1         | 2                 | 4          | 0               | 0           | 33,33      | 66,67      | 0,00       | 0,00       | 100        | 0          | +          |
| 2         | 5                 | 1          | 0               | 0           | 83,33      | 16,67      | 0,00       | 0,00       | 100        | 0          | +          |
| 3         | 4                 | 2          | 0               | 0           | 66,67      | 33,33      | 0,00       | 0,00       | 100        | 0          | +          |
| 4         | 2                 | 4          | 0               | 0           | 33,33      | 66,67      | 0,00       | 0,00       | 100        | 0          | +          |
| 5         | 0                 | 0          | 6               | 0           | 0,00       | 0,00       | 100,00     | 0,00       | 0          | 100        | -          |
| 6         | 0                 | 0          | 3               | 3           | 0,00       | 0,00       | 50,00      | 50,00      | 0,00       | 100        | -          |
| 7         | 0                 | 0          | 5               | 1           | 0,00       | 0,00       | 83,33      | 16,67      | 0,00       | 100        | -          |
| 8         | 3                 | 3          | 0               | 0           | 50,00      | 50,00      | 0,00       | 0,00       | 100        | 0          | +          |

Total Response + 500,000
Total Response - 300,000
Average of Positive Response 62,5
Average of Negative Response 37,5

Based on table 1, the results of the questionnaire analysis of students response to test instrument of the mathematical communication skill in limited trials showed the average of positive students response.
was 62.5% and the average of negative students response was 37.5%. So that the average of students positive response was 71.25% while the negative average was 31.25. It can be concluded that more than 50% of students gave positive responses. Thus according to the criteria in the student response questionnaire, the questionnaire of student response met the "achieved" criteria and there was no improvement/revision of the test instruments to be developed.

3.4 Reliability Analysis

This reliability test focused on the results of field trials involving students of class IX\textsubscript{o} of SMP Negeri 17 Makassar. The calculation of the reliability test for mathematical communication skills using SPSS is shown in the following Table 2:

| Reliability Statistics | Cronbach's Alpha | N of Items |
|------------------------|------------------|------------|
|                         | .709             | 9          |

Based on Table 2, it can be known that the reliability of the test instrument was 0.84 with a "High" interpretation revealed that the test instrument was reliable according to the criteria of instrument quality on the interval category of the reliability level explained by Hamzah in the mathematics learning evaluation book [15].

3.5 Difficulty Level Analysis

The difficulty of developed test instruments was also obtained from data on the results of student work on the trial test instrument. The analysis results of the difficulty level of the mathematical communication skill from the test instrument used the categories developed by Sudjana in the assessment book of the learning process [16]. Based on the analysis results of the questions difficulty level, it is known that in the trial questions number 2 had a difficulty level with the "easy" category, while questions number 1, 4, 5, 6, 7, 8, and 9 had a difficulty level with the "moderate" category, while question number 3 had a difficulty level in the "hard" category. Thus, regarding on the criteria for the quality of the mathematical communication skill of test instrument in the difficulty level category, there were some items had a bad level of difficulty because of having questions in the category was too easy and difficult.

3.6 Distinguishing Power Analysis

The distinguishing power of the developed test instrument items was obtained through the field trials data of student work results. Items of the mathematical communication skill test can be reached a good category if the test items had the smallest differentiation power (0.20) or revealed a minimum or sufficient distinguishing power. Based on the analysis of the result it is known that in field trials questions of the distinguishing power; number 1, 2 and 4 have existed in the "poor" criteria, number 3 and 5 categorized in"enough" criteria, number 7, 8 and 9 with "good" criteria and number 6 with a very good category. Unfortunately, there were no questions that had "very bad" criteria in the field of trials. Moreover, the quality criteria of the test instruments related to the power of distinguishing category, there were items in the instrument of mathematical communication skill tests stated to have poor differentiation criteria because they could not distinguish their mathematical communication abilities between low and high.

3.7 Analysis of Mathematical Communication Skill Test Results

The data of the test result measured students' mathematical communication skills and done based on the final score obtained when students were working on its test questions. The test result data is then analyzed to determine the level of mathematical communication skills of students and shown in the following table 3:

| No. | Students Score | Frequency | Percentage (%) | Category | Total Score of Students |
|-----|----------------|-----------|----------------|----------|-------------------------|
| 1   | 76 ≤ score ≤ 100 | 4         | 12,50          | Very Good | 1656,67                 |
| 2   | 51 ≤ score ≤ 75  | 9         | 28,13          | Good     |                         |
Based on the analysis of instrument data to measure students' mathematical communication skills it is known that from 32 field trial subjects there were 3 students (9.38%) got excellent category, 10 students (31.25%) met good categories, 17 students (53.13%) existed in enough categories, and 2 students (6.25%) had fewer categories. Additionally, the analysis of the average results of communication skills tests were 51.77% meaning that the average results of students' mathematical communication ability tests were in enough category by following the quality criteria of the test instrument from mathematical communication skills.

4. Conclusion
The process of developing the test instruments of mathematical communication skills for VIII grade of SMP through 4 stages, namely: (a) Preliminary Investigation (initial assessment), (b) design, (c) realization/construction, and (d) test, evaluation and revision stage (tests, evaluations and revisions).

The test results obtained from the test instruments of mathematical communication skills that met the quality of the criteria from the good test instruments consists of 5 items of description questions. Based on the results of the trial, it is known that from 32 students there were 3 students (9.38%) who included in the very good level of mathematical communication skills, 10 students (31.25%) who existed in the good category, 17 students (53.16%) who included in the sufficient category and 2 students (6.25%) who presented in the less category of mathematical communication skill.

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