Development of Mathematics Teaching Materials Based on Realistic Mathematics Education and Literacy in Junior High School

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***Abstract*—the backround of the research was low mathematics literacy of ninth grade students at SMPN 1 Bukittinggi. It was proved by result of Mathematics literacy tests. The result showed 36.24% of questions could be answered by the students correctly, with an average score 31.87. It stated that the mathematics literacy junior high school students in Bukittinggi is also low. It was caused by many factors, such as the teaching materials used in schools did not support students' mathematical literacy achievement yet. This study is aimed to develop validity, practicality and affectivity of mathematics teaching materials based on Realistic Mathematics Education and Literacy to improve students' mathematical literacy. This research focuses on preliminary research in the development of mathematics teaching materials based on Realistic Mathematics Education. The research was design research that proposed by Plomp which consisted of three stages, preliminary research phase, prototype or development phase, and summative evaluation phase.**

Keywords—teaching materials, realistic mathematical education, mathematics literacy.

I. INTRODUCTION

Regulation Minister of National Education Republic of Indonesia Number 22 of 2006 concerning Content Standards for Primary and Secondary Education Units emphasizes that mathematics underlies the development of technological progress and has an important role in various disciplines and advances in the power of human thought [1]. One formulation of the 21st century national education paradigm also mentions that to face the 21st century which is increasingly required by technology and science in a global society in this world, our education must be oriented to the science of mathematics and natural sciences accompanied by social and human sciences (humanities) with a reasonable balance [2]. Based on the information above, it shows that mathematics needs to be taught in schools and mastered by students as a basis for mastering science and technology.

Mastery of students' mathematics is strongly influenced by the quality of mathematics education itself. The extent to which students' mastery of mathematics and the quality of mathematics education in Indonesia can be seen from the results of surveys of international institutions, one of which is *Programme for International Student Assessment* (PISA). This is because the assessment in PISA does not just ascertain whether students can reproduce knowledge; it also examines how well students can extrapolate from what they have learned and apply that knowledge in unfamiliar settings, both in and outside of school [3]. The PISA is triennial international survey, which aims to evaluate education systems worldwide by testing students' knowledge and skills in mathematics, reading and science [4].

Today, everyone is required to use mathematics as a tool in daily life. PISA's assessment of students' mathematical knowledge and skills is rooted in the concept of "mathematical literacy"[5]. Mathematical literacy is an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognize the role that mathematics plays in the world make and to the well-founded judgments and decisions needed by constructive, engaged and reflective citizens [6].

The mathematics Literacy of Indonesian students since the first Indonesian participation in PISA in 2000 until 2015 never progressed far below the international average (Table 1). The result indicates that more less nine years of mathematics learning students of Indonesian were not able to solve mathematical problems in daily life, they were not aware of mathematical phenomena around them as well.

Table 1. Students Performance in Mathematics Literacy

Year	Indonesian		Number of Participant	International
	Scor	Rank	Countries	Average Score
2000	367	39	41	500
2003	360	38	40	500
2006	391	50	57	498
2009	371	61	65	496
2012	375	64	65	494
2015	386	63	70	490

Source: OECD

Mathematics literacy tests was conducted on 25th and 31st August 2016 to 62 students of grade ninth at SMPN 1 Bukittinggi got the average result that only 36.24% of the questions could be answered by the students correctly, with an average score 31.87 (Fig. 1). These results indicated that, although SMPN 1 Bukittinggi is a superior school, but the students' math literacy is low. Based on this result, it can be concluded that the mathematics literacy of junior high school students in Bukittinggi is still relatively low [7].

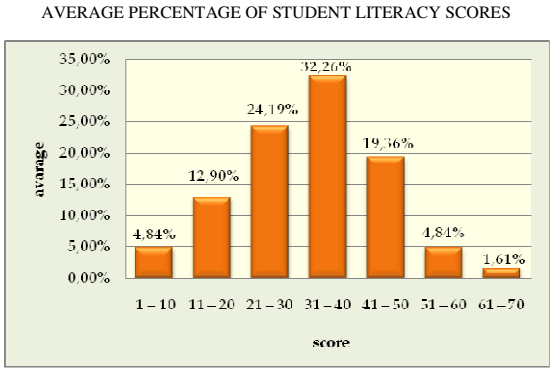

Fig. 1. The Score of Mathematical Literacy of the Students of Grade Ninth of SMPN 1 Bukittinggi

The low mathematics literacy of students in Indonesia and in Bukittinggi in particular, of course was caused by many factors. Based on previous researchers shown that the teaching materials used in schools were not enough to support the achievement of students' mathematical literacy yet [8], [9]. This is presumed to be one of the factors causing the low mathematics literacy of students. This research aims to develop valid, practical and effective mathematics teaching materials based on Realistic Mathematics Education and Literacy (RMEL) to improve students' mathematical literacy. This paper only presents the development of mathematics teaching materials based on RMEL on preliminary research phase.

II. METHODS

This type of research was educational design research with type of development studies. The mathematics teaching materials that would be developed used Plomp's design research model which consisted of three phases namely, preliminary research phase, prototype or development phase, and assessment phase.

The preliminary research phase was needed to gain insight into the problem of low student mathematics literacy and the possibilities for improvement and innovation; and to specify the desired tentative features of the intervention (tentative design principles) and how these can be developed.

The prototype or development phase commenced after the preliminary research phase ended and a first set of tentative design guideline. Development of a sequence of prototypes that would be tried out and revised on the basis of formative evaluations.

The assessment phase was conducted to conclude whether the solution or intervention met the pre-determined specifications. In other words, the assessment phase was aimed at determining the actual effectiveness of the complete intervention (which has resulted from the development or prototyping phase). Also whether target users could work with intervention (actual practicality) and were willing to apply it in their teaching (relevance & sustainability).

The intervention in this study was in the form of mathematics teaching materials consisting of teacher books and student books. The discussion in this paper was focused on the development of mathematics teaching materials based on RMEL on preliminary research phase. The preliminary research phase was discussed in more detail in the following sections.

A. Preliminary Research Phase

The preliminary research phase was needed to analyze the main problems underlying the importance of development of teaching materials based on RMEL. In addition, through the preliminary research, researchers obtained a temporary picture of the product being developed. Important activities that are typically performance during a preliminary research phase include: 1) needs and context analysis, 2) review of literature, and 3) development of a conceptual or theoretical framework. These activities are explained consecutively in more detail in the following sections.

1. Need and Context Analysis

The needs and context analysis in this reseach was based on the rationality of the need to develop mathematics teaching materials based on RMEL. A need analysis looked into the perceptions of stakeholders on the current situation – what works well, what should be change – and the features of more desirable situation. Context analysis was aimed exploring the problem environment and mapping out the scope for innovation. Question to be asked during a context analysis included: What does the user cantext look like? What is the innovation scope, considering needs and abilities of those involved? The activities conducted in the needs and context analysis are a) need analysis of potential users, b) curriculum analysis, c) concept analysis, and d) analysis of student characteristics.

Need analysis of potential users was conducted through interviews with teachers and some students. Information taken related to mathematical literacy, learning tools, learning models/ approaches and assessment instruments.

The curriculum analysis was done through documentary studies to study the purpose of the lesson, the content of the lesson, the organization or the composition of teaching materials and the evaluation of learning.

Concept analysis was the identification of the materials discussed in the lesson. These materials were arranged systematically by linking a concept with another relevant concept to form a concept. This analysis aimed to determine the content and subject matter needed so that it could help

learners in achieving the desired competence was the ability of mathematical literacy. The concept of material discussed in this research is Systems of Linear Equations in Two Variables. Concept analysis comes with concept map creation

Analysis of student characteristics was done by giving questionnaires to students to examine the characteristics of students. Characteristics of interest included student identity, mathematical ability, learning styles and interes self. This analysis was taken as a consideration in designing the Student Book.

III. Results and Discussion

1. Need and Context Analysis

The results of interviews with five mathematics teachers from three Junior High Schools in Bukittinggi on May 23th, 2018 obtained information: 1) Some factors causing low literacy of mathematics students were: (a) students were lazy to read; (b) mastery of low student concepts, and (c) students was not trained in working on Higher Order Thinking Skill (HOTS) questions; 2) Efforts that teachers needed to do to increase student literacy were: (a) provide teaching materials that stimulate students to want to read; (b) giving more practice HOTS questions; 3) Relating to the literacy component: (a) The most difficult mathematical content for students is geometry and algebra; (b) The teacher's usual context is the personal context, some relating to the context of the job, rarely or never using a social and scientific context; (c) the mathematical process that often arised in mathematical problems given by the teacher was the employment process, whereas the formulate and interpret process was difficult to design the teacher in a mathematical problem; (d) assessment instruments used in essay and multiple choice formats, but few contain the context, and did not yet represented the level of students' math skills; 4) The things teachers needed are: (a) Teaching materials that integrate the concept of mathematical literacy; (b) learning model/approach with group characteristics, contextual, guiding students to find the formula, stimulate students to read, solve problems and make students have HOTS.

The results of interviews with six students VIII SMPN 2 Bukittinggi on May 24th, 2018, obtained information: 1) In learning mathematics: (a) students wanted explanation of teachers; (b) students needed to know how to find the formula; (c) it was important to introduce the usefulness of the formula in everyday life; (d) a contextual learning model and the creation of interactions between students and students and students with teachers; 2) Learning tools: (a) students were less easily understood; (b) the student wished for a Group Worksheet and Individual Worksheet; (c) students want learning tools that were practical, effective, and easily understood; 3) Associated with the literacy component: (a) Mathematical content that was difficult for students was algebra and geometry, (b) the context that appealed to students was science; and (c) a difficult mathematical process for students was to interpret.

Curriculum analysis that had been done through documentation studies obtained information: 1) The purpose of mathematics lessons in junior high school was: that students were able to: (a) understand the concept and apply the procedures of mathematics in everyday life; (b) perform mathematical operations for simplification, and analysis of existing components; (c) make a mathematical reasoning which includes making generalizations based on patterns, facts, phenomena or existing data, making conjectures and verifying them; (d) solve problems and communicate ideas through symbols, tables, diagrams, or other media to clarify circumstances or problems; (e) cultivate positive attitudes such as logical, critical, meticulous, meticulous, and not easily give up in solving problems (Kemendikbud, 2017: 6); 2) Mathematics content in SMP Class VIII semester I consist of Numbers, Algebra, Geometry and Measurement; 3) The composition of teaching materials for these three fields is Number Pattern, Cartesian Field, Relation and Function, Equation of Straight Line, Linear Equations Two Variables and Pythagorean Theorem; 4) The evaluation used includes attitude, knowledge and skill assessment.

Concept analysis was carried out on the subject matter of Systems of Linear Equations **i**n Two Variables (SLETV). A system of linear equations is two or more equations that contained the same variables. A solutions to a system of equations were the point where the lines intersect. There were three methods to solving systems of linear equations in two variables: graphing, substitution, elimination. Concept map of SLETV can be described as follows (Fig. 2).

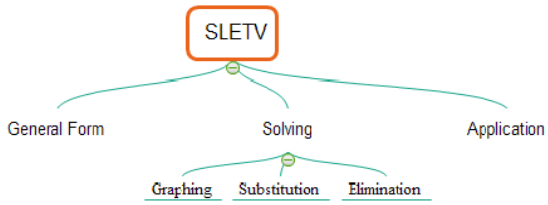

Fig. 2. Concept Map of SLETV

Analysis of student characteristics was done by giving questionnaires. Based on the questionnaire given to 16 students of grade VIII SMP on May 24th, 2018, obtained information: 1) Student Identity: (a) Religion: 81.25% Moslem; (b) Tribe: 75% Minang; (c) Gender: 25% Male, 75% female; (d) The age of students ranges from 14 to 17 years; 2) Students' learning styles were evenly distributed on audio, visual and kinesthetic types; 3) Interes self: (a) most students hobby reading, art and sports; (b) more than half of students had aspirations to become doctors/nurses and teachers / lecturers; (c) 93.75% students loved traditional cuisine; and (d) all students loved the colors.

2. Review of Literature

PISA assesses the extent to which students the end of compulsory education have acquired key knowledge and skills that are essential for full participation in modern societies. The assessment, which focuses on mathematics, reading, science and problem solving, does not just ascertain whether students can reproduce knowledge; it also examines how well students can extrapolate from what they have

learned and apply that knowledge in unfamiliar settings, both in and outside of school [10].

PISA's assessment of students' mathematical knowledge and skills is rooted in the concept of "mathematical literacy"(OECD, 2003, p.4). Mathematical literacy is an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognize the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens [11].

For purposes of the assessment, the PISA 2012 definition of mathematical literacy can be analysed in terms of three interrelated aspects: 1) the mathematical ***processes*** that describe what individuals do to connect the context of the problem with mathematics and thus solve the problem, and the capabilities that underlie those processes. The categories to be used for reporting are as follows: (a) *formulating* situations mathematically; (b) *employing* mathematical concepts, facts, procedures, and reasoning; and (c) *interpreting*, applying and evaluating mathematical outcomes; 2) the mathematical *content* which is the content or material or subject of mathematics learned at school. There are four categories characterise the range of mathematical content that is central to the discipline and illustrate the broad areas of content that guide development of test items for PISA 2012: (a) *change and relationships;* (b) *space and shape;* (c) *quantity;* and (d) *uncertainty and data*; and 3) the *contexts* is a situation that is reflected in a problem. For purposes of the PISA 2012 mathematics framework, four context categories have been defined and are used to classify assessment items developed for the PISA survey: (a) personal, (b) occupational, (c) societal, and (d) scientific.

The low mathematics achievement of students in PISA illustrates the low level of student mathematical literacy. Several attempts have been made by teachers and researchers to improve students' mathematical literacy. Among them are applying various new models or approaches in learning mathematics in schools such as, Realistic Mathematics Education (RME) [12]. At this stage students will use their literacy skills to formulate real problems into mathematical problems, then solve them and interpret them in a real context. In this way they use their mathematical literacy skills as well as develop them [13].

RME is a theory of teaching and learning mathematics that has been developed in the Netherlands since the early 1970s [14]. This theory is strongly influenced by Hans Freudenthal's concept of 'mathematics as a human activity' [15]. According to Freudenthal, pupils should not be treated as passive recipients of ready-made mathematics, but rather that education should guide the pupils towards using opportunities to discover and reinvent mathematics by doing it themselves.

According to Gravemeijer [16], there are three key heuristic principles of RME for instructional design namely *guided reinvention through progressive mathematization, didactical phenomenology, and self developed models or emergent models* [17]. The principle of PMR is also called the PMR theoretical basis [18].

The process of designing a sequence of instructional activities that starts with experience-based activities in this research was inspired by five characteristics (tenets) for realistic mathematics education defined by Treffers (1987) that are described in the following ways: 1) *Phenomenological exploration;* 2) *Using models and symbols for progressive mathematization;* 3) *Using students' own construction;* 4) *Interactivity;* and 5) *Intertwinement*. The characteristics of PMR are also referred to as the applicative basis for PMR [19].

However, in the period of 2000, since the first Indonesian participation in PISA, until now not so visible improvement in mathematics achievement of Indonesian students according to international survey institutions, such as PISA. This of course can be caused by many factors. However, the solution to the above-mentioned problem needs to be sought [20].

Several factors causing the low mathematics literacy of students according to Rusdi [21], are: 1) the teachers' knowledge about mathematical literacy was low, 2) the learning approach still did not related to the material with the context of students' daily lives, 3) the assessment instruments was far from the mathematical literacy, 4) realistic mathematics education approach ever developed by researchers in learning mathematics has not been combined with the concept of literacy yet. According to Whardhani and Rumiati [22] and Masduki, et al [23], the teaching materials used in schools were not enough to support the achievement of students' mathematical literacy yet.

There are several research design models to develop mathematics teaching materials. The development of the mathematics teaching materials based on Realistic Mathematical Education and Literacy in junior high school uses Plomp's design research model, because according to researchers it is more simple and flexible. Plomp Model [24] has three stages or phases, namely 1) Preliminary Research, 2) Development or Prototyping Phase, and 3) Assessment Phase.

Teaching materials are a generic term used for describes the use of learning resources by the teacher to convey learning. In this way, teaching materials can support student learning and increase success his. Teaching materials can be defined as breakdowns from a set of materials arranged in a manner systematically both written and unwritten creating an environment or atmosphere allows students to study [25].

Teaching materials are a set of learning tools or tools that contain learning material, methods, boundaries and how to evaluate that are designed systematically and attractively in order to achieve the expected goals, namely achieving competence or sub- competence with all its complexity[26].

The existence of teaching materials is needed by teachers and students. Teaching materials help students to learn more easily. While for teachers, teaching materials help in implementing learning. Teaching materials can help the learning process and learning if in its preparation pay attention to the principles in the selection of teaching materials. Some principles that need to be considered in the preparation of teaching materials include the principles of relevance, consistency and adequacy [27].

The principle of relevance, meaning that in compiling teaching materials should be relevant or have a relationship / relationship with the achievement of standards of competence and basic competencies. The principle of consistency, meaning that the preparation of teaching materials should be consistent with the achievement of standards of competence and basic competencies. The principle of sufficiency, meaning that teaching materials should be arranged in accordance with the material needs that students will learn. The material contained in the teaching material is not too little and not too much. If too little will affect the achievement of basic competencies that are not optimal. If too much will affect when using teaching materials that tend to waste time and effort

3. Development of a Conceptual or Theoretical Framework

Based on the description above can be developed the conceptual framework or theoretical framework of this research as follows (Fig. 3).

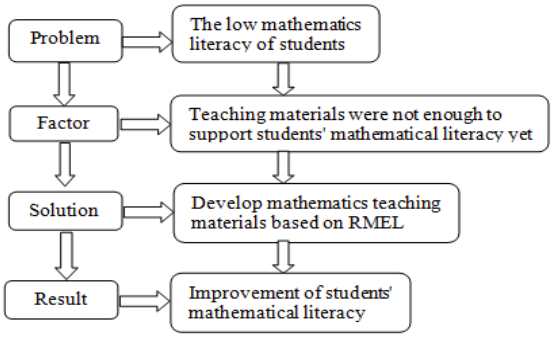

Fig. 3. Development of a Conceptual or Theoretical Framework

IV. CONCLUSIONS

Based on the results of the preliminary study, it was concluded that one of the factors causing the low mathematics literacy of students was the teaching material used in schools was not enough to facilitate the achievement of students' mathematical literacy yet. Therefore, it is necessary to design mathematics teaching materials that can improve students' mathematical literacy. Designed teaching materials consist of teacher books and student books that have specifications context-based and HOTS questions. This can be done by designing mathematics teaching materials based on Realistic Mathematics Education and Literacy.

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