Designing Mathematics Learning Models Based on Realistic Mathematics Education and Literacy

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Abstract. This research was formed the backround of the low mathematics literacy of junior high school students in Bukittinggi. The purpose of this research is to develop valid, practical and effective mathematics learning model based on Realistic Mathematics Education and Literacy to improve students' mathematical literacy. This type of research was Plomp model design research which consisted of three stages, namely preliminary research phase, prototype or development phase, and assessment phase. However, this research is still at designing prototypes in development phase. Based on preliminary research results were obtained, 1) one of the factors that causes the low level of student mathematics literacy is students not trained in working on higher order thinking skill questions; 2) the teachers needed the learning models that could improve students' mathematical literacy; 3) the students wanted contextual learning; 4) the curriculum used was the 2013 curriculum, content of mathematics in 8th grade junior high school students semester I consist of Numbers, Algebra, Geometry and Measurement; 5) The main concepts in the subject matter system of linear two-variable equations were, general form, solving and application; 6) students have characteristics between 14 and 17 years old, learning styles were evenly distributed on audio, visual and kinesthetic types, most students like traditional food; and all students like the colors. Based on the results of the preliminary research phase, need to be developed learning models based on Realistic Mathematics Education and Literacy. The results of designing prototype in the development phase were the components of the learning model consisting of learning syntax, social system, the principles of reaction, support systems, and instructional effect and nurturant effect.

Keywords: Mathematics learning model, realistic mathematical education, mathematics literacy.

1. Introduction
Mathematics is one of the most important lessons mastered by students in school[1]. This is because there are many problems in daily life that require mathematics to solve, for example determining the price of an item, the area and circumference of a building, profit and loss, etc.. Mathematics education is needed as a basic tool to develop further knowledge and skills in mathematics and for survival in our tasks and work [2]. In Minister of Education Regulation No. 22 of 2006 concerning the Standard Content of Mathematics Subjects for Primary and Secondary Education Units emphasizes that mathematics underlying the development of technological advances has an important role in various
disciplines and advancing human thinking [3]. Based on some of the information above, it can be concluded that mathematics needs to be taught in schools and mastered by students, in addition to being a basis for mastering and developing science and technology, as well as many uses in everyday life. 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 [4]. The PISA is triennial international survey, which aims to evaluate education systems worldwide by testing students’ knowledge and skills in math, reading and science [5]. PISA’s assessment of students’ mathematical knowledge and skills is rooted in the concept of “mathematical literacy” [9]. In the context of PISA, literacy is defined as, 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 [10].

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.

| Year | Indonesian | Number of Participant | International | 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 (Figure 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.

![Average Percentage of Student Literacy Score](image1)

**Figure 1.** The Score of Mathematical Literacy of the Students of Grade Ninth of SMPN 1 Bukittinggi
Several factors causing the low mathematics literacy of students 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, 5) the teaching materials used in schools were not enough to support the achievement of students' mathematical literacy yet [11] [12]. Based on these results, researchers need to develop Mathematical Learning Models Based on Realistic Mathematics Education and Literacy (MLMB-RMEL) for the achievement of students' mathematical literacy.

2. Methodology
This type of research was educational design research with type of development studies. The mathematics learning model 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).

2.1 Preliminary Research Phase
The preliminary research phase was needed to analyze the main problems underlying the importance of development of MLMB-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.

2.1.1 Needs and Context Analysis
The needs and context analysis in this research was based on the rationality of the need to develop MLMB-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 context 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.

In order to make relevant and valid design of the MLMB-RMEL, it was important to gain insight into the state of the knowledge base. This could be done by means of literature review. The literature review was done by analyzing the theory and concept related to the development of MLMB-RMEL. Theory was chosen, analyzed and reviewed so that it became the basis for the development. Literature review included the phenomenon of students' mathematical literacy, the importance of mathematical literacy, the concept of mathematical literacy according to PISA, a suitable learning approach to facilitate the improvement of students' mathematical literacy, and the theory of teaching material development.

2.1.2 Development of a Conceptual or Theoretical Framework
A Conceptual or Theoretical Framework was a diagram that explained the outline of the logic flow went to a development of mathematics teaching materials based on RMEL. The framework was based on the formulation of the problem, the factors that caused the problem, alternative solutions to the problem, and the results that wanted to expect, and represented a set of several concepts and relationships between these concepts.

2.2 Development or Prototype Phase
This phase aims to produce a valid prototype. This stage consists of three steps of activities, namely: 1) designing prototypes, 2) formative evaluation, and 3) prototype revision.

2.2.1 Designing Prototypes
This phase is the prototype design phase. The prototype is a temporary product that will be further developed. The product that was designed as a prototype in this research was MLMB-RMEL for the achievement of students' mathematical literacy. At this stage, the activity carried out is to design the MLMB-RMEL component which includes, a) learning syntax, b) social system or learning environment, that is the situation or rules that apply in the contextual model, c) the principles of reaction, namely the description for teachers about how to respond and respond to the behaviors shown by students in learning, d) support systems that are devices that support the implementation of the learning process and the achievement of learning objectives well. The results of the design are made in the form of Learning Model Books, Teacher’s Books and Student’s Books, e) Instructional Effect and Nurturant Effect.

2.2.2 Formative Evaluation
Evaluation is important to do in research development, because it will determine the quality of the results of research development. Evaluation technique that is often done is formative evaluation. Formative evaluations in MLMB-RMEL development research were selected and carried out based on Tessmer's evaluation theory (1993) (Figure 2), namely self evaluation, expert review, one-to-one evaluation, small group evaluation, and field tests [13]. The experts who act as validity are mathematicians, mathematic education expert, education experts, language experts and teachers as practitioners.

a. Self Evaluation, The formative evaluation phase begins with an evaluation by self evaluation of the prototype design results. The purpose of this self-evaluation is to re-check the complete structure of the Model Book, Teacher's Book and Student's Book which was developed and indicate the presence or absence of obvious errors. After the evaluation results themselves are analyzed, then a revision is made. The results of self evaluation are called Prototype 1 which will then be tested for validity through expert judgment.
b. Expert Review, At this stage, Prototype 1 is assessed and evaluated by experts. The experts examined the content, constructs, and language of Prototype 1. Responses and suggestions from experts (validators) about Prototype 1 were written on the validation sheet as a basis for determining whether Prototype 1 that has been produced is valid or needed to be revised. After the prototype 1 is prepared is declared valid and produces prototype 2, then conducted a trial to evaluate the prototype 2 by way of one-to-one evaluation and small group evaluation.

c. One-to-one evaluation is done by asking three students consisting of low, medium and high ability students to provide comments on the product that has been designed. The determination of the three students is done by researchers through the help of teachers with reference to the mid-semester grades. One-to-one evaluation is conducted face-to-face between the researcher and one high-capacity student, then the researcher and the medium-capable student, and the researcher with a low-ability student. This evaluation was carried out to identify possible errors such as poorly understood grammar, misspelled spelling, unclear usage instructions, ease of use, and suitability of the existing images for the given problem. The instruments used in individual evaluations were questionnaires and interview guidelines. After the individual evaluation is complete, the product is revised based on the individual evaluation, and the results of the product revision (prototype 2) are referred to as prototype.

d. Small Group, Then prototype 3 products were tested in small groups. The number of students in small groups consists of six students with diverse learning abilities. Determination of the six students is also determined by researchers assisted by mathematics teachers. The instruments used in small group evaluations were questionnaires and interview guidelines. Before use, the instrument was validated by several experts. After evaluating a small group, the revised product is called prototype 4.

e. Field Test This prototype 4 was then trialled in the field (Field Test) and the results were revised to obtain the final product. Field test to find out whether the learning model developed is practical and effective. This field test is carried out in the third phase of the research, namely the assessment phase.

2.3 Revisi Prototipe
Revisions to prototype design are based on expert and practitioner input and advice. Expert or practitioner assessments must show that the prototype is valid so that it is appropriate to use. If the expert or practitioner recommends that the prototype is not suitable for use or needs to be revised, a revision will be carried out and the formative evaluation phase will be repeated. If the assessment of experts or practitioners has stated a valid prototype, the research continues to the assessment phase.
The intervention in this research was in the form of developing MLMB-RMEL. The discussion in this paper is focused on developing the MLMB-RMEL as a result of the Preliminary Research Phase and Designing Prototypes in Development Phase (Figure 3).

Figure 3. Diagram of Developing the MLMB-RMEL on Preliminary Research Phase and Designing Prototypes in Development Phase

2.4 Preliminary Research Phase
2.4.1 Need and Context Analysis
The results of interviews with five mathematics teachers from three Junior High Schools in Bukittinggi on May 23rd, 2018 obtained information: 1) Some factors causing low literacy of mathematics students were: students were lazy to read; mastery of low student concepts, and 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: provide teaching materials that stimulate students to want to read; giving more practice HOTS questions; 3) Relating to the literacy component: The most difficult mathematical content for students is geometry and algebra; 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; 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; 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: Teaching materials that integrate the concept of mathematical literacy; learning model 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 on May 24th, 2018, obtained information: 1) In learning mathematics: students wanted explanation of teachers; students needed to know how to find the formula; it was important to introduce the usefulness of the formula in everyday life; a contextual learning model and the creation of interactions between students and students with teachers; 2) Learning tools: students were less easily understood; the student wished for a Group Worksheet and Individual Worksheet; students want learning tools that were practical, effective, and easily understood; 3) Associated with the literacy component: Mathematical content that was difficult for students was algebra and geometry, the context that appealed to students was science; and a difficult mathematical process for students was to interpret.

Curriculum analysis that had been done through documentation studies obtained information 1) Mathematics content in SMP Class VIII semester I consist of Numbers, Algebra, Geometry and Measurement; 2) 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; 3) The evaluation used includes attitude, knowledge and skill assessment.
Concept analysis was carried out on the subject matter of Systems of Linear Equations in 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.

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: Religion: 81.25% Moslem; Tribe: 75% Minang; Gender: 25% Male, 75% female; 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: most students hobby reading, art and sports; more than half of students had aspirations to become doctors/nurses and teachers/ lecturers; 93.75% students loved traditional cuisine; and all students loved the colors.

3. Literature Review
In this research, the mathematical learning model based on realistic mathematics education and literacy (MLMB-RMEL), or abbreviated as the RMEL model, was developed for the achievement of students' mathematical literacy. This model combines the RME approach with the model of mathematical literacy in practice [14] (Figure 4).

The outer-most box in Figure 4 shows that mathematical literacy takes place in the context of a challenge or problem that arises in the real world. In this framework, these challenges are characterised in two ways. The context categories, which will be described in detail later in this document, identify the areas of life from which the problem arises. The context may be of a personal, societal context, an occupational context, or a scientific context. Problems are also characterised by the nature of the mathematical phenomenon that underlies the challenge. The four mathematical content categories identify broad classes of phenomena that mathematics has been created to analyse. These mathematical content categories (Quantity, Uncertainty and data, Change and relationships, and Space and shape) are also identified in the outer-most box.

To solve such contextualised problems, individuals must apply mathematical thought and action to the challenge, and the framework characterises this in three different ways. First, Figure 4 acknowledges the need of the individual to draw upon a variety of mathematical concepts, knowledge and skills during the work. This mathematical knowledge is drawn upon as the individual represents and communicates mathematics, devises strategies, reasons and makes arguments, and so forth. These mathematical actions are characterised in the framework in terms of seven fundamental mathematical capabilities which are listed in Figure 4 and described in detail later in the document. As an individual works on the problem- which may require problem formulation, employing mathematical concepts or procedures, or interpretation of a mathematical solution.
The visual depiction of the mathematical modelling cycle in the inner-most box of Figure 4 portrays an idealised and simplified version of the stages through which a problem solver moves when exhibiting mathematical literacy. It shows an idealised series of stages that begin with the “problem in context.” The problem solver tries to identify the relevant mathematics in the problem situation and formulates the situation mathematically according to the concepts and relationships identified and simplifying assumptions made. The problem solver thus transforms the “problem in context” into a “mathematical problem” amenable to mathematical treatment. The downward-pointing arrow in Figure 4 depicts the work undertaken as the problem solver employs mathematical concepts, procedures, facts, and tools to obtain the “mathematical results.” This stage typically involves mathematical reasoning, manipulation, transformation and computation. Next, the “mathematical results” need to be interpreted in terms of the original problem (“results in context”). This involves the problem solver interpreting, applying, and evaluating mathematical outcomes and their reasonableness in the context of a real-world-based problem.

RME is a theory of teaching and learning mathematics that has been developed in the Netherlands since the early 1970s. This theory is strongly influenced by Hans Freudenthal's concept of 'mathematics as a human activity'. 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, 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. The principle of PMR is also called the PMR theoretical basis.

The process of designing a sequence of instructional activities that starts with experience-based activities in this research was inspired by five characteristics for realistic mathematics education defined by Treffers (1987) that are described in the following ways: Phenomenological exploration; Using models and symbols for progressive mathematization; Using students’ own construction; Interactivity; and Intertwinement. The characteristics of PMR are also referred to as applicative basis for PMR [15].

Based on the description above can be developed the conceptual framework or theoretical framework of this research as follows (Figure 5).

![Figure 5. Conceptual or Theoretical Framework](image)
Designing Prototypes

a. Syntax
Syntax is the steps, phases, or sequence of learning activities. So the syntax is the description of the model in action. Each learning model has a different phase sequence. The sequence of activities or phases in learning will be a guide for teachers and students in implementing the learning process [16]. The MLMB-RMEL model syntax is designed based on three principles of RME, five characteristics of RME, and model of mathematical literacy in practice. The result of MLMB-RMEL syntax design consists of 8 steps, namely: Giving the Realistic Problem, Developing the Model, Working Mathematically, Doing Interpret, Doing Evaluate, Classroom Discussion, Giving Another Realistic Problem in Same Context, Practice of Mathematics Literacy Questions.

b. Social System
The social system is a description of the role and relationship of teachers with students and the underlying norms. In this RMEL model, the roles and relationships of teachers and students include: Teachers as designers, teachers are tasked with designing and planning learning, and preparing various matters related to learning; The teacher as a guide; The teacher as a mediator; The teacher as a motivator; The teacher as a facilitator; and The teacher as an evaluator.

c. Principle of Reaction
The principle of reacting patterns of activities that explain how a teacher appreciates, places and responds to what is done by students. Joyce & Weil (1992) outlines that the principle of reaction is a guideline for teachers to appreciate and respond to stimuli in the form of student behavior in the learning process. In this RMEL model: 1) The teacher places students as subjects in learning; 2) The teacher increases students' mathematical literacy; 3) The teacher facilitates the learning process; 4) The teacher holds group discussions and makes all students participate to contribute during the group discussion; 5) The teacher pays attention to and appreciates student contributions or ideas so that an exchange of ideas occurs in the learning process.

d. Support System
Support system is everything that is needed to implement the learning model so that the model can be implemented effectively. For this RMEL model a support system is needed in the form of: 1) The Model Book, which contains rational models, supporting theories and model characteristics; 2) Teacher's Book, is a guide to learning activities contained in the Student Book with the aim of helping the teacher in managing learning outlined in the Lesson Plan; 3) Student's Book, is a teaching material to handle for students with the aim of helping students in the learning process.

e. Instructional Effect and Nurturant Effect
The instructional effect of applying the RMEL model is, Increased understanding of students' mathematical concepts, Achievement of students' mathematical literacy. The nurturant effect of the application of the RMEL model is as follows, Increase student motivation, Increase student learning activities, Ability to learn in various contexts, Ability to construct knowledge, Ability to work together.

4. Conclusion
The results of the design of mathematics learning models based on realistic mathematics education and literacy in the form of a model syntax consisting of 8 steps, namely: Giving the Realistic Problem, Developing the Model, Working Mathematically, Doing Interpret, Doing Evaluate, Classroom Discussion, Giving Another Realistic Problem in Same Context, Practice of Mathematics Literacy Questions. The syntax was designed based on the three principles of RME, five characteristics of RME, and model of mathematical literacy in practice

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