Mathematical modeling in realistic mathematics education

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Abstract. The purpose of this paper is to produce Mathematical modelling in Realistics Mathematics Education of Junior High School. This study used development research consisting of 3 stages, namely analysis, design and evaluation. The success criteria of this study were obtained in the form of local instruction theory for school mathematical modelling learning which was valid and practical for students. The data were analyzed using descriptive analysis method as follows: (1) walk through, analysis based on the expert comments in the expert review to get Hypothetical Learning Trajectory for valid mathematical modelling learning; (2) analyzing the results of the review in one to one and small group to gain practicality. Based on the expert validation and students' opinion and answers, the obtained mathematical modeling problem in Realistics Mathematics Education was valid and practical.

1. Introduction
By modeling, mathematics education for student becomes more meaningful and justification of modeling is the essential goal of teaching mathematics [1, 2]. In fact, mathematical modeling learning in schools is very few. Everyday, in many countries, teaching mathematics seldom apply the modeling because it is difficult for the teachers to do [1, 2]. In addition, modeling is actually rather difficult for students). Then Blum [1] states that students find it difficult to mathematical modeling due to the demands of modeling tasks. Modeling is inseparable from other mathematical competencies, i.e. reading and communicating, designing and implementing problem-solving strategies or working mathematically such as reasoning, computing, etc. [3]. It is closely related to PISA, Stacey [4] state that PISA has moved away from the dubious traject of concluding students’ ability to perform mathematical heuristics in the abstract (e.g. solving equations, performing calculations).

The 2013 Curriculum states that Mathematics in schools is expected to support the achievement of the competence of elementary and secondary education graduates through learning experiences in order to be able to understand concepts and apply mathematical procedures in everyday life, make generalizations based on patterns, facts, phenomena, or existing data, conduct mathematical operations for simplification, and analysis of existing components, do mathematical reasoning that includes making allegations and verifying them, solve problems by communicating ideas through symbols, tables, diagrams, or other media to clarify circumstances or problems, and grow positive attitude such as logical, critical, meticulous, and not easily give up in solving problems.

To achieve these competencies requires an innovation, one of which is by modeling. According to Bliss [5] that 21st century skills are creativity and innovation, critical thinking and problem-solving,
and communication and collaboration which are all achievable through modeling. The importance of preparing students for mathematical literacy is by equipping them with 21st century competencies [6]. Mathematical modeling is one way to achieve this goal [7]. Thus, to achieve the competency goals of elementary and secondary school graduates and 21st century mathematics and literacy skills are by learning mathematical modeling in schools.

Freudenthal [8] argues that the traditional problem-solving practice in mathematics learned in schools does not quite fit into the idea of mathematical modeling since the mathematical modeling is the structuralization of reality by the use of mathematics, whereas the type of problem solving does not contain mathematical heuristic strategies. Furthermore, according to Mousoulides [9] modeling activities not only can help students to use essential mathematical ideas in problem-solving, and but also can help teachers to develop students' sense of thinking. Traditionally, students do not learn mathematical modeling until they reach secondary school [10]. Whereas mathematical modeling can and should be started early when the students already have basic competence then modeling can be developed [11, 12]. It is also supported by [5] that mathematical modeling should be taught in every level of mathematics education for the students. This means modeling learning in primary and secondary schools has to be taught. In fact in Indonesian, mathematical modeling is not formally introduced at any school level [13].

This means that junior high schools have to include modeling in learning. Based on the previous description, the authors were interested in conducting a study entitled "Mathematical modeling in Realistic Mathematics Education". The problems of the study were formulated in the following questions as follows: 1. How is the Mathematical modeling Problem in Realistic Mathematics Education made valid? 2. How is the Mathematical modeling Problem in Realistic Mathematics Education made practical? This study aimed to produce valid and practical Mathematical modeling Problem in Realistic Mathematics Education for junior high schools. The expected benefits of the results of this study were for teachers, students, policy makers, and researchers.

2. Method
This study used development research methods developed by Akker, et al. [14] consisted of 3 stages, namely analysis, design and evaluation. In the analysis step, student analysis, curriculum and mathematical modeling are carried out. The second step designed and produced (Mathematical modeling). The final step used a formative evaluation design (Figure 1) consisting of self-evaluation, one-to-one, expert review, small group, and field tests [15, 16]. This study was only conducted until the small group phase.

![Design of Formative Evaluation](image)

**Figure 1.** Design of Formative Evaluation [15, 16]

The success criteria of this study used the form of Mathematical modeling for learning modeling that was valid and practical for students. The validity was obtained from the validation of experts and
the practicality was obtained from the students' opinions and observations of the small group and one-to-one. Practicality means easy to use, interpretable, and unambiguous.

The subjects of this study were students of SMP Negeri 6 Kayuagung, Ogan Komering Ilir District, South Sumatra. The techniques of collecting the data were (1) walk through based on the expert review to get a valid mathematical modeling problem in content, construct and language aspects. (2) interview derived from one to one and small group to find out the practicality of the problem. The collected data were analyzed using descriptive analysis method: (1) walk through sheet analysis based on the expect comments in expert review to get valid mathematical modeling problem; (2) analyze the results of the review in one to one and small group to get practicality.

3. Results and Discussion

3.1 Results

Validity of the mathematical modeling problem in Indonesian Realistic Mathematics Education was done by Zulkardi [16]. Zulkardi [16] suggested using Uber context while my problem is using bus hire context and book pen spending in Mathematics modeling problem in Indonesian Realistic Mathematics Education on Material of Two Variable Linear Equation System. Therefore, the design of the mathematical modeling in IRME used Uber context. Darmawijoyo suggested using real photos in contextual use and immediately raising questions from the photo. Therefore, the images were used in designing modeling problems. The validation of these two experts obtained a valid mathematical modeling problem in the Indonesian realistic mathematics education using Uber context. The mathematical modeling problem is as follows:

![Mathematical Modeling Problem in Realistic Mathematics Education](image)

**Figure 2. Mathematical Modeling Problem in Realistic Mathematics Education**

After design being validated by the experts, then one-to-one was conducted to find out the practicality of Mathematical modeling Problem in Realistic Mathematics Education. One-to-One was conducted at SMP Negeri 6 Kayuagung on Tuesday, October 3, 2016. There were three students of grade VIII.2 selected, namely Kaysha Frida Pracillia, M. Rahman Aria Pratama and Orin Allysia. The following are one-to-one photographs.
The one-to-one result based on the student opinion showed that the modeling problem was good and could make the students think reasonable. However, there were some terms that had to be explained first because the students were not familiar with the terms such as assumptions, parameters, and essential variables. In addition, they did not yet understand the language of identification and specify the problem to be resolved. Thus, it should be given an explanation first in order to make them understand the language. The following are the student's responses to the modeling problem.

Judging from the student's answer, it shows that the students were able to make identification and problem specifications, make assumptions, do math to get the solution and provide recommendations although they cannot be generalized. Based on the validation and one-to-one results, we obtained valid and practical mathematical modeling problem in realistic mathematics education for learning mathematical modeling for material equations and system of linear equations of two variables. The student answers seen in Figure 5.
3.2 Discussion

The Traditional Approach to teaching mathematics is not sufficient for strengthening student problem-solving skills and thus can not help students to develop competence in math and application [17, 18, 19]. In the traditional approach of learning there were more emphases on the mechanistic and memorize solutions and operations of mathematics. For example, according to Bahmaei [20] in elementary schools in general, early arithmetic teaching focused on computational skills. Further, it is also supported by the assertion that the results of traditional approaches in mathematics are mechanistic or reminding of solutions to story problems/word problem [21, 22]. Furthermore, according to Zulkardi [23] in traditional programs, objectives are classified as low-level goals based on the skills of formulas, simple algorithms, and definitions. Bustang [24] state that learning process not only takes place within individuals themselves, but it also involves the social interactions among them. Furthermore, in the traditional approach, students solve without understanding the problem [25], as well as in traditional dominant learning strategies the dominantly solving problems look for keyword interpretation rather than thinking deeply about the problem [17, 26]. Based on this it is necessary to have a new learning approach. Based on the study conducted by Mouselides [27] it recommends that the development of more specific problem solving strategies (modeling process) is needed. Furthermore Zulkardi [28] states that there are 4 steps of doing mathematics or the use of mathematics in everyday life are identifying where math can be applied, changing the practical problem into a problem or mathematical model, solving math problems, and interpreting and evaluating the obtained results.

Furthermore Zulkadi [28] states that during the focus of mathematics education is in step 3 it can all be done by a computer. Thus, the focus of mathematics education is important to move on to the other three steps. It also means that there are needs for innovation in mathematics learning in schools in order to achieve competence or skills in the digital community. This is in accordance with Zulkardi’s [28] statement that mathematical competence is known in mathematics education as the competence required for the digital community: application or modeling, understanding and checking. In other words it is very important to apply the modeling competence in mathematics education in schools.

Furthermore Bliss [5] states that modeling in pre-kindergarten up to grade 8 is a way to float and maintain the mathematical disposition of students to mathematics. This is in line with Gravemeijer [29] assertion that there is a tendency to shift mathematical learning approaches in mathematics education in primary schools from "knowledge transfer" to "construction of knowledge" and also this certainly happens in junior high schools. This fits perfectly with learning by modeling. This is also supported by Bliss [5] that mathematical modeling should be taught in every level of student math education. Mathematical modeling (the process of translating between the real world and mathematics in both directions) is a topic in mathematics education that is most discussed and developed over the last few decades [1].

Everyday the teaching of Mathematics in many countries is very few with modeling, and this is due to the fact that the modeling is difficult for teachers [1]. Also Sumarto [30] states that It is not easy for a teacher to facilitate all the students’ needs by giving an individual coach for every student in the class. Then, traditionally,
students were not introduced Mathematical modeling through junior high schools [10]. Furthermore, Mathematical modeling is not formally introduced at the school level in Indonesia[13]. In fact, Mathematical modeling should be and could be started early, when students already have basic competencies then modeling can be developed [11, 12]. It is also supported by Bliss [5] that Mathematical modeling should be taught in every level of mathematics education. On the Competency Standards of the 2013 Curriculum students must have 21st Century Skills [31]. The 21st century skills are creativity and innovation, critical thinking and problem solving, communication and collaboration which are all accessible via modeling [5, 32-34].

This study conducted the designing process of mathematical modelling problem in Realistic Mathematics Education which was valid and practical, i.e. on linear equation material and system of linear equation of two variables which were recommended to be done in small group and field test further. With small groups and field tests it can be obtained mathematical modelling problem that has a potential effect [23, 35]. In this case researchers conducted the small groups and field tests further to obtain valid and practical mathematical modelling problems, had potential effects, and could prepare students having 21st century skills and improve their high-order thinking skill (HOTS) according to the hope of revised edition of 2013 curriculum. This study as a continuation of the study Mouselides [27] that study about to develop a smaller and more focused theoretical model and modeling as problem solving activities for teaching, learning and development in Elementary and junior high school. This study about how to design mathematical modeling in realistic mathematics education in junior high school. Morever, this study also relate to Zulkardi [23].

4. Conclusion
The validation and one-to-one results produced valid and practical mathematical modeling problem in realistic mathematics education for learning mathematical modeling of material equations and system of linear equations of two variables.

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