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Realistic Mathematics Education Based on Emergent Modeling

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Abstract

The unconsciousness of a teacher in obtaining knowledge due to students, can be known if the teacher was notified when he was a student. A student has an important role in learning and the teacher has a responsibility to support the smooth learning. Students' problem-solving processes need to be found because each student's reasoning ideas in solving problems are different. This study focuses on students' thinking processes by using Realistic Mathematics Education based on Emergent Modeling. Prospective teachers were selected as research subjects as many as 74 people consisting of 3 classes. The research method uses descriptive qualitative. As learning activities progress, students get a kind of model of that seems as solutions in solving problems given by the teacher. Various kinds of models emerged from various student ideas, and ended with a mutually agreed for a model for.

Keywords: descriptive qualitative; Emergent Modeling; model of; model for; Prospective teachers; Realistic Mathematics Education

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Introduction

The progressive concept of a model is a core element in Realistic Mathematics Education (Sumirattana et al., 2017). The key to using this progressive concept involves the relationship between the development of the use of symbols and the development of the meaning of mathematics itself. Vygotsky (Oers, 2002a; Walshaw, 2017) has advised that the development of student knowledge can be seen from different levels. Wertsch (Wertsch, 1985; Oers, 2002a; Kaiser, 2020) named this level difference as 'genetic domains' and divided it into four levels related to 'modeling', namely: 1) the phylogenetic level, can be seen as the level of development of a person's thought representation function during phylogenesis; 2) the sociogenetic level, can be seen as a process of developing modeling as a cultural tool in history or natural science; 3) the ontogenetic level, trying to describe and explain the process of development of a person related to symbol functions and modeling; and 4) the micro genetic level, refers to the process in deciding a model to be used in a particular situation.

Any students, in solving mathematical problems, often use words or movements that are difficult for teachers to understand. This happens in children aged 4-5 years, mathematical ideas that arise at this age we name the knowledge or activity 'pseudomathematical' (Oers, 2002b; Danesi, 2018). These pseudomathematical pseudoconcepts in mathematics explain that a child can predict the situation precisely through the terminology he did himself, but cannot give arguments to influence others why we can be sure that the answer is correct.

Children aged 8-9 years start to progress in making their mathematical system based on the object being seen and its relation to the surrounding circumstances (Lehrer & Pritchard, 2002; Abdulhameed & Rashid, 2021). Therefore, the learning process in the form of activities can be a suitable starting point to begin the development of children's mathematical characteristics. A child will gain broad practical experience, mathematical and modeling provide a new perspective on symbolization, not just activity. The teacher is not as simple as simply focusing on his activities, a teacher supports students to consider how students' mathematical thinking can generate along with the learning activities. Things like this are an important role of a teacher in helping students build their identity as someone who thinks mathematically (Mead, 1934, 1938; Lehrer & Pritchard, 2002; Kieren, 2020).

Students can think mathematically in the learning process with support from the teacher, not a refusal, in promoting the representations/models they perform (Meira, 2002; Hefendehl-Hebeker, et al., 2019). The situation requires to be made as if students only have a focus on aspects of developing knowledge. Students' knowledge develops along with the development of the representations they do. A rich and meaningful number of ideas is needed in promoting representation. DiSessa (2002) revealed three quality criteria for representation, i.e: 1) rich and generative of meaning, 2) reactive and unclear; and 3) connected with design; not all can relate in all contexts.

The development of representation/models of a mathematical concept does not develop fully directly, but develops slowly through social interaction in discussions about concepts/problems encountered during learning activities take place, and are related to each other. The linkage of these activities can be through pseudo-concepts and experiments in using and evaluating notations used as communication media with other students, or with teachers (Presmeg, 2002; Carroll et al., 2018). In Oers research (Oers, 2002a), a child is in the transition zone between playing and learning mathematics, so Oers takes a transition activity that can be used by children to play chili learning. This transition zone happens at the ontogenetic level and produces new psychological phenomena that are integrated and exceed previous knowledge.

During the transition zone, a child experiences a progressive process of mathematics on a large scale (Lehrer & Pritchard, 2002; Silinskas & Kikas, 2019). This can be indication that pseudo-concepts and the role of social interaction in the learning process activities are going properly. Meanwhile, Meira (2002) figured that the system of notation (writing or representation) built by students as a learning media tool can be a trigger for the sustainability of mathematics learning activities. Not just writing or representation as to the final result of learning, but as an important transition, component to be seen as a student's process of making a solution of a mathematical problem situation.

This study intends to see Realistic Mathematics Education Based on Emergent Modeling applied in the classroom. Researchers hope that through this learning, students get more meaningful learning based on the context of daily problems and solution models.

Methods

This study is qualitative research that proposes to analyze and explain the answers of students in solving the problems given (Afriansyah, et al., 2019). The data analyzed is the students' written answers in groups, each group of five people. Obtained from working on written problems with research subjects as many as three classes, a total of 74 people. The subjects of this study were the student from the Mathematics Education Study Program of the Institut Pendidikan Indonesia. The idea of this study was carried out from Gravemeijer's mathematical concept.

Gravemeijer (1999, 2007) explained the new mathematical concept as the main goal of mathematics learning activities through modeling. Thus, in the 'emergent' perspective, modeling activities can be understood as a mathematical process where the situation appears during the transition zone of mathematical relations. Situations and models emerge at the same time and form one another (Gravemeijer, 2002b; Afriansyah, 2021). In this way, students acquire high levels of 'common sense' (Freudenthal, 1991; Fredriksen, 2021) for reasoning about new phenomena in their reality, and formal mathematics emerges naturally from student activities. The term 'emergent' refers to two different but interrelated processes, i.e: the emergence of a model for mathematical reasoning; and at the same time the emergence of more formal mathematical knowledge (Gravemeijer, 1999).

In the beginning, the model that emerged was a particular situation model and earned its meaning from the activity in assigning tasks. This is a model of a particular process (Gravemeijer, 1999). Through extensive activities in assignments, students eventually begin to be able to conclude. The model does not change, but the meaning changes. No longer meaning certain circumstances, it has become a model-for way of thinking that is more formal. The learning process that begins to a shift from model-of to model-for states itself as a sequence of sub-models (Gravemeijer, 1999, 2007; Gravemeijer & Bakker, 2006].

However, to highlight more on the emergence of concepts required for modeling, Gravemeijer (2002a, 2007) offered an alternative view where the model is the outcome of arranging activities. This is in the process of structuring the problem situation that the model emerges (Gravemeijer, 2002b). From this perspective, the situation model functions to earn insight into phenomena and create simple generalizations. At the same time, concepts must not remain situationally specific but can also function in the creation of models for designs about different situations, thus allowing for deeper insights into the concepts themselves.

Gravemeijer (2007) put ahead careful consideration in the teaching and learning process to support the emergent modeling process in learning. Two questions appear in the design of assignments like this: What new concepts should students create and what are the overall models? For data analysis, Gravemeijer (2007) offered the concept of "distribution as an entity". For him, the idea of form is the core of this concept and can be obtained through a series of sub-models that change.

New ideas or concepts can be obtained from the perspective of 'emergent modeling' as the transfer of the role of a model, particularly: a model of to a model for (Buscher & Schnell, 2017). The situation model is context-specific and acts as an assistant used to talk about a specific phenomenon. The purpose of this model is to understand the given situation and to allow informal deducing beyond the data provided. Model-for reasons in some situations and allows the organization terms of setting various similar and new contexts.

Buscher & Schnell (2017) revealed that this 'emergent modeling' can be seen as an approach. The 'emergent modeling' approach is applied (1) as a theoretical framework to describe students' conceptual progress by providing model-of and model-for as a means to follow student development, and (2) as a design heuristic for developing teaching and learning settings intended at developing insight, one of which is the choice of contexts that are 'meaningful'. Therefore, two important roles can be played by 'emergent modeling', i.e: to design and explain student learning.

Meanwhile, in creating a theoretical framework based on 'emergent modeling', Doorman & Gravemeijer (Doorman & Gravemeijer, 2008) provides an overview of (1) how students are expected to act and reason with 'tools', (2) how activities are related to previous activities and (3) conceptual development aimed at the activity. This tool emphasizes the context used at the situational level and the models that emerge at the next level. This theoretical framework based on 'emergent modeling' cannot be separated from learning Realistic Mathematics Education. In Indonesia, we name Realistic Mathematics Education with Pendidikan Matematika Realistik Indonesia (PMRI). PMRI still using all theories of Realistic Mathematics Education, and add with Indonesian context (Afriansyah et al., 2021).

In the learning process, Zulkardi (Riyanto & Putri, 2017) states the stages of learning Realistic Mathematics Education, namely: 1) What is done at the beginning is to prepare realistic problems. The teacher must understand the problem and have difference strategies that students might practice to solve it; 2) Students are introduced to learning strategies that are used and introduced to realistic problems; 3) Then students are asked to solve the problem in their way; 4) Students try various strategies to solve these problems according to their experiences, the problems can be done individually or in groups; 5) Then each student or group present their work in front of the class, students or other groups respond to the presenter's work; 6) The teacher observes the course of class discussion and responds while directing students to get the best strategy and find rules or principles that are more general in nature, and 7) After reaching agreement on the best strategy through class discussion, students are invited to conclude the lesson at that time. At the end of learning, students must go on evaluation problems in the form of formal mathematics.

Meanwhile, Wijaya (2012) stated the stages of the mathematical process in learning Realistic Mathematics Education, namely: 1) Starting with real-world problems; 2) Identifying mathematical concepts that are relevant to the problem and then organizing problems according to mathematical concepts; 3) Gradually leave the real-world situation through the process of formulating assumptions, generalizations, and formalization. This process tries to translate real-world problems into representative mathematical problems; 4) Solving mathematical problems (this process happens in the world of mathematics); and 5) Re-translating mathematical solutions into real solutions, including recognizing the limitations of the solution.

Based on the numerous theories discussed earlier, the researcher arranges the stages of learning Realistic Mathematics Education based on Emergent Modeling, shown in Table 1.

Table 1. The Stages of Realistic Mathematics Education based on Emergent Modeling.

No	Stages	Activity	
		Student	**Teacher**
1.	Situational	Recognizing together about numerous real-world problems	Communicate on various problems in the real-world
		Identify mathematical concepts that are related to the problem	Request about mathematical concepts that are related to the problem
		Understand the problem presented	Present mathematical problems related to the material
		Solve mathematical problems	Go around observing student work
2.	Referential	Study for associations between problem languages with symbols, images, or other mathematical representation models	Observe, motivate, and provide restricted direction to students so they can find their solutions
		Look for associations between problem languages with symbols, images, or other mathematical representation models	
3.	General	Understand different mathematical representations	Ask different groups that have different answers to explain the results of their work
		Perform mathematical arguments about different ways	Acting as a control of the direction of the discussion

		Generalize (model for) the correct way to solve	Collectively concludes the most meaningful and easy to understand solution
4.	Formal	Repeating and reflecting mathematical arguments	Ask back to students, what concepts are needed in solving the problem
		Apply formal mathematical language and symbols	Reply to different student answers and conclude together formal solutions from previous problems
		Formulate a formal solution	

Results

The results of written questions taken from all groups of students were analyzed based on the stages of learning Realistic Mathematics Education based on Emergent Modeling. This study proposes to manage the application of Realistic Mathematics Education learning that can focus on the answer models' students make. The following analysis is conducted by researchers based on the stages of Realistic Mathematics Education based on Emergent Modeling, i.e:

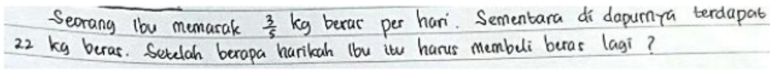
Situational Stages

At this level, lecturers talk about various contexts of daily problems related to the division of fraction material with the hope that students can realize the problems around their lives. General discussion is held to draw student motivation in the context of daily problems. After that, students are invited to think a little about the mathematical concepts involved in daily problems. Students need to know for themselves, what mathematical material is used for each problem that has been discussed.

The activities continued with group activities, students were divided into groups, each group consisting of five students (Figure 1).

Figure 1. Some student groups consisting of five people

Teachers present mathematical problems (Figure 2), students try to understand these problems in groups.


Seorang Ibu memasak $\frac{3}{5}$ kg beras per hari. Sementara di dapurnya terdapat 22 kg beras. Setelah berapa harikah Ibu itu harus membeli beras lagi ?

A mother cooks $\frac{3}{5}$ kg of rice per day. While in the kitchen there is 22 kg of rice. After how many days did the mother have to buy rice again?

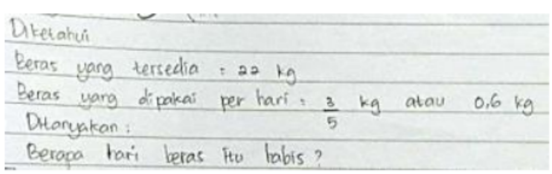
Figure 2. Mathematical problem

Around 60 minutes, students must be able to solve these problems in the best way they can think of (Figure 3). The teacher went around to see how the mathematical problems of each group were being worked on.

Figure 3. Students discuss in their groups

Referential Stages

Each student group needs to first interpret the mathematical problem by understanding the language of the given problem. After that, they need to represent the problem in other models, such as pictures, symbols, short sentences (Figure 4), and so on. They can use this representation as a tool to understand more than the problems given. Teachers keep going around and are always ready if there is a group that is having difficulty in the process of working on the question.


Diketahui
Beras yang tersedia : 22 kg
Beras yang dipakai per hari : $\frac{3}{5}$ kg atau 0,6 kg
Ditanyakan :
Berapa hari beras itu habis ?

Known
Available rice = 22 kg
Rice used per day = $\frac{3}{5}$ kg or 0.6 kg
Asked:
How many days did the rice run out?

Figure 4. Representation of the problem in the form of short sentences

The teacher observes, motivates, and gives guidance to each group so that each student in each group can find their solution. Different ways/models (models of) emerge, the answer models given by each group display their thought processes and their discussion processes. Following are the models of each group and their analysis:

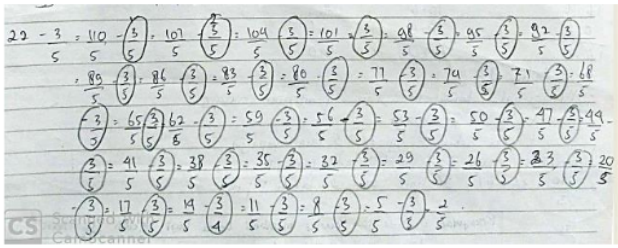
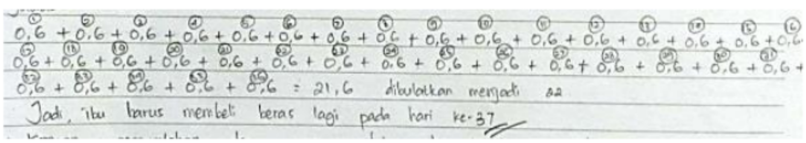


Figure 5. Model of reduction of repeated fractions

This model of reduction is a fairly easy method because it only needs to use the concept of reducing fractions. This method uses repeated fraction reduction (Figure 5), but this method is considered to be at great risk of making miscalculations. The method of adding together can also be said to be similar because it is an easy way to do, but it is risky for errors and requires a considerable amount of time.



0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 +
0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 +
0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 + 0.6 = 21.6 rounded up to 22
So, a mother has to buy rice again on the 37th day

Figure 6. Model of the addition of decimals

This model of addition is a fairly easy method. This method uses the concept of changing fractions into decimals and adding decimals (Figure 6). This method is better than reducing fractions repeatedly because it can minimize errors in making calculation errors and also the processing time is not too long. How to reduce repeating decimals can also be said to be similar, because it is an easy way to solve.

General Stages

At this level, the teacher questions many groups that have different answers to explain the results of their work. Each different model of the answer is presented in front of the class (Figure 7) so that each student can understand more than the work of his peers.

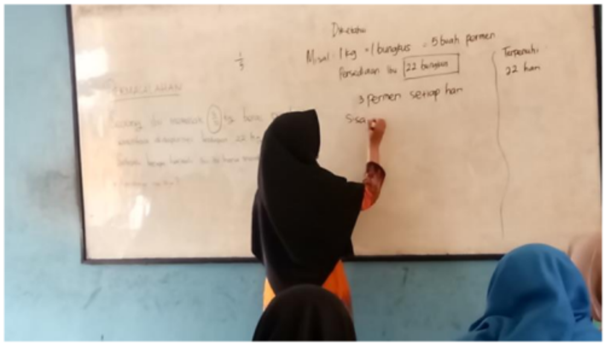


Figure 7. The first group shows the model of problem answers

Other students can give arguments for the work of students who have different ways. The lecturer acts as a regulator of the course of the discussion, must not blame one of the parties, only need to return it back to the student if there is an error made by students during the presentation. After that, the activity was continued by together concluding the most appropriate and meaningful solution, so that it could be easily understood and did not take up much time, namely the model for answers.

The model-for is not obtained from the lecturer, but the model-for is obtained from the work of the students themselves. These answers become answers that must be displayed by lecturers in front of the class (Figure 8).

Figure 8. The third group shows the model of problem answers

The answers were accepted and recognized by other friends as models for answers to the most suitable problems (Figure 9).

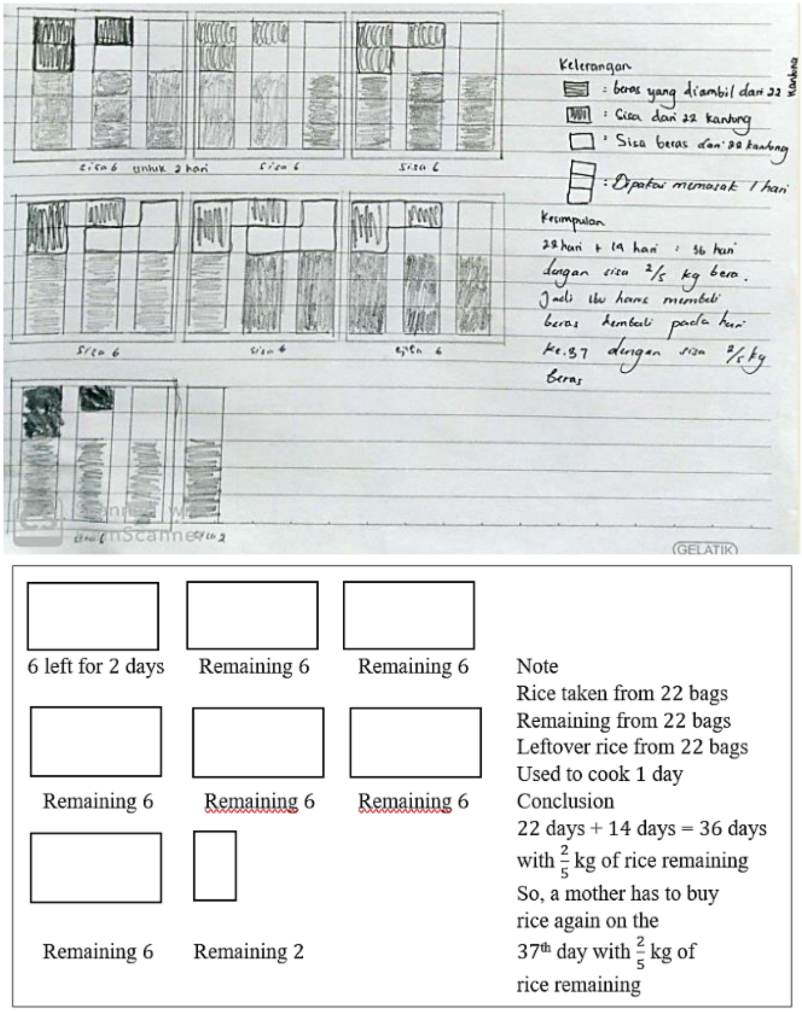


Figure 9. Model for fractional grouping

The model for grouping is a fairly effective way. Ideas in this work need a variety of mathematical concepts and critical abilities are quite good. This method uses a repeated grouping of fractions (Figure 9). The method of adding together repeated fractions can be said to be the best way that can be given.

Formal Stages

At this level, all answers are collected. Then, the teacher invites the students again what concepts are needed in solving these mathematical problems. The discussion activity was opened, the teacher replied to many student answers and concluded together (Figure 10) as a formal solution to the previous problem, namely the model for answers.

Figure 10. Conclusion activities together

Discussion

The explanation of these stages can accommodate a clear understanding of Realistic Mathematics Education based on Emergent Modeling. In line with several other studies that chose Realistic Mathematics Education as the core of their research, such as Realistic Mathematics Education based on ethnomathematics (Octizasari & Haji, 2018; Ardianingsih, Lusiyana, & Rahmatudin, 2019; Witha, Karjiyati, & Tarmizi, 2020), Realistic Mathematics Education based on learning trajectory (Sarvita & Syarifuddin, 2020; Mardiah, Permana, & Arnawa, 2021; Afriansyah & Arwadi, 2021), Realistic Mathematics Education based on progressive mathematization (Johnson, 2013; Herman, 2018), and other studies. Therefore, this study exists to complement other current studies.

Conclusion

The stages of Realistic Mathematics Education based on Emergent Modeling have been successfully implemented. Students can learn a lot. The knowledge earned is not limited to teachers, but can be received from other friends. Not only that, students are required to change ideas with their friends to learn the most suitable answers together. This can motivate students to be active, participate in the learning process. This learning phase can be applied if the center of learning is on the diversity of students' answers, so students can interpret the problem from various perspectives.

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Conflicts of Interest

The authors declare that no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely by the authors.

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