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A Concrete Situation For Learning Decimals

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Abstract

Learning about decimals is an important part in mathematics. However at the same time, decimals are known as the abstract numbers for students. Mostly in Indonesia, decimal is taught only as another notation for fractions or percentages. There are no meaningful references for them such as the use of concrete situations. This study aimed at investigating one situation that enables students to learn about decimals in a meaningful way, i.e. measurement activities. Design research was chosen to reach the research goal. Realistic Mathematics Education (RME) underlies the design of context and activities. Our findings are that the students could discover decimals and get meaningful situation from it. Measurement activities can promote the students' notion of decimals which, then, provoke the students' thinking into the idea of using number line as a model for placing the magnitude of decimals. Based on these findings, it is recommended that RME be implemented as an approach of teaching and learning decimals.

Keywords: decimals, Realistic Mathematics Education (RME), number line, design research.

Abstrak

Pembelajaran bilangan desimal merupakan bagian yang sangat penting dalam matematika. Akan tetapi, bilangan desimal dikenal sebagai bilangan yang abstrak untuk siswa. Pembelajaran bilangan desimal di Indonesia sebagian besar diajarkan hanya sebagai bentuk lain dari pecahan dan persentase. Belum ada acuan yang bermakna seperti halnya penggunaan situasi yang konkret (nyata). Penelitian ini bertujuan untuk menginvestigasi salah satu situasi yang memungkinkan para siswa untuk mempelajari bilangan desimal dengan cara yang bermakna, seperti kegiatan pengukuran. Metode desain riset dipilih untuk mencapai tujuan penelitian. Pendidikan Matematika Realistik mendasari desain konteks dan aktivitas pada penelitian ini. Penemuan kami adalah para siswa dapat menemukan bilangan desimal dan mendapatkan situasi yang bermakna dari penemuan tersebut. Kegiatan pengukuran dapat mendukung pemahaman siswa terhadap bilangan desimal, yang kemudian memancing pemikiran siswa terhadap ide penggunaan garis bilangan sebagai model untuk menempatkan besaran bilangan desimal tersebut. Rekomendasi berdasarkan hasil penelitian ini adalah Pendidikan Matematika Realistik sangat cocok untuk diterapkan sebagai pendekatan pembelajaran bilangan desimal.

Kata kunci: bilangan desimal, Pendidikan Matematika Realistik/ Realistic Mathematics Education (RME), garis bilangan, desain riset.

Introduction

Learning about decimal is difficult because it requires an extension of the number concept built on natural numbers (Desmet et al, 2010). At the same time, decimal is very important for students because they will encounter it very often in their calculation. Besides that, fractions, proportions, and percentages must be converted into decimals whenever the calculator is used (Van Galen et al, 2008).

There are many researches which have documented students' difficulties of decimals from primary to college levels (e.g., Glasgow, Ragan, Fields, Reys, & Wasman, 2000; K. Irwin, 1995; Padberg, 2002; Steinle &Stacey, 1998b, 2001, 2002 in Widjaja, 2008). Many students assumed that decimal is just the number containing point (*comma*) without knowing the meaning of it. According to Markovits&Even (1999), locating the decimal point by counting the total number of digits after the decimal point (a commonly taught technique) sometimes ends up with a mistaken answer. Therefore, the learning process needs such meaningful situations which bring the students' notion of decimals.

However, based on analysis of some Indonesian commercial textbooks, the approach to teaching and learning decimals is very symbolic and no attention is given to creating meaningful referents such as concrete models (Widjaja, 2008). Besides that, usually the teaching and learning decimals are less attention to the application in daily life. According to Zulkardi (2002), the material textbooks in Indonesia contain mainly sets of rules and algorithms and they lack applications that are experientially real to the pupils. In fact, the results of the tests indicated that most pupils lacked understanding of the basic skills that they were supposed to have learned in primary school and in everyday application problems. The meaningful situation is important in order to avoid students' misconception toward decimals.

This research has aim to contribute to the classroom activities in learning decimals. In this research, we designed the context and activities which enable students to discover decimals and get insight about their magnitude through measurement activities. Realistic Mathematics Education (RME) underlies the design of context and activities. The context designed is about the precise measurement on the activities of weight and volume measurement. The research question is:

"How do measurement activities promote students' notion of decimals?"

The mathematical goals in this research are:

1. Students are able to make connections between daily life situation (measurement activities) and mathematical idea (the notation of decimals).
2. Students are able to determine the relative position of decimals on the number line.

Theoretical Framework

1. Learning Decimals

Learning about decimals is an important part in numeracy because it is needed in all walks of life (Vicki et al, 1999). According to Widjaja (2008), the word 'decimal' is used to refer to a base ten number that is written with a decimal point. In Indonesia, usually we use comma (,) instead of point (.) to represent decimals. For examples 3,5 is read as three *comma* five.

Van Galen et al (2008) said that the students in primary school may have hardly worked with percentages and decimals. There are many studies shown that many children used some implicit and incorrect rules in doing decimals (Desmet et al, 2010). Hiebert and Wearne in Lachance&Confrey (2002) claimed that much of what students know about decimals can be classified as procedural rather than conceptual knowledge.

2. Measurement Activities

When we measure something such as length, height, weight, or temperature as precise as possible, sometimes it is not provided in whole numbers (discrete numbers). In this case, the amount is continuous. Vicki et al (1999) stated that the need to describe continuous quantities often occurs in commerce and everyday activities involving measurement where amounts of a basic measurement unit intermediate between two whole numbers need to be specified and communicated. Merenluoto (2003) stated that the students need to be aware of how they think about numbers and pay attention to the differences between different kinds of numbers which, then, showing that the students changed their abstraction of discrete numbers to an operational level of abstraction by adding decimals and moreover. In this research, we will use the context of precise measurement in the activities of weighing duku (original fruit from Palembang, Indonesia), weighing the body, weighing the rice (the main food for Indonesian people), and measuring the volume of beverages.

3. Realistic Mathematics Education

To build the conceptual knowledge of decimals, the problems which are given should be meaningful for students. In this research, Realistic Mathematics Education (RME) underlies the design of context and activities. Zulkardi&Ilma (2006) stated that the context is a main point for students in developing mathematics. Furthermore, they said that the context itself should be meaningful and real for students' mind.

RME is a theory for teaching and learning mathematics that has been developed in the Netherlands since the early 1970's. This approach emphasizes increasing pupils' understanding and motivation in mathematics (de Lange, 1987; Freudenthal, 1991; Gravemeijer, 1994; Streefland, 1991; in Zulkardi, 2002). In Indonesia, RME is adapted for over last ten years, namely *Pendidikan Matematika Realistik Indonesia* (PMRI), with the support of a group of Dutch math educators to create a new image of mathematics education in primary schools (Sembiring et al, 2010). As a basis of this research, RME approach is defined elaborately through five tenets for Realistic Mathematic Education by Treffers (1987 in Bakker, 2004):

a. Phenomenological exploration.

In order to develop intuitive notions as the basis for concept formation of decimals, in the first activity, we collected the information about students' background knowledge in decimals through playing come closer game. In the second activity, the students were experienced directly by weighing the fruit (Duku Palembang) and weighing their body in order to find the notation and the sequence of one-digit decimals. In the third activity, the students measured the weight of rice in order to explore the notation of one-digit decimals. In the fourth activity, they measured the volume of beverages in order to explore the notation of two-digit decimals. Through the contexts familiar for students, we expect that those can motivate them to engage in the learning process and help them to make mathematics become meaningful.

b. Using models and symbols for progressive mathematization.

The progressive mathematization here means the development from intuitive, informal, context-bound notions toward more formal mathematical concepts (Bakker, 2004). The sequence of designed activities in this research has purpose to bring the students' thinking in order to build self-developed model. Since the form of weight scale and measuring cup contain the scale, we expect those will bring students' thinking into the idea of drawing number line as a model for placing the magnitude of decimals.

c. Using students' own constructions and productions.

When students can construct number line from their experience in measurement activities, we expect that they can determine the magnitude of decimals by making ten partition of each range. From this strategy, the students could see that there are ten partitions containing one-digit decimals between two consecutive whole numbers, and there are ten partitions containing two-digit decimals between two-consecutive one-digit decimals. From this production, we expect the students can realize that decimal is the number base ten.

d. Interactivity.

From their own production (such as drawing number line or drawing the representation of the scales), we expect that students can make a meaningful discussion and they can share their finding with the others. The role of the teacher here also plays an important part in order to stimulate guided reinvention for students. Freudenthal (in van Nes, 2009) posits the importance of guided reinvention for stimulating mathematization. Finally there will be vertical interaction (between teacher and students) and horizontal interaction (between student with the other students).

e. Intertwinement.

Learning about decimals of course can be a basis which also can be integrated with other domains such as fractions, percentages, proportions, measurement and the development of number sense. When students are able to understand about decimals, it will be easier for them to do calculation such as addition, multiplication, division, etc.

4. Emergent Modelling

Models are primarily used to constitute a concrete point of departure for developing formal mathematics (Gravemeijer, 1994). The development from *model of* into *model for* is elaborated in the following four level structures, i.e. situational level, referential level, general level, and formal level.

a. *Situational level*

The level of the situation; where domain-specific, situational knowledge and strategies are used within the context of the situation (Gravemeijer, 1994). Here, we use the context of weighing scale and measuring the weight of fruit (Duku Palembang), the body, the rice, and the volume of beverages as experience-based activities in order to support students' learning of decimals.

b. *Referential level*

A referential level; where models and strategies refer to the situation which is sketched in the problem (Gravemeijer, 1994). The accomplishment of the referential level is shown by the use of the stripes on the number line. In this stage, the students are expected to consider the representation of the weight scale as a model of situation. Moreover, in this stage the representation of the weight scale becomes the base of the emergence of student-made measuring instruments.

c. *General Level*

A general level; where a mathematical focus on strategies dominates the references to the context (Gravemeijer, 1994). When students have already drawn number line and made the partition base ten or the partition base tenth of tenth, then we expect they will come up to model for reasoning in which they use number line to determine the magnitude of decimals by determining the more right position of decimals on the number line, the larger their magnitude.

d. *Formal Level*

The level of formal arithmetic; where one works with conventional procedures and notation (Gravemeijer, 1994). In this research, our focus is not really until formal level because we will more focus into the role of number line in placing the magnitude of decimals through measurement activities. However, this research can be a basis for the next stage (formal level) when the students are able to compare decimals without relying on the number line.

Methods

This research has aim to contribute to the classroom activities in learning decimals. Design research was chosen to acquire the research question and to achieve the research goal.

1. Research Methodology

a. Preliminary Design

The first phase starts with formulating mathematical learning goals, combined with anticipatory thought experiments in which one envisions how the teaching-learning process can be conducted in this classroom. This first step results a conjectured local instruction theory that is made up of three components: (a) learning goals for students, (b) planned instructional activities and the tool that was used, and (c) a conjectured learning process in which one anticipates how student's thinking and understanding could evolve when the instructional activities are used in the classroom (Gravemeijer, 2004). In this phase, a sequence of instructional activities (related to decimals) containing conjectures of students' strategies and students' thinking (either in solving the problem or in the discussion) was formulated. The conjectured of hypothetical learning trajectory was developed based on literatures and was adjusted to students' actual learning during the pilot and teaching experiment.

b. Teaching Experiment

Before the teaching experiment was conducted, we tried out the activities in the pilot experiment. The pilot experiment has purpose to test and to see the underlying principles explaining how and why this design works in order to be elaborated and refined for conducting the teaching experiment. This also included the pre-assessment which has aim to assess students' pre-knowledge toward decimals. The try out activities and interview with the teacher and students were held for adjusting the improved Hypothetical Learning Trajectory (HLT).

73 students were involved in the pre-assessment (26 students in class 5A, 23 students in class 5B, and 24 students in class 5C), but only 7 students involved in the series of activities of pilot experiment. The decision of choosing small group because we expect to be more focused to the adjustment of HLT. We expected that choosing 7 students containing various students' abilities (2 high level students, 3 average level students, and 2 low level students) would represent the ability of the other students in whole class.

In teaching experiment, instructional activities were tried, revised, and designed on a daily basis during the teaching experiment (Gravemeijer, 2004). The teaching experiment aimed at collecting data for answering the research question. In this research, the teaching experiments were conducted in six lessons. The teaching experiments emphasize that the mathematical ideas (related to the magnitude of decimals) and conjectures could be adjusted during the teaching and learning process. Before doing the teaching experiment, the teacher and the researcher discussed about the series of activities in order to prepare the designed activities conducted in the class. After each activity was done, the teacher and the researcher made reflection in order to improve the designed activities and also as a feedback for repairing the weakness or the difficulties in the teaching and learning process. 26 students and a teacher in class 5A, SDN 21 Palembang were involved in the teaching experiment.

c. Retrospective Analysis

In this phase, all data collected during experiment were analyzed. Hypothetical Learning Trajectory (HLT) was compared with students' actual learning. All activities in the class including the group discussion were recorded on video. This data has aim to compare HLT and students' actual learning. The important fragments were selected and analyzed.

The written data included students' works in each activity, the results of assessments including the final assessment and some notes collected during the activities were conducted. Data interview with students and the teacher also were included to know about the feedback of the lesson and the activities in the class.

The result of this research is the underlying principles explaining how and why this design works. The Hypothetical Learning Trajectory served as a guideline in the retrospective analysis to investigate students' learning of comparing the magnitude of decimals.

2. Research subjects

Twenty six students and a teacher for grade 5 SDN 21 Palembang Indonesia became the research subjects in the teaching experiment. This school has been involved in PMRI (*Pendidikan Matematika Realistik Indonesia*) Project since 2010. The students are about 10 to 11 years old, and they had learnt about measurement in grade 1,2,3, and 4, and introduction to fraction in grade 4 semester 2.

3. Decimals in Indonesian Curriculum for 5th Grade

Based on Indonesian curriculum, decimal is taught in grade 5 semester 2 (Kurikulum *Tingkat Satuan Pendidikan Sekolah Dasar*, Depdiknas (2006):

Table 1. Decimals in Indonesian Curriculum Grade 5

Standard Competence	Basic Competence
Numbers	
5. Using fraction in problem solving	5.1 Converting fraction into percentages and decimals forms or vice versa
	5.2 Adding and Subtracting many forms of fraction
	5.3 Multiplying and dividing many forms of fraction
	5.4 Using fraction in solving ratio and scale problems

Decimal is taught in relation with fractions and percentages. Sometimes, the teaching and learning of decimal in Indonesia is very formal. In some textbooks, decimal is directly converted from fraction which has denominator ten or one hundred (see figure 1).

Contoh: $0{,}72 = \frac{72}{100} = 72\%$

$0{,}135 = \frac{135}{1.000} = \frac{13{,}5}{100} = 13{,}5\%$

$50\% = \frac{50}{100}$

$= 0{,}5$

Figure 1. One example about teaching and learning decimals in Indonesia

Hypothetical Learning Trajectory

Hypothetical Learning Trajectory (HLT) is a part of planning mathematics lesson which consists of the goals, the mathematical tasks (activities), and the hypotheses about the process of students' learning. Our hypothesis was that through the contextual situation the students can explore the notation and the meaning of decimals. Through observing the position of decimals on the scale, we expect the students can perceive the idea that decimals are in between two consecutive whole numbers. In addition, we expect they would realize that decimals are needed for precise measurement.

Table 2. Overview of HLT in Learning Decimals

Content Areas	Goals	Activities	Conjectures	Concept
Students' pre knowledge of numbers	Students are able to determine the numbers between the other numbers	Playing Come Closer Game	- 210BSome students might think that there is no number between two consecutive whole numbers - 211BSome students has already perceived an idea	Knowledge of numbers

Content Areas	Goals	Activities	Conjectures	Concept
			of the notion of decimals based on their daily life experiences	
The existing of decimals in between two consecutive whole numbers	Students are able to find decimals through weighing activity	Measuring the weight of the things (duku and body) using weight scale and digital weight scale	The students will find decimals through weight measurement activities	One-digit decimals
The meaning of one-digit decimals (partition base ten)	Students are able to explore one-digit decimals and put them on the number line	Measuring the weight of rice	- 212BThe students are able to find the sequence of one-digit decimals and put them on the number line correctly - 213BThe students get difficulties in sequencing one-digit decimals and assumed that 0,10 might come after 0,9 - 214BThe students can explore that 0,1 is one over ten and 0,5 is a half or five over ten based on their position on the number line	The relative position of the magnitude of one-digit decimals
The meaning of two-digit decimals (partition base tenth of tenth)	Students are able to explore two-digit decimals and put them on the number line	Measuring the volume of beverages	- 215BThe students are able to find the existing of two-digit decimals in between two consecutive one-digit decimals.	The relative position of the magnitude of two-digit decimals

Results and Analysis

The findings in this research are: 1) measurement activities (weight and volume measurement) can promote the students' notion of decimals in which the students could discover decimals and determine their position in between two consecutive whole numbers (on the scale); 2) based on observation, the visualization of the scales containing the sequence of the numbers could provoke the students' thinking into the idea of using number line as a model for placing the magnitude of decimals; 3) Number line plays an important role in bridging the experience-based activities into more formal level of mathematics (placing the magnitude of decimals). Through observing the position of one-digit and two-digit decimals on the number line, the students used it as their reasoning for showing their magnitude.

The situational level, where situational knowledge and strategies were used within the context of the situation, emerged in the measurement activities. Through the context of precise measurement, the students could find decimals in weighing body activity by observing the scales that when the needle pointed to the position between two consecutive whole numbers, e.g. between 33 kg and 34 kg, then there should be *comma numbers* (decimals) in it, e.g. 33,4 kg which was appeared on digital weight scale (see figure 2-5).

Figure 2. Body weight scale

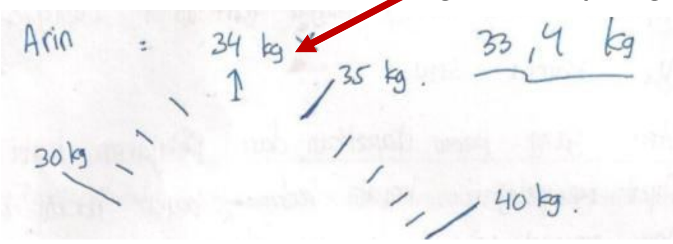

Figure 3. Sebastian's answer

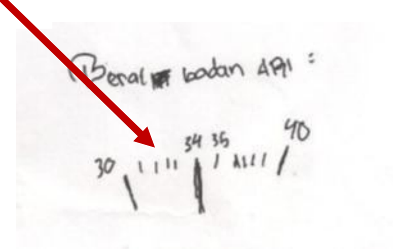

Figure 4. Farhan's answer

Figure 5. Body digital weight scale

Similarly, in weighing duku activity, the students also found that there were one-digit decimals in between two-consecutive whole numbers (e.g between 0 kg and 1 kg there were 0,1 kg; 0,5 kg; 0,8 kg; etc.). They found decimals by estimating the scale first and after that they opened the covered sticker to see the actual weight on the scale.

Figure 6. Weighing the fruit (duku) activity

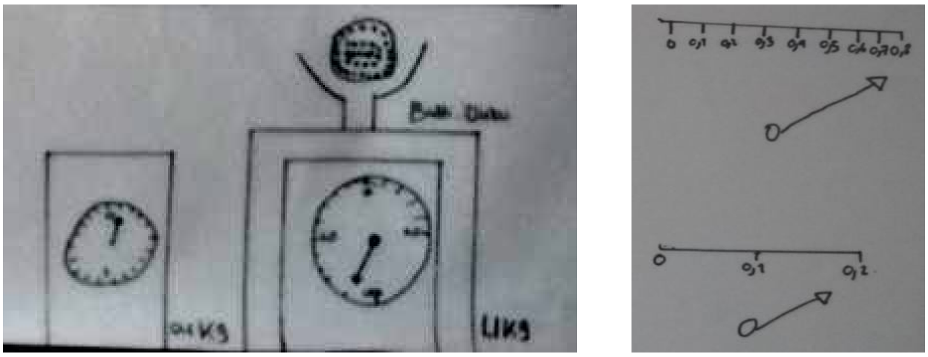

Figure 7. Students made the representation of the weight scale

In weighing rice activity, the students started to make the sequence of decimals (one-digit decimals) through counting the long stripes (major scales) using the approach of sequencing whole numbers (the first stripe was 0,1 kg; the second stripe was 0,2 kg; the third stripe was 0,3 kg, ... , the ninth stripe was 0,9 kg). From that invention, the students could find that there were ten partitions containing one-digit decimals in between two consecutive whole numbers which finally could bring the students into the idea of decimal referring to the number base ten, i.e: 0,1 is at the first stripe from ten stripes overall (one over ten); 0,5 is at the fifth stripe from ten stripes overall (five over ten), etc.

Figure 8. Weighing rice activity

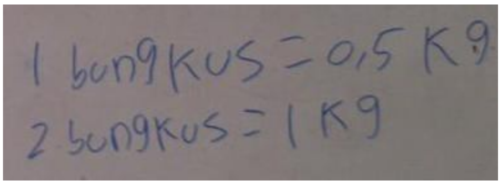

Figure 9. Rico's answer

Teacher : *"How much is this?"* (The teacher pointed to two packs of rice measured)

933B*Students* : *"1 kg."*

934B*Teacher* : *"So, how much for one pack?"*

935B*Students* : *"A half……zero point five…"*

936B*Teacher* : *"How about two packs?"*

937B*Students* : *"1 kg"*

938B*Teacher* : *"So, what can you conclude? What is the meaning of 0,5? 0,5 is how much of 1?*

Students : *"A half."*

Teacher : *"Who of you can explain your reasoning?"*

Rico : *"We have seen that when we weighed one pack, the weight is 0,5 kg. When we added another same pack (0,5 kg), the weight became 1 kg. So, 0,5 kg plus 0,5 kg is 1 kg."*

The activity of measuring the volume of beverage was aimed to develop students' acquisition for the idea of two-digit decimals. In this activity, the students began to make the representation of measuring cup containing small stripes in between two consecutive one-digit decimals. The visualization of measuring cup could encourage the students to perceive the idea that there were two-digit decimals in between two consecutive one-digit decimals. Through this discovery, the students got insight about the idea of density of numbers (between two consecutive whole numbers there are decimals, and between two consecutive one-digit decimals there are other decimals, i.e. two digit decimals, etc.). In addition, they also found the idea that two-digit decimals refer to the partitioning base tenth of tenth (on the number line), e.g. 0,25 is at the twenty fifth stripe from one hundred stripes overall.

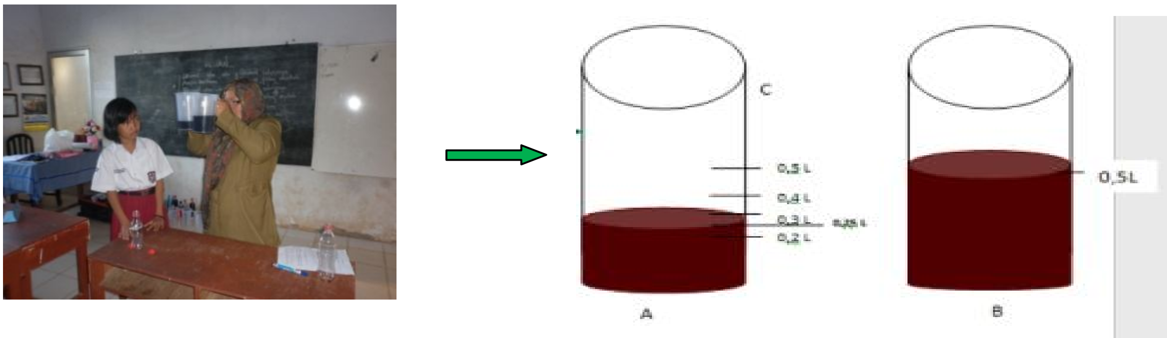

Figure 10. Measuring the volume of beverage activity

Through the contextual situation (weight and volume measurement), the students' learning toward decimals can develop from informal level to pre-formal level. Starting from making representation of the weight scale and measuring cup as *a model of* situation, the students' thinking shifted into the idea of using number line as *a model for* placing the magnitude of one-digit and two-digit decimals.

The phases of students' learning are 1) Knowing the existing of decimal form through contextual situation (weighing duku and body); 2) Exploring the meaning of one-digit decimals through weighing rice; 3) Using number line as a model for placing the position of one-digit decimals (partition based ten); 4) Exploring the meaning of two-digit decimals through measuring the volume of beverages; 5) Using number line as a model for placing the position of two-digit decimals (partition based tenth of tenth);

Based on the result of post assessment, 69% students shows a good ability in reading the scale, 85% students have a good knowledge of decimals, and 77% students could master the idea of density of decimals on the number line. Based on the result of interview, 92% students chose number line as the tool to placing the magnitude of decimals.

Conclusion

Before the activity was conducted, it was suitable with the conjectures in HLT that most students thought that there were no other numbers between two consecutive whole numbers. The struggles of the students were that when they weighed the things, some of them could not see the scale precisely. They just thought about the shown number on the scale without considering the accuracy. However, after they did measurement using weight scale and digital weight scale, they realized that decimals exist in between two consecutive whole numbers, and decimals were needed to measure the things precisely. Through the series of activities, the students could develop their idea into the density of numbers on the number line which bring them into the idea of partitioning base ten and tenth of tenth.

We concluded that the context and activities designed (weight and volume measurement) can become the concrete situation for learning decimals. It can bring the students' learning develops from informal level to pre-formal level containing insightful mathematical ideas. Starting from making representation of the weight scale and measuring cup as *a model of* situation, the students' thinking shifted into the idea of using number line as *a model for* placing the magnitude of decimals.

Concerning the findings of this research, we give recommendation for further studies about decimals to apply Realistic Mathematics Education as the basic approach for teaching and learning decimals. Even though decimals were known as the abstract number for the students, but in this designed activities we can show that decimals can be taught in a meaningful way within measurement activities (weight and volume measurement). The students could discover decimals by themselves and could develop their ideas to come to the number line as a model for placing their magnitude.

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