The development of an RME-based geometrycourse for Indonesian Primary schools

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Abstract

The aim of this study was to develop and implement a valid, practical, and effective RME-based geometry course for Indonesian primary schools using design research approach. The research activities were divided into three stages namely front-end analysis, prototyping stage, and assessment stage that were conducted in a four year period. The focus of the chapter is to present detail and rational regarding the three stages. The result of the study was a high quality RME-based geometry course for teaching geometry at grade 4 in Indonesian primary school consisted of teacher's guide and student book. In the products lies the local instructional theory for teaching geometry that was effective for improving pupils' understanding, reasoning, activity, creativity, and motivation.

1. Introduction to the problem

The study reported in this chapter has been conducted in the period 1998 - 2002. At that time the quality of mathematics education in Indonesia, especially in primary and secondary education, was considered poor (see Soedjadi, 1992, 2000), whilst the mathematics learning and teaching process in the classrooms was dominated by the traditional method (see Somerset, 1997; Marsigit, 2000). The traditional way of teaching had a negative influence on the pupils' attitudes towards mathematics which means that most pupils did not like to learn mathematics, and that some of them were even afraid of mathematics (Marpaung, 1995, 2001). This study aimed to explore whether another approach to mathematics education could address these shortcomings by developing and implementing an exemplary course viz. *Realistic Mathematics Education (RME)-based geometry course*, for teaching and learning the topic Area and Perimeter at Grade 4 in Indonesian primary schools.

The focus of the study was to develop and implement a valid, practical, and effective RME-based geometry course by applying design research approach. These processes were guided by the main research question:

What are the characteristics of a valid, practical and effective RME-based geometry course for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary school?

2. Context of study: mathematics education in Indonesia

The general goals of mathematics education in Indonesian primary education were phrased as follows

- Preparing the pupils to be able to deal with the dynamic changes of world situations effectively and efficiently through practical works based upon logical reasoning, rational and critical thinking, caution and honesty.
- Preparing pupils to be able to use mathematics and mathematical reasoning in their everyday life and in studying other sciences.

After reading the lofty goals, questions arose as to why the *quality* of mathematics education in Indonesian primary schools was still poor. The following paragraphs will discuss some primary causes of poor quality of mathematics education in Indonesian primary schools.

The first cause was that the lofty goals have become blurred when they came into practice. The specific instructional objectives from Grade 1 till Grade 6 were still dominated by remembering facts and concepts and reproducing them verbally, studying computational aspects, and applying formulas.

The second reason was poor quality of mathematics textbooks. In the textbooks, many abstract concepts were introduced without paying much attention to aspects such as logic, reasoning, and understanding (Soedjadi, 2000). The topics that were taught seem far removed from pupils' daily life. Even the teachers themselves sometimes did not know the usefulness of the topics they have taught.

A third reason for poor quality of mathematics education in Indonesian primary schools was related to teachers. Most teachers preferred a traditional approach in teaching mathematics. In general, the climate in Indonesian classrooms (see Fauzan, 2000, 2001; Fauzan, Slettenhaar & Plomp, 2002a, 2002b; Somerset: 1997), was similar to that in several African countries as was summarised by De Feiter and Van den Akker (1995) and Ottevanger (2001) as follows:

- 'chalk and talk' is the preferred teaching style;
- emphasis on factual knowledge;
- lack of learning questioning;
- only correct answers are accepted and acted upon;
- whole-class activities of writing/there is no practical work carried out.

The impact of the situations described above was that most students dislike learning mathematics because they were not learning the mathematics they need. They also did not have the opportunity to learn significant mathematics, and lack commitment towards or were not engaged in existing curricula. The other impact was that the students' achievements in mathematics were poor from year to year (see Fauzan 2002). The poor performance of Indonesian students could also be seen from the Trends in International of Mathematics and Science Study (TIMSS) report (Mullis et al., 2000). Related to geometry, some findings indicated that geometry tended to be the most difficult among the mathematics topics not only for students but also for teachers (see Fauzan, 1996,1998; Herawati, 1994; Amin, 1995). The poor performance of the students in geometry and their negative attitude toward geometry became the big challenges for this study. These issues together with the fundamental problems mentioned in section 1 lead to the following questions.

- *How to design a high quality course that could promote not only pupil learning but also pupil's attitude in learning mathematics?*
- *How to support teachers in implementing the course?*

The questions, which became the main focus in this study, were addressed in a research project aimed at developing and implementing an RME-based geometry course.

3. Design research as the research approach

This study built upon two "schools of thought" of design research. The first one emerges in the context of more general design and development questions (see Van den Akker, 1999; Van den Akker & Plomp, 1993; Plomp, 2009; Richey & Nelson, 1996). The second one developed within the area of mathematics education by mathematics educators in the Freudenthal Institute (FI), The Netherlands (see Freudenthal, 1991; Gravemeijer, 1994a, 1994b, 1999). In the following part we will characterize how we perceived and used design research in this study.

What is design research?

According to Van den Akker & Plomp (1993), design research is characterized by its twofold purpose:

- Development of prototypical products (curriculum documents and materials), including empirical evidence of their quality.
- Generating methodological directions for the design and evaluation of such products.

This study was about development and implementation of an RME-based geometry course that fits the first purpose.

Richey & Nelson (1996) and Van den Akker (1999) distinguish two types of design research. These are summarized by Nieveen et al. (2006) as development studies and validation studies.

- *Validation studies* have a focus on designing learning environments or trajectories with the purpose to develop and validate theories about the process of learning and how learning environments can be designed. Validation studies aim at advancing learning and instruction theories, such as Realistic Mathematics Education (Gravemeijer & Cobb, 2006).
- *Development studies* aim at design principles for developing innovative interventions that are relevant for educational practice. "Development studies integrate state-of-the-art knowledge from prior research in the design process and fine-tune educational innovations based on piloting in the field. … By unpacking the design process, design principles that can inform future development and implementation decisions are derived." (Nieveen et al., 2006: 153).

Considering that this study was aiming at developing a high quality RME-based geometry course, it may be categorized as development study type of design research. But as this research also aimed at validating whether the constructivist approach of Realistic Mathematics Education could be successfully applied in the context of Indonesian mathematics education, this research was a validation study type of design research as well.

Important activities in design research are its cyclic nature (of analysis design, development, implementation, evaluation and reflection) and the use of formative evaluation as a key activity to establish evidence of product quality and to generate guidelines for product improvement (Ottevanger, 2001). Related to this, Nieveen (1997) and Van den Akker (1999) mentioned three main stages or phases in design research (see also Plomp, 2009), which are *front-end analysis/ preliminary investigation; prototype phase,* and *assessment phase,* consisting of summative evaluation of the final product. Throughout all these activities, a systematic reflection on the development methodology has to take place to produce design principles (Plomp, 2009).

Following these activities and the work of Nieveen (1997) and Ottevanger (2001), the study was divided into three stages namely *front-end analysis*, *prototyping stage*, and *assessment stage*. During the prototyping stage, the design research approach proposed by Freudenthal Institute (see Gravemeijer 1999; and Gravemeijer & Cobb, 2006) was applied. This approach was followed in developing the content of RME-based geometry course, especially in designing the instructional sequences. Freudenthal (1991, p. 161), in relation to the development of RME, defines design research as:

"Experiencing a cyclic process of development and research so consciously, and reporting on it so candidly that it justifies, and that this experience can be transmitted to others to become like their own experiences"

Gravemeijer (1999; and see also Gravemeijer & Cobb, 2006) states that in this approach researchers direct their attention to developing instructional sequences in learning mathematics. To do so, they start with thought experiments, thinking about the learning route that will be passed through by pupils. By reflecting on the results of instruction experiments in which the results of the thought experiments are tried out, they continue with the next thought experiment. Researchers in this approach have a long term learning process in mind. In this long-term process, the subsequent of thought and instruction experiments are connected. This situation leads to the description that development can be seen as a cumulative cyclic process, as it is shown in Figure 1.

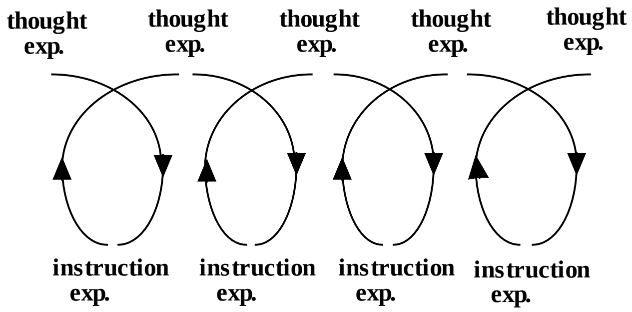


Figure 1: Design research as a cumulative approach (source: Gravemeijer, 1999)

The cycles of the thought and instruction experiment described above indicate the activities carried out on a daily basis developing a learning sequence. For example, the second thought experiment is conducted based on the results of the first instruction experiment. The results of this thought experiments are tested through the second instruction experiment on the next day. This process is continued until the instructional sequences, consisting of a number of lessons for teaching a mathematics topic that work well, are developed. The instructional sequences are called *local instructional theories*. Gravemeijer and Cobb (2006) call the daily basis of the development a micro cycle and the development of the whole learning sequences a macro cycle (see Figure 2).

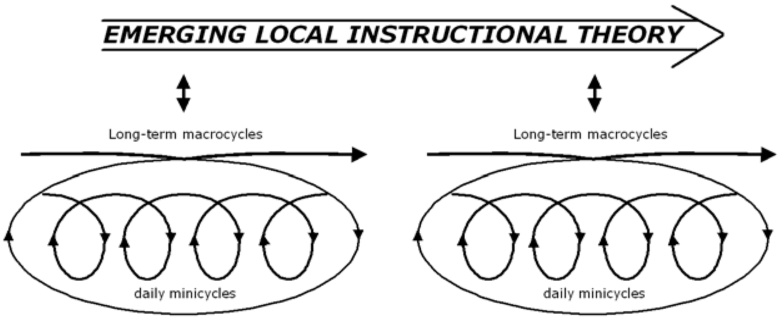


Figure 2: Micro and macro cycles of design research (Gravemeijer & Cobb, 2006)

Our study combined the two approaches in design research, as is summarized in Table 1.

Table 1: The summary of design research

Type of research	Design research (development and validation studies).
Main focus	Design and research on the RME-based geometry course and testing of the characteristics.
Aims	To develop a high quality RME-based geometry course that was suitable for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools.
Expected results	1. A high quality RME-based geometry course.
	2. Lesson learned about: • characteristics of a high quality RME-based geometry course; • development process of the RME-based geometry course; • implementation process (how teachers teach in the classrooms and how pupils learn); • the improvement on pupils' understanding, reasoning, activity, creativity, and motivation; • the local instructional theory for learning and teaching the topic Area and Perimeter.

A high quality RME-based geometry course referred to three quality criteria namely *validity*, *practicality* and *effectiveness* (Nieveen, 1997; 1999).

- *Validity* refers to the extent that the design of the intervention include "state of the art knowledge" (content validity) and the various components of the intervention are consistently linked to each other (construct validity).
- *Practicality* refers to the extent that users (teachers and pupils) and other experts consider the intervention as appealing and usable in normal conditions.
- *Effectiveness* refers to the extent that the experiences and outcomes from the intervention are consistent with the intended aims.

The stages of the research

As mentioned in the previous section, the design research was conducted in three stages (see Figure 3). These processes were realized in a four-year research, which included three field-work periods in Indonesian primary schools.

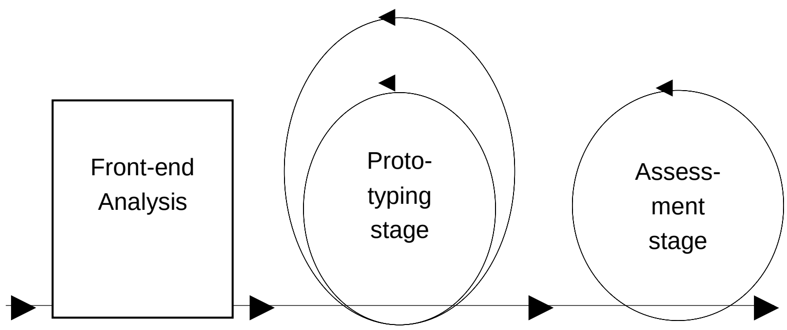


Figure 3: The general research design

In the design, the prototyping stage is presented in two cycles to indicate that there were two consecutive prototypes of the RME-based geometry course that were developed during this stage. The cycles in the design also include the formative evaluations that were conducted in each stage of the study.

4. The results of the study

Following the phases described in Figure 1, the focus, research activities, data collection techniques, and the results of the study in each stage will be elaborated in the next sections.

Front-end analysis

The purpose of front-end analysis is to get a picture of the starting point and the potential end points of the course. The work done in this stage included context and problem analysis, literature review, and analysis of available and promising examples.

The context and problem analysis was conducted by doing several activities such as review of Indonesia curriculum documents and related research results, classroom observations, interview with principals, the fourth grade teachers and some pupils from six primary schools (3 schools in Padang, West Sumatra and 3 schools in Surabaya, East Java). The schools have been chosen purposively by considering the quality of the schools (high, middle, and low). The summary of these activities has been described in section 2.

The literature review on the RME theory gave the pedagogical direction to design the first draft of the RME-based geometry course on the topic *Area and Perimeter* for pupils at Grade 4 (pupils around 10 years old). As it was designed based on the RME approach, it needed to reflect the three key principles of RME: guided reinvention, didactical phenomenology and emergent models (Gravemeijer; 1994a, 1999).

The guided reinvention principle was applied to sequence the learning trajectory so that pupils could learn the topic Area and Perimeter as intended based on the RME point of view. The second RME principle was realized by using contextual problems as starting point so that the pupils would experience the process of horizontal and vertical mathematization (see Gravemeijer, 1999). The contextual problems would also facilitate the pupils to use their own models (*model of*) to solve the problems until one of them emerges into a formal way to solve a mathematical problem (*model for*).

Based on context analysis (Indonesia) and review of literature and related documents (see Fauzan 2002), it was decided to design an RME-based geometry course with the vision was to broaden the concept of Area and Perimeter. The rationale for broadening of the concepts was that when we talk about Area and Perimeter in our daily life, we are not only dealing with regular shapes such as squares, rectangles or triangles, but also irregular shapes or surfaces of 3-dimentional objects such as cakes, lands, and tiles.

The vision of the RME-based geometry course was elaborated further by broadening the concepts of Area and Perimeter through the following aspects.

- *Relating Area and Perimeter to other "magnitudes"*
  The concepts Area and Perimeter are frequently involved in our daily activities. For that reason, it is considered to be important to relate them to other magnitudes such as *costs, weight, paint, rice field, cake* and *fence*. By relating the concepts to other magnitudes, it gives the pupils the opportunity to learn the concepts in a more meaningful way.
- *Introducing the exchange of measurement units as a counting strategy*
  In most literature on *traditional mathematics* the square is introduced as the only measurement unit. However, in reality we use various non-square measurement units, such as rectangle or triangle tiles. So that, introducing the exchange of measurement units as a counting strategy would be useful for helping pupils to understand area.
- *Investigating the relation between Area and Perimeter*
  There is a strong belief that Area and Perimeter are directly proportional to each other (Gravemeijer, 1992), in which people think that the bigger the perimeters the bigger the areas, or vice versa. To prevent pupils from this confusion, in the RME-based geometry course the concepts of Area and Perimeter are taught consecutively.

- *Connecting measurement units to reality*
  This aspect of broadening the concept of area is to make the pupils aware that many objects in their real life can be used as a measurement unit. Moreover, relating the measurement units such as cm^2, m^2, and km^2 cm to reality (for examples, the sizes of: the thumb nails, the surface of the tables, the forests) will help the pupils to understand the idea of the relative sizes of those measurement units as well as the relationship between one measurement unit and the others.
- *Making pupils aware of the model-character of the concept (approximation, neglecting irregularities)*
  Teaching the topic Area and Perimeter in traditional mathematics causes pupils to think that areas of the rectangular shapes are always the product of two lengths and that learning the topic Area and Perimeter is identical with applying the formulas (see Romberg, 1997). In reality we mostly deal with irregular shapes. It means that we need to teach pupils about the idea of approximation regarding Area and Perimeter, in order to make them aware that the measurement is never exact.
- *Integrating some geometry activities*
  In traditional mathematics, the geometry activities for learning the topic area are dominated by counting grids and applying the formulas. In the RME-based geometry course some geometry activities are involved such as *re-shaping*: cutting a figure into pieces and reallocating these pieces to get another shape, and *tessellation*: arranging tiles in various ways. Re-shaping is considered as an important activity in the RME-based geometry course because it not only makes it easier for pupils to find areas of various geometry shapes but also makes them aware of the conservation of area. Meanwhile, tessellation will make the pupils aware of the possibilities of compensation. Gravemeijer (1992) argues that the tessellations are just like an excursion in geometry, and at the same time it makes the pupils realize that area units do not have to be squares.
- *Involving reallotment problems*
  Reallotment is a concept in which the area of a shape remains the same when it is reshaped. By working on the reallotment problems, for examples the problems about tessellations, pupils will better understand that: a shape can be seen as the sum of other shapes or as a portion of another shape; a shape can also be arranged to form a different shape by cutting and pasting. The concept of reallotment will also help pupils to realize that the objects that have the same areas can have various shapes.

Based on the vision and the review of related documents, such as the realistic geometry textbooks developed from the Wiskobas project in The Netherlands (see Gravemeijer, 1994a; Klein, 1999; Treffers, 1991), the paper entitled *Reallotment* written by Gravemeijer (1992), and the book with the same title used in the project Mathematics in Context (MiC) in the USA (see NSF, 1997), the hypothetical learning trajectory in the RME-based geometry course was designed. The detail of the hypothetical learning trajectory can be found in Fauzan (2002).

Prototyping stage

A prototype is a preliminary version or a model of all or a part of a system before full commitment is made to develop it (Smith, 1991). According to Nieveen (1997) the term "develop" in this definition refers to the construction of the final product. So, the prototypes are all products that are designed before the final product will be constructed and fully implemented in practice.

As applying the RME principles into Indonesian context needed some adjustments, the prototyping approach was used in this study because this approach gives the opportunity to develop an RME-based geometry course fitting the Indonesian context (see Goodrum, Dorsey & Schwen, 1993; Nieveen, 1997; Shneiderman, 1992; Tessmer, 1994). Two prototypes of the RME-based geometry course for learning and teaching the topic Area and Perimeter were developed in this stage namely, *prototype 1* and *prototype 2*. The latter was built upon the experiences in prototype 1. Each prototype consisted of a student book and teacher guide for ten lesson periods (one lesson takes 70 minutes). The way that the prototypes were developed followed the design research approach of Freudenthal Institute (*see section 3*).

Prototype 1 of the RME-based geometry course

It was important to determine that the draft course would fit not only the Indonesian curriculum, but also the ideas underlying RME. For this purpose, prototype 1 was reviewed by two Dutch RME experts (in RME and geometry) and three Indonesian subject matter experts (in mathematics curriculum and also familiar with RME).

The main focus of developing prototype 1 was to reach a valid RME-based *g*eometry course. This activity was guided by the next research question:

What are the characteristics of a valid RME-based geometry course for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools?

The investigation into the content validity of the RME-based *g*eometry course was focused on the following issues:

- *Does the content of the RME-based geometry course include the subjects/topics that are supposed to be taught for topic Area and Perimeter?*
- *Does the content of the RME-based geometry course reflect the RME's key principles?*
- *Does the RME-based geometry course reflect the RME's teaching and learning principles?*
- *Does the RME-based geometry course reflect the important aspects of realistic geometry?* (see De Moor, 1994).

Meanwhile, the construct validity or the internal consistency of the RME-based geometry course dealt with the following questions.

- *Is the content of the RME-based geometry course sequenced properly?*
- *Is the content well chosen to meet the objectives/goals described in the beginning of each lesson?*

Research activities in answering the questions above are summarized in Table 2.

Table 2: The summary of evaluation of prototype 1

Focus of evaluation (What?)	**The purposes of valuation (Why?)**	**Evaluation activities (Method (How?))**	**Instruments**
Validity of the RME-based geometry course, focused on the content and construct validity.	To test the characteristics of the RME-based geometry course whether they meet the criteria mentioned in the questions above.	Interview and discussion with the Dutch RME experts and Indonesian subject matter experts, classroom observations, analyzing pupil's portfolios.	Interview guidelines, observation scheme.
The learning and teaching process using the RME-based geometry course.	To assess whether the hypothetical learning trajectory works as intended.	Classroom observations in two schools and interviews with pupils and teachers from those schools.	Observation scheme, interview guidelines.

Based on the results of experts' reviews, it was concluded that the RME experts approved of the content and the construct validity of the RME-based geometry course as well as the hypothetical learning trajectory for learning and teaching the topic Area and Perimeter. Nevertheless, the RME experts recommended that some contextual problems should be improved in order to strengthen the conjectured learning trajectory.

After the revision process, prototype 1 was implemented in two primary schools in Indonesia. The reason to choose the two schools was because they had different conditions. The pupils from school 1 were very heterogeneous in mathematical ability, while the pupils in school 2 were rather homogeneous. It was assumed that the variations between the schools would enrich the results of the classroom experiments. Another reason was the willingness of the two schools, especially the teachers and principals, for collaboration.

Some problems emerged during classroom experiments such as:

- Some pupils could not finish working on the given contextual problems because of several problems regarding their negative attitude (such as very dependent to the teacher and not used to working in-group) and the time constraint.
- There were some contexts that were not used by the pupils when they were solving some contextual problems. This was because the statement in those problems did not guide the pupils to use the contexts. See Fauzan (2002) for more details.

Prototype 2 of the geometry course-based RME

The results of the classroom experiments as described in the previous section led to the development and implementation of prototype 2 of the RME-based geometry course. The main focus of the development and implementation of prototype 2 was to investigate the validity and the practicality of the RME-based geometry course. The validity was re-investigated at this stage because the results of the development and implementation of prototype 1 showed that the validity of the RME-based geometry course needed to be improved. The research question for this stage of the study was:

What are the characteristics of a valid and practical Geometry course-based RME for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools?

As mentioned by Van den Akker (1999), practicality refers to the extent that users (and other experts) consider the intervention as appealing and usable under normal conditions. It means that the RME-based geometry course should meet the needs and wishes of pupils and teachers at Grade 4 in Indonesian primary schools. For this purpose, some questions were formulated to investigate the practicality of the RME-based geometry course, for examples:

- *Has the RME-based geometry course potential for developing student's understanding?*
- *Is the student book easy to use?*
- *Does the learning process progress as intended?*
- *Do teachers use the teacher guide as intended?*

Research activities in developing and implementing prototype 2 of the RME-based geometry course consisted of two cycles, namely expert reviews and classroom experiments as has been elaborated in Table 3.

Table 3: The summary of evaluation of prototype 2

Focus of evaluation (What?)	**The purposes of evaluation (Why?)**	**Evaluation activities (Method (How?))**	**Instruments**
Validity of the RME-based geometry course (continued).	To test the characteristics of the RME-based geometry course to see whether they meet the criteria (see the questions in section 5a).	Interview and discussion with two Dutch RME experts and three Indonesian subject matter experts, classroom observations.	Interview guidelines, observation scheme.
Practicality of the RME-based geometry course.	To check whether the learning and teaching process using the RME-based geometry course meet the criteria (see the questions before Table 3).	Interview and discussion with the Dutch RME experts, Indonesian subject matter experts, teachers, principals, supervisors and pupils, and classroom observations in two schools.	Interview guidelines, observation scheme.

Prototype 2 of the RME-based geometry course was implemented (by the researcher as a teacher) in two primary schools from two different provinces, after the revision process. The main reasons for choosing the two schools were similar to those when implementing prototype 1. Moreover, the cultures of the two places were different, especially in working habits, so this would probably enrich the results of the research.

The results from the experts' validation showed that prototype 2 of the RME-based course met the criteria of the content and construct validity. However, the experts did have suggestions such as:

- *add the contextual problems that would show the idea of approximation and that the results of measurements are never exact;*
- *relate Area and Perimeter to other magnitudes, reshaping, adding and subtracting area.*

The findings from the classroom experiments also indicated that the conjectured learning trajectory for the topic Area and Perimeter worked as intended for most pupils. Based on these results it was concluded that the RME-based geometry course met the criteria of the *content* and *construct validity*. It means that the local instructional theory designed in the RME-based geometry course was valid for learning and teaching the topic Area and Perimeter.

The experts, supervisors, and principals agreed that prototype 2 of the RME-based geometry course had potential to develop pupils' understanding, reasoning, activity, creativity and motivation. They also agreed that the RME-based geometry course would be usable and useful for teaching the topic Area and Perimeter. Based on the classroom observations, it was observed that the RME-based geometry course could be used by the pupils and teachers as intended. The results from the interviews with the pupils and teachers also indicated that the student book and teacher guide were easy to use. Based on these results it could be concluded that prototype 2 of the RME-based geometry course reached the criteria of the practicality.
At this stage of the study, the practicality of the RME-based geometry course was only evaluated in two schools in which the researcher acted as teacher. Therefore, the course needs to be evaluated in more schools in the assessment stage by involving teachers in the implementation processes, to generate more evidence about its practicality. In addition, the effectiveness of the RME-based geometry course had also to be investigated in order to show its effect on the pupils' learning.

The assessment stage

After the development and implementation of two prototypes of the RME-based geometry course during the prototyping stage, this study moved to the last phase called the assessment stage. In this stage the *final version* of the RME-based geometry course was implemented in five Indonesian primary schools in order to gain more insights in the practicality and effectiveness. The term *further insights* means two things: first, the number of schools for the classroom experiments would increase, and five additional classroom teachers would be involved in the implementation to find out whether they could teach the RME-based geometry course. Second, this assessment stage would lead to an opportunity to further evaluate the conjectured learning trajectory.
In preparing the teachers to be able to implement the RME-based geometry course, a series of workshop-based doing mathematics activities (see Gravemeijer, 1994a; Treffers, 1991) and reflections after the teaching practices have been conducted (see also Fauzan, 2002). The research question for the assessment stage was:
What are the characteristics of a practical and effective RME-based geometry course for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools?

The RME-based geometry course reached the effectiveness criteria if it would have a positive impact on the pupils and teachers in learning and teaching the topic Area and Perimeter. These criteria were measured using four of five levels of effectiveness mentioned by Kirckpatrick (1987) and Guskey (1999, 2000) namely *participants' reaction*, *participants' learning*, *participants' use of new knowledge and skills*, and *impact (the learning outcomes)*. The participants in this study were the pupils and teachers. The level *impact to organization* was not used to assess the effectiveness of the RME-based geometry course because it was not applicable to this study. The levels of effectiveness in this study were elaborated upon by posing the following questions:

- *Participants' (pupils and teachers) reactions*:
  Did they like the RME-based geometry course?
  Was their time well spent?
  Was the RME-based geometry course useful for them?
- *Participant's learning*:
  Did the teachers and pupils acquire the intended RME knowledge?

- *Participant's use of new knowledge and skills*:
  Did the teachers and pupils effectively apply the RME knowledge and skills?
- *Pupils' learning outcomes*:
  Were the pupils more confident as learners than before?
  What was the impact of the RME-based geometry course on the pupils' performance and achievement?

The learning outcomes in this study consisted of pupils' achievement and reasoning, pupils' motivation, activity, and creativity. In RME pupils learn mathematics based on activities they experience in their daily life; pupils have a big opportunity to construct their knowledge by themselves, etc. These conditions led to a hypothesis that the RME-based geometry course would increase pupils' achievement. Moreover, in solving a contextual problem pupils are always stimulated (written in the teacher guide) to explain "*what do they do and why?"* This requirement was assumed to have potential to promote pupils' reasoning.
Research activities in the assessment stage are summarized in Table 4.

Table 4: The summary of evaluation of final version

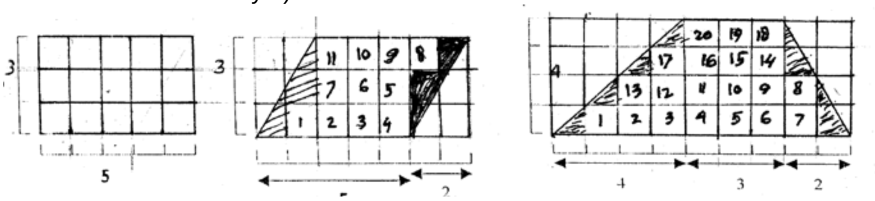
Focus of evaluation (What?)	**The purposes of evaluation (Why?)**	**Evaluation activities (Method (How?))**	**Instruments**
Practicality of the RME-based geometry course (continued).	To gain more insight into whether the learning and teaching process using the RME-based geometry course meet the criteria.	Interview with teachers and pupils, and classroom observations in five schools.	Interview guidelines, observation scheme.
Effectiveness of the RME-based geometry course.	To gain more insight regarding the impact of the RME-based geometry course on the pupils for each level of effectiveness.	Interview with teachers and pupils, classroom observations, pre-test and post-test, and analyzing pupil's portfolios.	Interview guidelines, observation scheme, test and assessment materials, and questionnaire.
Teachers ability to implement the Geometry course-based RME.	To gain information as to whether the teachers could implement the RME-based geometry course as intended.	Classroom observation and interviews with teachers.	Observation scheme, interview guideline.

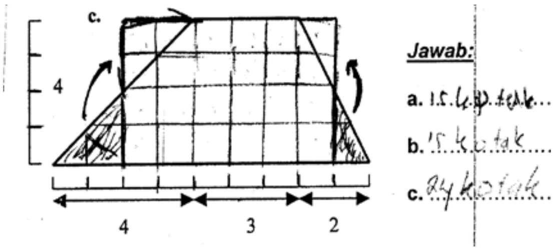
As mentioned before, the final version of the RME-based geometry course (comprising 10 lesson periods, one lesson takes 70 minutes) was implemented in five primary schools (involving five teachers and seven classes). The results of the assessment stage can be summarized as follows (see also Fauzan 2002):

1. The pupils could use the student book without any difficulties and they could learn the topic Area and Perimeter as intended according to the RME point of view. The teacher guide was useful for the teachers in implementing the RME-based geometry course. Three teachers

said that the teacher guide was easy to use, while one teacher suggested that the teacher guide should be elaborated in more detail (*note*: she used to teach lower grades pupils before). From these findings it can be concluded that the RME-based geometry course met the criteria of the practicality. The practical RME-based geometry course can be characterized as follows:

- The RME-based geometry course had the potential to develop pupils' understanding, reasoning, activity, creativity and motivation in learning the topic Area and Perimeter. These results can be seen on the example of pupils' works below, when finding the areas of rectangle, parallelogram, and trapezoid using their own ideas (the pupils did not know the formulas yet).





Another pupil used *global reallotment* to find that the area of the trapezoid was 24.

The results on the first row show that the pupils used combination of counting and reallotment strategies to find the areas. On the second row, the pupil used global realloment first, then used counting strategy. There are two important findings showed in the example. The first, the hypothetical learning trajectory worked well (the context used by the pupils to find various strategies). The second, the RME-based geometry course had stimulated pupils' creativity and reasoning in finding the area of a shape.
- The teaching learning process using the RME-based geometry course fostered pupil-centered learning.
- The pupils could use the student book without any difficulties, and they could also learn the topic Area and Perimeter (using the student book) as intended according to the RME point of view.
- The teacher guide was useful for and easy to use by the teachers.
- The RME-based geometry course met the criteria of *the effectiveness* as it resulted in some positive impacts on the pupils. The positive impacts of the RME-based geometry course on the pupils are characterized as follows:
  - The pupils liked the RME-based geometry course. They said that the RME-based geometry course was useful and gave them more confidence as the learners.
  - Most pupils acquired the intended RME knowledge which then enabled them to find out for themselves several concepts included in the RME-based geometry course. They could also use the new knowledge and skills that they had acquired from one lesson in the next lessons.
  - The pupils' attitudes in learning mathematics developed in a positive direction. The pupils became less dependent and did engage actively in the learning and teaching processes. They also became more motivated to find different strategies in solving the contextual problems. Their reasoning developed from being very

weak at the beginning to being able to reason mathematically by the end of the classroom experiments.
- The pupils actively engaged in the learning process and they also creatively found various solutions in solving the contextual problems in the student book.
- The pupils' achievements (in the experimental classes) in the post-tests were significantly higher than those in the pre-tests. The pupils' achievements in the experimental classrooms were significantly higher than the achievements of the pupils in Grade 4 and 5 who had been taught the topic Area and Perimeter using the traditional method.
- A significant difference was found between the motivation of the pupils before and after they had been taught the RME-based geometry course, especially on the aspect *self-concept of mathematical ability* (see Blöte, 1993)

2. The teachers liked the RME-based geometry course, and in general they could implement the Geometry course-based RME as intended, although sometimes they still used the traditional way of teaching. It was also observed that at some occasions the teachers could not fully apply the RME knowledge and skills that they had gained from the training probably because they were not yet used to the RME approach.

5. Conclusion

After a four-year study of the development and implementation of the RME-based geometry course at Grade 4 in Indonesian primary schools using design research approach, some conclusions can be drawn (see also Fauzan, 2002):

a. The RME-based geometry course for pupils at Grade 4 in Indonesian primary schools met the criteria of validity (*content and construct validity*), *practicality*, and *effectiveness*. It suggests that the learning trajectory designed in the RME-based geometry course can be used as a local instructional theory for learning and teaching the topic Area and Perimeter.
b. The RME approach could be utilized in Indonesian primary schools. Further, the RME approach could address some problems mentioned earlier in this chapter, especially in changing the classroom climate and providing guidelines in how to develop and implement a good quality course material for teaching mathematics.
c. The two "schools of thought" of design research that were combined in this study resulted a high quality RME-based geometry course and the local instructional theory aimed for.

The results outlined above indicated that the RME approach could be utilized in Indonesian primary schools. Further, the RME approach could address some problems mentioned earlier in this chapter, especially in changing the classroom climate and providing guidelines in how to develop and implement a good quality curriculum material for teaching mathematics.

Key source

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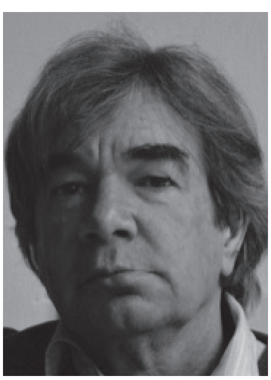

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