APPLYING REALISTIC MATHEMATICS EDUCATION (RME) IN TEACHING GEOMETRY IN INDONESIAN PRIMARY SCHOOLS

Ahmad Fauzan

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ter verkrijging van
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door

Ahmad Fauzan

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This dissertation is dedicated to:
my wife Yasmurti P. Sari,
and my sons Ryan & Ogy.

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Enschede, November 2002

CHAPTER 1

INTRODUCTION AND OVERVIEW OF THE STUDY

This chapter introduces the study about the development and implementation of the IRME curriculum for mathematics instruction in Indonesian primary schools. It provides a background of the study (section 1.1) and brief information about the context of the study: Indonesia (section 1.2). The aims of the study and research questions are described in section 1.3, while section 1.4 outlines an overall view of the research approach. Finally, an overview of the following chapters is presented in section 1.5.

1.1 INTRODUCTION

What would the reader think if some students in senior high schools do not know the geometry objects such as squares, rectangles and right angles; and furthermore that some other students in university cannot solve simple mathematics problems such as 1/3 + 1/4, -2 – 3, after they have been taught those concepts for years (Fauzan, 1995, 1996, 1998)? Bearing this information in mind one may argue that there is something wrong with mathematics education in the primary or secondary levels.

The idea to conduct this study came from dissatisfaction with mathematics education, especially in primary school, and the will to contribute to solving some fundamental problems in Indonesia. After investigating the essence of the problems, and studying the international research trends and reforms in mathematics education (see Gravemeijer, 1999; Kelly & Lesh, 1999; Sosniak & Ethington, 1994), it was argued in this study that Realistic Mathematics Education (RME) is a promising approach to be utilised in Indonesia. Through this study, it was explored the extent to which RME could address some of the problems in mathematics education in Indonesia, more specifically in the geometry instruction.

The illustrations below show a number of different problems in mathematics education in Indonesia. The first one is an extract from an actual classroom observation in a primary school in Surabaya, Indonesia. This example also reflects a common situation of how the mathematics learning and teaching process is conducted in Indonesian primary schools (see also Fauzan, 1999). The second and the third illustrations present vignettes from interviews with two primary school teachers.

> *Teacher: OK pupils, today we are going to learn about multiplication of two digit numbers by two digit numbers. Please pay close attention to what I am going to explain, otherwise you will not understand this lesson.*

The teacher writes a problem of multiplication of two two-digit numbers on the blackboard and starts solving it himself. In solving the problem, the teacher does it by talking and writing simultaneously. Sometimes he asks the pupils as a whole the result of a step in the solution, and the pupils give the answers in choir. The teacher give the responses by saying '*good*' whenever the pupils come up with the right answers, but he does not comment if the responses are wrong. He then finishes solving the problem:

> *Teacher: Do you understand what I explained?*
> *Pupils: Yes (some pupils answer in choir, and the rest are silent)*
> *Teacher: To make it more clear I will show you another example.*

He repeats the process, and at the end he asks the same question to check if the pupils understand or not. The 'yes' sounds louder and the teacher seem to be satisfied. He continues:

> *Teacher: Now open your textbook page… then solve the exercises … number….. the same way as I just showed you.*

The pupils start working individually in silence (because the teacher reminds them to be silent and does not allow them to work together), and the teacher uses the time for checking the homework (*note:* It is not only mathematics' homework but also the homework of other subjects. Sometimes teachers may use this moment for administration business in the office). After the pupils finish working, the teacher asks them to exchange their work with the pupil sat next to them. Then, by listening to the correct answers, which are read out by the teacher, the pupils check if the answers of their friends are right or wrong. Finally, the teacher gives the marks on the pupils' work based on the number of correct answer written in their exercise books.

A Grade 6 teacher in Padang:

> *I do not really understand my pupils. When they were in grade 5, I taught them very well about the changes of measurement units, and they could understand the concepts. But now when I ask them again, they completely forget everything. I have to explain it again just like I had done before (note:* there is a repetition of topic measurements in Grade 6)…….*.I think our curriculum is not sequenced well. Every time I move to the next topic in the curriculum, it seems that the pupils learn a topic that is completely new. And as soon they learn a new topic, they also forget the previous one…….. Sometimes I do not know the use of the topic. For example, topic 'co-ordinate' what does that mean in relation to the pupils at grade 4?*

A Grade 4 teacher in Padang:

> *I do my best to explain mathematics concepts to my pupils. If it is food, I already put the food in their mouth. They only need to swallow it. But they still cannot do it very well…… The pupils nowadays are really terrible.*

When modern mathematics was introduced in the mid 70's, Indonesia was one of the countries that adopted this approach. However, after almost three decades of implementation of modern mathematics in Indonesia, success is still far from being a reality. Until recently, the quality of mathematics education in Indonesia, especially in primary and secondary education, was still poor (see Soedjadi, 1992, 2000). The poor quality is not only reflected in the pupils' achievements but also in the learning and teaching process. The averages of the pupils' achievements in national examination from years 1984 until 2001 are always below 6, on a scale of 1 to 10 (see www.depdiknas.co.id). Meanwhile, the mathematics learning and teaching process in the classrooms is dominated by the traditional method, as is shown by the example mentioned earlier in this section (see also Somerset, 1997; Marsigit, 2000). This traditional way of teaching has a negative influence on the pupils' attitudes towards mathematics which means that most pupils do not like to learn mathematics, and that some of them are even afraid of mathematics (Marpaung, 1995, 2001).

This study aims to explore whether another approach to mathematics education can meet this shortcoming. In the remainder of this chapter, a first description of the context will be given, resulting in a problem statement. This is followed by a first sketch of the direction chosen in this study, namely exploring through development research whether RME is a feasible approach for Indonesia.

1.2 CONTEXT OF THE STUDY: INDONESIA

Section 1.1 described some problems in mathematics education in Indonesia. The Department of Education in Indonesia has put much effort into overcoming these problems, such as changing the curriculum, improving teacher qualification, and applying some innovations in mathematics education. In the last three decades, the curriculum has been changed four times (curriculum 1975, 1984, 1994 and 2002). Each curriculum used a different approach and each was described as an ideal curriculum (see Goodlad, 1984). For example, curriculum 1984 focused on Students Active Learning (SLA); even curriculum 1994 focused on problem solving. But the changes from one curriculum to another did not result in any significant improvement.

There are several reasons for the lack of significant improvement. Firstly, the changes of the curriculum were always done in a Top-Down model (see Noor, 2000). The initiative to change the curriculum came from the government, or a group of people who have power and influence on the government. Meanwhile, the need for changes, especially at the school level, was never investigated thoroughly. Questions such as 'what was wrong with the old curriculum', or 'what happened when the old curriculum was being implemented' were never answered satisfactorily when the government changed a curriculum. Secondly, each curriculum that was implemented lacked an implementation strategy. The inservice training provided for teachers to implement a curriculum seems not to have been effective (see Somerset, 1997, Hadi, 2002). Most teachers who had been through the training frequently 'got lost', when they tried to implement the new ideas in their schools. Because there was no adequate supervision and evaluation after the training (see Fauzan, 1999), the teachers preferred to teach in the way they used to teach before. Thirdly, the implementation of the curriculum was never evaluated properly. The only standard used by the government to measure the success of the curriculum implementation was the pupils' achievements. Meanwhile, information from the process of curriculum implementation such as how the learning and teaching process is conducted in classrooms, how the pupils learn, or the difficulties the teachers faced in implementing the curriculum (see for example the results of the interviews in section 1.1) remains unknown. Because of the lack of information about the reasons for curriculum changes in Indonesia, an anecdote is being told in the country: *If the minister of education is changed then the curriculum will be changed.*

The very centralised system in Indonesian education is also a factor that hampered the changes or innovations in mathematics education. In this system, the government, through the department of education, determines almost all regulations in education. For example, all schools or teachers have to use the same curriculum as well as textbooks decided upon the government, otherwise their pupils will be in 'danger' when they take regional as well as national examinations (*note:* it is an obligation of the schools to take regional and national examination). These situations do not give much space for schools or teachers to develop their own ideas for implementing the curriculum. The centralised system also makes it difficult to develop an intervention in Indonesian education, especially an intervention that does not suit the ongoing curriculum.

In 1991, the government decided to improve the qualification to be a teacher in primary school. Anyone, who wants to be a teacher in primary schools, now has to complete two years study in the institute of teacher training (PGSD) instead of three years education after junior high school (SPG). Again, this program was never evaluated properly, so that there is no proof that this change has any significant impact. Nevertheless, Somerset (1997), Marsigit (1999) and Mukhni (2002) found that most mathematics teachers in primary and secondary education were still lacking mathematics knowledge and skills.

In collaboration with foreign organisations such as the British Council and AUSAID, the Department of Education in Indonesia was also developing some innovations such as Students Active Learning (CBSA), The School of Development Preparation (Sekolah Persiapan Pembangunan), and the Core Teacher (Guru Pamong) (see Noor, 2000). However, such innovations were only running smoothly when they were in 'project status'. After the projects were finished, the innovations were abandoned and never implemented.

From the explanation above, we can summarise some fundamental problems in mathematics education in Indonesia:
1. The approach to teaching mathematics is very mechanistic and conventional.
2. The learning and teaching process concentrate only on learning objectives and learning outcomes, while the process that leads to these learning outcomes remains a black box. Most of the learning objectives only focus on memorising facts and concepts, and computational aspects (i.e. applying formulae).
3. The changes and innovations in mathematics education have never addressed the previous two problems because those changes and innovations lacked an implementation strategy.

Through this study there was developed and implemented a piece of curriculum material namely *Indonesian Realistic Mathematics Education (IRME) curriculum*, for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools. The term *curriculum* referred to an operational plan for instruction and involves what mathematics pupils need to know, how pupils are to achieve the identified goals, what teachers are to do to stimulate pupils develop their mathematical knowledge, and the context in which learning and teaching occur (see NCTM, 1989). The operational plan was realized in this study in the form of a teacher guide and a student book. The basis for designing the teacher guide and the student book was formed by the instructional unit 'Reallotment' that was developed in a collaborative project of the University of Wisconsin, Madison, USA, and the Freudenthal Institute (FI) in the Netherlnads, which was funded by the American National Science Foundation (NSF, 1997).

The focus of the study was to develop an intervention that addressed a number of fundamental problems mentioned above. Given the size and complexity of the problems, certain limitations have to be taken into account. The most important, next to the limitation for primary education, is the focus on learning and teaching the topic Area and Perimeter for pupils at Grade 4. In this case the IRME curriculum was developed and implemented based on RME approach, but it still took into consideration the mathematics curriculum in Indonesian primary schools.

RME is rooted in *mathematics as a human activity* (see Freudenthal, 1973; Gravemeijer, 1994; de Lange, 1987, 1996; Treffers, 1987). The key idea here is that pupil should be given the opportunity to reinvent mathematical concepts under the guidance of an adult (teacher). Within realistic approach, mathematics is viewed as an activity, a way of working. Learning mathematics means doing mathematics, of which solving every day life problems (contextual problems) is an essential part (Gravemeijer, 1994). Given its characteristics, RME is considered a very promising approach to improve mathematics teaching and make it more relevant for pupils in Indonesia.
The RME approach has been implemented in the Netherlands in the last three decades, and has achieved good results, especially in reducing the gap between weak students and smart students (de Lange, 1996). It has also been implemented in other countries such as Malaysia, England, Brazil, South Africa (see www.fi.uu.nl; www.fi.uu.nl/ramesa; de Lange, 1996) and the USA (see NSF, 1997). The first RME project in USA resulted in a complete curriculum for grade 5-9, called Mathematics in Context (MiC) (see NSF, 1997). The RME approach is also being employed in a multi-year project in USA namely 'Core-Plus Mathematics Project (CPMP)' (http://www.wmichh.edu/cpmp/front.html). This study was built upon experience gained in those countries, especially in the Netherlands and USA (project Mathematics in Context).

1.3 AIMS OF THE STUDY

The main aim of this study was to develop and implement a *valid, practical* and *effective* IRME curriculum for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools. The terms valid, practical and effective referred to the classifications created by Kirkpatrick (1987), Nieveen (1997, 1999), and Guskey (1999, 2000) (will be discussed in Chapter 4). This aim of the study was elaborated further as follows:

- The development of a valid IRME curriculum referred to the development of *local instructional theory* (see Gravemeijer, 1999) and to methodological guidelines for further development of RME materials in Indonesia.

- A practical IRME curriculum addressed the question of whether the RME approach could be utilised in Indonesian primary schools.
- An effective IRME curriculum refers to the extent to which the RME approach could address some of the problems in mathematics education in Indonesian primary schools, more specifically in the geometry instruction.

1.4 RESEARCH APPROACH

This study followed two development research approaches. The first approach mentioned by van den Akker (1999), van den Akker & Plomp (1993), Plomp (2002), and Richey & Nelson (1996), and the second one proposed by Freudenthal (1991) and Gravemeijer (1994, 1994a, 1999). According to van den Akker & Plomp (1993), development research is characterized by its twofold purpose:

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

This study was about development and implementation of the IRME curriculum that suits the first purpose. Richey and Nelson (1996) categorized this kind of study as type 1 of development research.

Following the work of Nieveen (1997) and Ottevanger (2001), the development and research activities in this study were conducted in three stages. The first stage was *the front-end analysis*, in which the current situation of Indonesian education, especially the situation of geometry instruction at primary schools was analyzed. The analysis in this stage was followed by a review of literature on RME and research trends in mathematics education.

The second stage of the study was called *the prototyping stage*. This stage consisted of the development of prototype 1 and prototype 2 of the IRME curriculum and formative evaluation of each prototype. In this stage, the appropriateness of the IRME curriculum for Indonesian pupils and how they learned mathematics using the IRME curriculum were investigated. These activities followed the development research approach proposed by Freudenthal (1991) and Gravemeijer (1994, 1994a, 1999). According to Freudenthal:

> *Development research means: 'experiencing 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.*

Freudenthal explained further that the cyclic process in this development research means a cyclic process of thought experiments and instruction experiments. Gravemeijer (1999) figure out the process as followed:

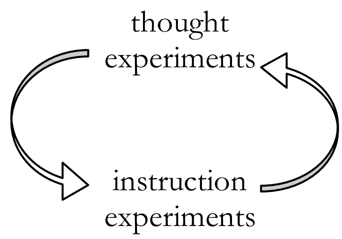


Figure 1.1
Cyclic process of thought experiments and instruction experiments

The cumulative cyclic process in this method of development research leads to developing a theory of designing and teaching a specific topic in mathematics Gravemeijer (1999) calls it *local instructional theory*. Following this method of development research this study intended to develop a *local instructional theory for learning and teaching the topic Area and Perimeter* at Grade 4 in Indonesian primary schools.

The third stage of the study was called *the assessment stage*. In this stage the final version of the IRME curriculum was developed and implemented, followed by summative evaluation activity. Reflecting on the development methodology ended this stage of the study.

This study, together with three other studies (see Armanto, 2002; Hadi, 2002; Zulkardi, 2002) was the first pilot study of RME in Indonesia. It has been conducted in two places, namely Padang (West Sumatera) and Surabaya (East Java). All these RME studies have different focuses but are similar in vision in that they explore the extent to which the RME approach could be utilised in Indonesia, and could stimulate a reform in Indonesian education.

1.5 OVERVIEW OF THE FOLLOWING CHAPTERS

The activities conducted in the different stages of the study and their outcomes are presented in subsequent chapters. The context of the study is elaborated upon Chapter 2, in which mathematics education in Indonesia is described more thoroughly based on front-analysis activity. Chapter 3 presents the outcomes of a literature study on Realistic Mathematics Education (RME) and the research trends in mathematics education. Chapter 4 describes the research design of the study. In this chapter the three stages of the study (*front-end analysis, prototyping* and *assessment stages*) are elaborated upon further. The characteristics of the IRME curriculum are formulated in Chapter 5. The results of the prototyping stage are presented in the following two chapters. Chapter 6 presents the development and implementation of prototype 1 of the IRME curriculum, while Chapter 7 discusses the development and implementation of prototype 2. The results of the assessment stage are elaborated upon chapter 8. Finally, Chapter 9 presents the summaries and conclusions of the study, and puts them into perspective.

CHAPTER 2
THE CONTEXT OF THE STUDY: INDONESIA

This chapter presents the outcomes of the context analysis that took place during the front-end analysis stage. The main focus of the context analysis was to gain more insight about mathematics education in Indonesian primary schools, in order to develop an intervention that addressed a number of fundamental problems mentioned in Chapter 1. Chapter 2 begins with an introduction that describes the general conditions of education in Indonesia (section 2.1). Section 2.2 discusses educational policies and practices. In section 2.3, mathematics education in Indonesian primary schools is presented, focusing on geometry instruction. The last section (section 2.4) discusses the need for improvement on mathematics education in Indonesian primary schools.

2.1 INTRODUCTION

Indonesia covers most of the world's largest archipelago, and is a domain of over 13,000 islands stretching more than 5,000 kilometres east to west across seas that separate continental Southeast Asia from Australia. Based on an estimation of July 2001, the population of Indonesia is around 228,437,000. There is tremendous diversity in the cultural, ethnic, religious and linguistic backgrounds of the people of Indonesia. Ethnically there are Javanese (45%), Sudanese (14%), Madurese (7.5%), coastal Malays (7.5%), and others (26%), and religious affiliations include Muslim (88%), Protestant (5%), Roman Catholic (3%), Hindu (2%), Buddhist (1%), and other (1%) (http://www.odci.gov/cia/publications/factbook/). The country's geographic character, consisting of thousands of widely dispersed, mountainous islands, has made social interaction among the region's peoples difficult, thereby promoting the evolution of many separate cultures. Another important cultural factor is language. More than 350 indigenous languages are spoken in Indonesia today.

The nature of the present-day Indonesian educational system has been significantly influenced by several factors mentioned above together with governmental structure and educational history (Moegiadi, 1994; Thomas, 1991). To some extent, these factors cause problems for education in Indonesia. From the country's geographic character for example, some regions such as Java and Bali are far more developed than other regions such Papua or Mentawai Island in West Sumatera. This situation has an impact on the quality of education in those regions because more developed regions have much more resources (i.e. textbooks, teachers) than the less developed regions do. The religious diversity means that in several schools there is more focus on religious aspects than there is attention paid to the scientific aspects of education.

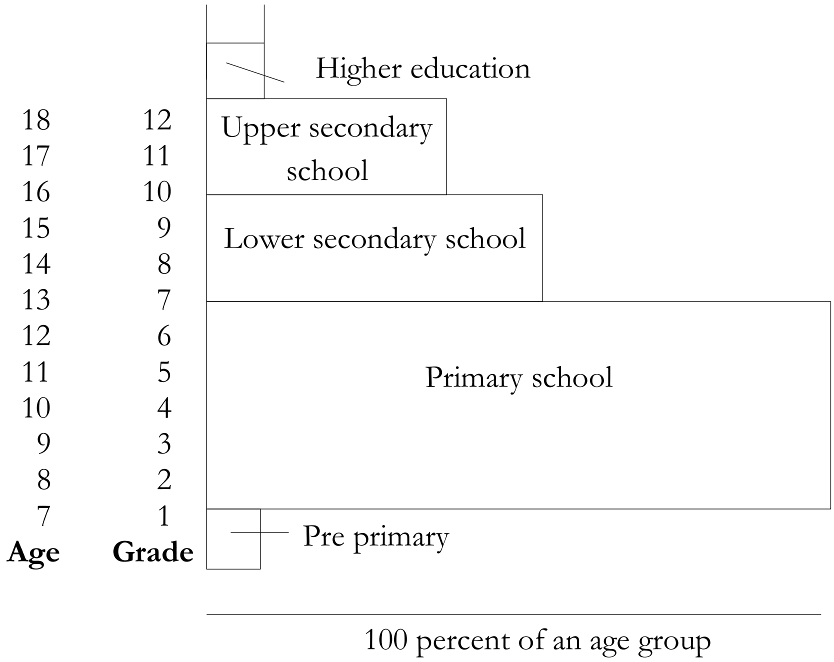
The factors mentioned by Moegiadi and Thomas and their influence on education, especially mathematics education are very interesting to discuss. Nevertheless, to make it more relevant to this study, this chapter only discusses the last two factors: governmental structure and educational history. The reasons for choosing these subjects are to: justify the motive to conduct this study; locate the study in Indonesian education system that is rather complex; learn from the history of education in Indonesia; make a distinction between this study and the previous studies/projects. Above all, the discussion in this chapter will be used as a point of reference to reflect on the results of the study.

2.2 EDUCATIONAL POLICIES AND PRACTICES

This section describes some policies regarding education in Indonesia together with the results from the practices. Section 2.2.1 briefly discusses the educational system in Indonesia, followed by a discussion of the school curricula (section 2.2.2). Policies about teacher education are presented in section 2.2.3, while some innovation projects in education that have been conducted in Indonesia are presented in section 2.2.4.

2.2.1 Educational system

In terms of levels of education, the existing structure of education in Indonesia consists of primary, secondary, and higher education. This structure, which involves large out-of-school educational programs such as vocational, professional, religious and armed forces education, is summarised in Figure 2.1.



Source: Thomas, 1991.

Figure 2.1

Structure of formal education system

As mentioned in Chapter 1, the system of education in Indonesia is centralised. In the national level, the Ministry of Education controls the school system with the power to appoint, transfer or dismiss teachers (except at primary level); and to create, expand or improve schools (except primary) (Cowen & McLean, 1984). There is a dual control for primary school. The Ministry of Home affairs is responsible for teachers, buildings and equipment in primary schools, while the Ministry of Education is responsible for professional standards and supervision. The situation becomes more complicated because the Ministry of Religion also administers its own parallel system of education.

For each province there is a provincial office of education. Within each province there are also district and then subdistrict offices of education. The latter takes control of primary schools in the subdistrict. As the system of education is centralistic, with each unit carrying out the request of the higher unit, almost all regulation and policies follow Top-Down model.

With relation to this study, the system caused some disadvantages. Firstly, there was a long administrative chain that had to be passed in order to get the permission to conduct the study. Secondly, it limited the interventions that could be done in the schools. In other words, we could not carry out an intervention in the schools if it was not suited to the ongoing curriculum.

2.2.2 Curriculum

Since independence in 1945, five curricula have been introduced in Indonesian education namely in 1947, 1963, 1975, 1984, 1994. The discussion in this section is only focused on the last three curricula.

Curriculum 1975 was comprised of (i) general aims for education as reflected in the nation's socio-economic development plan and; (ii) more specific objectives derived from logical analysis of the general aims, with the specific objectives assigned to particular subject-matter areas (Thomas, 1991). The second item implies that every teacher should know exactly what objectives are to be achieved by the pupils while planning the teaching-learning activities and implementing the lesson plan. Because only instructional objectives were provided, the teachers were also responsible for creating or locating instructional materials and preparing the method of teaching for each lesson. However, observations of the curriculum implementation showed that:

- Many teachers lacked the skills, resources, initiative, time and energy to create effective learning activities for pursuing the objectives.
- In most classrooms traditional lecture and question-answer methods prevailed.
- Teachers continued to use traditional textbooks

In curriculum 1975 mathematics education developed a 'new look' because in this curriculum the idea of modern mathematics was adopted. The main idea brought by the new approach was a mathematics curriculum based on set theory and logic. After nine years of implementation, the Research and Development Centre of the Ministry of Education (Balitbang) identified weaknesses of curriculum 1975 in three domains: (i) the relevance of curriculum to the government's socio-economic plan, (ii) the suitability of the curriculum contents to pupils' cognitive development, and (iii) an overload of course materials in certain subjects areas. To overcome these shortcomings, a revision of curriculum 1975 resulted in curriculum 1984. The new curriculum was also (i) to emphasise Indonesian's struggle to gain independence from colonialism; (ii) to produce a more suitable combination of core subjects and elective subjects; (iii) to match learning goals and activities more adequately to pupils' cognitive, emotional, psychomotor development; and achieve a better transition from school to the workplace (Thomas, 1991).

Curriculum 1984 introduced a new theme for mathematics education called active learning. This theme was established after a successful trial in Cianjur named the Active Learning through Professional Support Project (ALPS). More about this project will be discussed in section 2.2.4. However, a variety of problems continued in the 1990s such as:

- An overload of separate subjects at the primary school level so that pupil had insufficient time to master any given subject.
- Inadequate co-ordination among the agencies engaged in curriculum development and utilisation.
- Too few teachers' guide books and textbooks to equip all schools
- A lack of continuous assessment of pupils' progress
- The unsatisfactory implementation of principles of active learning and individualisation of instruction

In 1989, the Indonesian government announced the implementation of National Education Law No. 2. This law explains that the system of education aims at developing abilities and increasing the standard of living and dignity of the Indonesian people in order to achieve the national development goal. To realise this aim, curriculum 1984 was revised into curriculum 1994. The new curriculum introduced a compulsory nine-year basic education plan to replace the existing six-year basic education program. The discussion about curriculum 1994 will be elaborated in more detail in section 2.3.

2.2.3 Teacher education

Teachers in Indonesia are trained in different institutions and at different levels according to the type of school in which they intend to teach. Cowen and McLean (1984) mention that there are two major types of institution for pre-service training: primary and secondary teacher's colleges. The teacher training college for primary school teachers (SPG) is an institution in the level of upper secondary school. It accepts students from lower secondary schools for a three-year course. In order to improve the quality of primary schools, the government decided in 1991 to increase the education of primary school teachers from only an upper secondary education to a higher educational level with a two-year diploma course (DII) following the upper secondary education (see Moegiadi, 1994). The DII course for primary schools is conducted by the Institute of Teacher Training (IKIP).

The teacher training college for secondary school teachers (IKIP) is a tertiary level institution. Initially IKIPs accept students from upper secondary education for a three year course for those who want to teach at lower secondary school) or a four-year course for those who want to teach at upper secondary school). In 1990 the IKIPs stopped the first type of course and began requiring the four-year course for everyone that wanted to be a teacher at a secondary school.

To support teachers in their duties, the government established many in-service training programs. For example, at the primary level there was the Primary Education Project (P3D), which was in operation for five years with World Bank and Canadian support. The project came to an end in 1979. In current practice, in-service training for primary school teachers is conducted through a program called KKG in which teachers have a meeting every two weeks. Teachers from one school attend the KKG program by turn (the principle selects them), considering that the meeting is conducted in one of school days. In this meeting the teachers discuss all problems they encounter during their teaching learning processes.

Several in-service programs were also established for teachers at the secondary level. One such program was the PKG program, started in 1984, and supported by the World Bank. The PKG model was initially developed through a UNDP project, which ran from 1978 to 1984. Based on the research done by Somerset in 1996 it is known that the PKG program was not a success. He said that despite PKG's long history, wide coverage (the program was established in every district in Indonesia), and many innovative features, the program remains badly under-documented. No comprehensive account of PKG has ever been published, while the few summary accounts that have been written are, for the most part, difficult to locate.

2.2.4 Some innovative projects

Besides changing the curriculum, the government was also developing some innovations in order to enhance the quality of the curriculum implementations.

Most of the innovations were in relation to projects that were conducted in collaboration with foreign donors or countries. This section discusses some of these innovation projects.

Supported by USAID and Canada, an experiment known as *Pamong* had been conducted since 1973 in the town of Solo. The experiment attempted to use the primary school as a learning centre, which can be more flexible than a regular primary school in terms of students, teachers, methods and involvement with the community. Cowen and McLean (1984) mention that this experiment included modular self-instructional materials, peer-group teaching, programmed teaching of younger children by older children and teaching by members of the community.

The next innovation is the development school project (PPSP) that was established to develop the curriculum 1975. This project was conducted in eight provinces under the control of IKIPs. In this project the pupils learned using a module system: the pupils move from one module to another based on their capability and progress. This innovation was ended because of lack of funds to produce modules for pupils.

The Active Learning through Professional Support (ALPS) project was started in 1980 (see Moegiadi, 1994). This innovation paid attention to preparing realistic teaching plans; encouraging children's investigation, supporting children's discussions and interactions; and marking books and providing feedback. This promising project, which was also called 'Cianjur Project' achieved success during a trial in some primary schools in Cianjur. But when this innovation was extended to the other regions, it was ended unsuccessfully because of a lack of implemented strategy. Most teachers interpreted this project as 'a routine ritual' (pupils sitting in-groups and activities in the classroom following certain steps) in the teaching learning process.

The innovations that had been undertaken were meant to be implemented in the whole country. In fact, they had only a temporary effect (only during the project period) because of little effort put forth by the government, schools and teachers to maintain the innovations and also due to lack of resources (funding) and implementation strategy.

What can be learned from the innovation projects: (i) the innovations are top-down so that there was no sense of belonging of teachers toward the innovations; (ii) there was no follow up (i.e. discussion, supervision and evaluation) after the innovations were introduced. In other words, teachers were left alone to interpret and implement the innovations in their schools. Because of these two conditions, most teachers preferred to teach in the way they were used to (traditional method).

2.3 MATHEMATICS EDUCATION IN INDONESIAN PRIMARY SCHOOLS

Before talking about mathematics education in Indonesian primary schools, this section briefly describes the general conditions of Indonesian primary schools. An overview of Indonesian primary schools can be found summarised in the next table.

Table 2.1
Overview of Indonesian primary schools

Variables	Number of
1. Number of schools	150.612
2. Number of classes	1. 017. 661
3. Number of teachers	1. 141. 168
4. Number of pupils	25. 614. 836
5. Number of subject matter	8 + 2 local subject matter
6. Number of hours for teaching /year	1. 428 hours
7. Number of hour for teaching mathematics/week	8 (320 minutes)

Source: Aoer, 2000; http://www.pdk.go.id/statistik.htm#Statistik_sd.

From the table it is known that the ratio of pupils to classes is 25, and the ratio of pupils to teachers is 22, an ideal condition for teaching learning process. However, Moegiadi (1994) found some inefficiency in the educational system, one of which was teachers' deployment (a lack of teachers in certain schools/areas and an oversupply of teachers in other schools/areas). Even in the year 2002, and especially in the rural areas, we can find the same condition. In those schools the religion teachers or sports teachers are usually also taking on the role as classroom teachers. It means they teach almost all subjects including mathematics. In some schools the condition is even worse because a teacher has to teach more than one class (*note*: the ratio of classes to teachers is 0,89). The same situation is also found for the distribution of pupils. In some schools there are classes that have less than 10 pupils, while some other schools have more than 40 pupils in one class.

Regarding the number of subject matters, Indonesian curriculum has more subject matter than those do in China, Korea or Malaysia. The time allocated for teaching the subject matter per year in Indonesia is also much more compared to that in China, Japan, Korea or Malaysia (Aoer, 2000). But, the results of TIMMS Study in 1999 (see Mullis at al., 2000) showed that the achievement of Indonesian's students was far behind those countries.

The remainder of this section is focused on mathematics education in Indonesian primary schools. The goals of the mathematics curriculum for primary schools are described in section 2.3.1. Next will be a look into the contents of the mathematics curriculum for primary schools. The implementation of the mathematics curriculum in Indonesian primary schools is presented in section 2.3.2, while the pupils' achievements are discussed in section 2.3.4. The discussion in these sections refers to Curriculum 1994.

2.3.1 Mathematics curriculum

Mathematics curriculum for Indonesian schools contains particular mathematics topics that are selected based on the development of science and technology, in order to develop pupil's abilities and personality. This mathematics is called *school mathematics*. There are two main functions of teaching school mathematics in Indonesia that are mentioned in curriculum 1994:

1. Developing communication abilities and skills using numbers and symbols;
2. Sharpening reasoning in order to be able locate and solve problems in everyday life activities.

Based on these functions, the general goals of mathematics education in Indonesian primary education are phrased as follows:

- Preparing the pupils to be able to deal with the dynamic world situation 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.

To implement the curriculum, the Centre of Curriculum in Indonesia (Puskur) developed guidelines for the teaching program (GBPP). In these guidelines the general goals of teaching mathematics are refined into more specific goals. For the primary schools the specific goals of mathematics education are:

- Stimulating and developing arithmetic skills (using numbers) as a tool in everyday life.
- Enhancing the ability of the pupils to apply mathematics through mathematics activities.
- Developing basic knowledge of mathematics as a prerequisite for studying at junior high school.
- Developing pupil attitude to be rational, critical, cautious, creative, and discipline.

These specific goals are refined further into general instructional objectives, and then into specific instructional objectives, in order to help teachers to utilise the curriculum in the classrooms. The general instructional objectives reflect the goals that have to be achieved by teaching a mathematics topic and the specific instructional objectives have the same function but for the sub-topics. In general we can say that one instructional specific objective represents one concept or skill pupils have to master. The example below shows the general instructional objective for a geometry topic at Grade 4 in Indonesian primary school, followed by the specific instructional objectives of this topic.

- General Instructional Objective: pupils are able to measure the size of angles and areas, and to recognise measurement units.
- Specific Instructional Objectives: (1) pupils are able to determine the area of squares and rectangles by counting the number of square units and/or by counting the number of square units in one row then multiplying it by the number of rows; (2) pupils are able to recognise the formulas for area of squares and rectangles; (3) pupils are able to recognise standard measurement units for area.

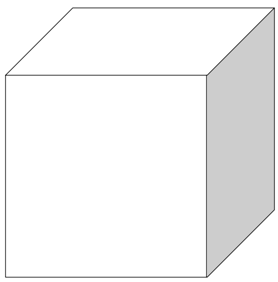
From the explanation above we can deduce that the mathematics curriculum for Indonesian primary schools intends to pay much attention to several important aspects of mathematics education such as developing pupils' reasoning, activity, creativity and attitude, and providing pupils with mathematics skills so that they can handle real life problems mathematically. These goals are similar to those mentioned by Niss (1996): Through mathematics education we want to provide pupils with prerequisites which can help them to cope with the various environments in which they live. In their standard, the National Council for Teaching Mathematics (NCTM) (NCTM, 2002) also stated a similar vision: the curriculum also must focus on important mathematics--mathematics that is worth the time and attention of students and that will prepare them for continued study and for solving problems in a variety of school, home, and work settings.

After reading the lofty goals of mathematics education in Indonesian primary school, questions may arise as to why the quality of mathematics education in Indonesian primary schools is still poor, and why most students hate to learn mathematics, why students' achievements in mathematics is poor from year to year. The remainder of this section will discuss the content of mathematics curriculum for Indonesian primary school in which these 'why' questions are answered.

As mentioned before, the general instructional objectives in the GBPP have been developed into the specific instructional objectives. After analysing the specific instructional objectives in the GBPP it is evident that this is the primary source of the problems in mathematics education in Indonesian primary schools, because the lofty goals have become blurred. The specific instructional objectives from Grade 1 till Grade 6 are dominated by remembering facts and concepts verbally, studying computational aspects, and applying formulas. In geometry instruction for example, the specific learning objectives are focused on remembering the definitions of two and three dimensional geometrical objects such as squares, rhombuses, cubes, prisms, and memorising the characteristics of these objects. When it comes to learning topic areas and perimeters, the objectives are dominated by remembering and applying the formulas (see the example of the specific learning objectives above). Suydam (1993) mentions that geometry is a brand of mathematics useful for developing logical thinking ability, while Moeharty (1993) says that the geometry lesson is very important because it gives us a way to interpret and to think about our environment. But if the learning objectives are designed in the way outlined above, how the usefulness of geometry instruction mentioned by Suydam and Moeharty can be achieved?

Mathematics textbooks are another reason why mathematics education in Indonesian primary schools often yields poor results. As the contents of the mathematics textbooks in Indonesian primary schools are a reflection of the specific instructional objectives in the GBPP, it follows that the textbooks have emphasised on introducing facts, concepts and formulas as well as practising computation skills or applying the formulas. Many abstract concepts are introduced without paying much attention to aspects such as logic, reasoning, and understanding (Karnasih & Soeparno, 1999; Soedjadi, 2000). The topics that are taught seem far removed from pupils' daily life. Even the teachers themselves sometimes do not know the usefulness of the topics they teach (see the first vignette in Chapter 1).

The next example, taken from the mathematics textbook for Grade 6, shows how a geometry topic is presented in the textbook. The topic is about the area of the surface of three-dimensional geometry objects.



How many sides does the cube have? What is the shape of each side? What is the formula for the area of a square? Yes, the number of cube sides is 6 and the shape of each side is a square. Meanwhile the area of a square is side times side with the formula **L = s x s** *in which* L = *the area of the square and* **s** = *the side of the square = the rib of the cube.*

> *Because a cube has 6 sides and the shape of each side is a square with the area* **s x s***, then the area of all sides of the cube or the area of the surface of the cube is* **6 x s x s.** *The area of the cube's sides (we call it as the area of a cube) is the sum of the area of cube's sides. Therefore, if* **L** = *area of a cube and* **s** = *side of a square as well as rib of the cube then* **L = 6 x s x s**

The explanation above is followed by the next example and its solution:

> *The area of a cube's surface is 294 dm2. The rib of the cube is how many dm?*

The formulas for areas of surface for other geometry objects such as blocks, cylinders, prisms and pyramids are introduced in similar manner and their introduction followed by many exercises involving applying the formulas. Most of the exercises are not more than simple computation problems as is shown by the following example taken from the mathematics textbook for Grade 6.

> *Determine the Area and Perimeter of a circle if: the diameter (d) = 7 (*there are 5 similar problems*); the radius (r) = 10 (*there are 5 similar problems*)*

The example above shows that mathematics topics are presented in a very mechanistic way (see Treffers, 1987) in the textbooks. Batista (1999) called this as traditional mathematics in which school mathematics has been seen as a set of computational skills.

Because of the concentration of mathematics topics that are presented in the textbooks, it has been said in the country that the contents of the mathematics curriculum for Indonesian primary schools are burdensome (see Aoer, 1999; Soedjadi, 1992). Teachers complain about the numbers of topics that they have to teach in a limited amount of time. Students complain about having too many exercises and too much homework to complete, while parents frequently become confuse when they are helping their children with their homework. This is because most parents are not familiar with the topics presented in the mathematics textbooks.

In 1999 the Department of Education in Indonesia announced the simplification of curriculum 1994. One item in this restructuring was reducing irrelevant/unessential topics. But most people were not happy with this action because, again, there were no 'scientific reasons' given by the Department of Education for the changes. Questions such as why topic A should be skipped instead of topic B, for example, or what the effect on learning mathematics in the primary schools as a whole would be after topic A had been skipped could not be explained. Aoer (1999) called this simplification an 'old song' because some ministers of education in the previous cabinets did the same thing before, to calm down the community. Aoer even said that it was a political trick, because the simplification was announced when the Reform Cabinet came to an end (*note*: it was two months before the impeachment of President Wahid).

Besides their heavy emphasis on formulas and repetitive exercises, there are also problems regarding the sequence of mathematics topics in the textbooks. Some of the problems with the textbooks are repetitions that are not necessary (i.e. in topic 'introducing the geometry objects', and topic 'area'); a lack of interrelationships among the topics; some related topics are separated (i.e. the topics introducing the area of rectangles, triangles and parallelograms are taught in different time or different grade). These situations give the impression to the pupils that every topic is 'new' every time they learn a mathematics topic (see also vignette 1 in Chapter 1). The situations described above are contradictory to those mentioned in standard 2000 NCTM. The standard mentions:

> *Mathematics is a highly interconnected and cumulative subject. The mathematics curriculum therefore needs to introduce ideas in such a way that they build on one another. Instead of seeing mathematics as a set of disconnected topics, students should perceive the relationships among important mathematical ideas. As students build connections and skills, their understanding deepens and expands.*

Curriculum 1994 also states that problem solving is important to develop pupils' understanding and reasoning. As a result, we can find some 'problem solving' at the end of every exercise in the textbooks. But when we analyse further, these problems are little more than traditional story problems (see Figueiredo, 1999) that mostly can be solved by applying formulas or using simple computations. The next example shows a 'problem solving' taken from mathematics textbook for Grade 6.

> *Mr. Puji has a square piece of land with the sides = 2 km. He wants to give ¼ of his land to Pipim. How many ha is the land that Mr. Puji gives to Pipim?*

In the classroom practices, solving these kinds of problems appears as a routine process in which pupils have to mention (write) three steps every time they solve the problems. First, they have to mention 'what is known' from the problem. Then 'what is asked', and finally 'what counting operations are involved'.

The last (but not least) issue about mathematics textbooks in Indonesian primary schools is related to aspects of spatial ability. Many reports have shown that spatial ability is an important factor that has to be developed through geometry instruction (see Del Grande, 1990; Del Grande & Morrow, 1993; Hoffer 1977; Yaminskaya, 1978). NCTM in one of its standards for curriculum states that spatial understandings are necessary for interpreting, understanding, and appreciating our inherently geometric world (http://www.nctm.org). Freudenthal Institute in the

Netherlands also uses the real phenomena of the space around the students as a starting point in geometry instruction (see de Moor, 1997). The goal of geometry instruction in Denmark is to develop students' visual awareness and ability through consideration and description of simple geometrical figures (Niss, 1996).

Although one goal of geometry instruction in Indonesia is that students develop spatial view ability through studying geometry objects (Depdikbud, 1995), there is no topic in mathematics textbooks that intentionally aims at developing pupils' spatial ability. In the contrary, the way in which the geometry objects are drawn in the textbook causes some misconceptions not only for pupils but also for teachers. For example, squares are always drawn as in figure 1**a** and rectangle as in figure 1**b.**

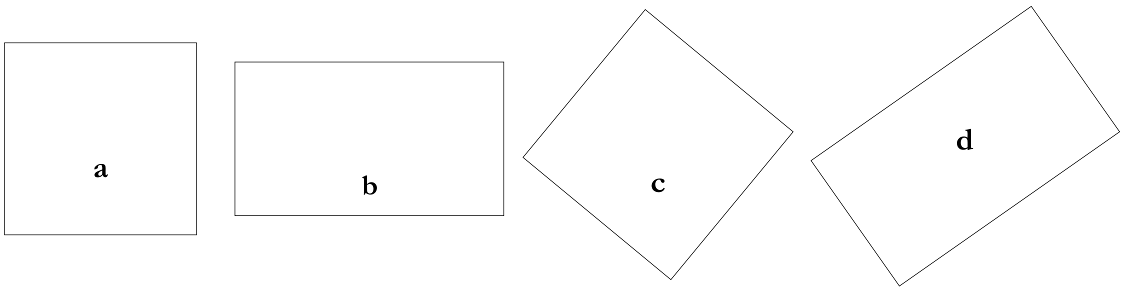


Figure 2.2
Squares and rectangles in various appearances

When the objects were drawn as in figure 1**c** or 1**d**, most students thought that they were no longer squares or rectangles. Some of them said that figure 1**c** was a rhombus and figure 1**d** was a parallelogram (Fauzan, 1996, 1998).

Van Hiele (1973) also observed similar situations in secondary education settings. He said that the students only recognize a rhombus by its shape, not by its properties. A square is not recognized as a rhombus, unless you place the square on its tip, like in figure 2**b**.

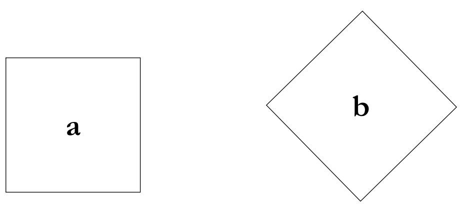
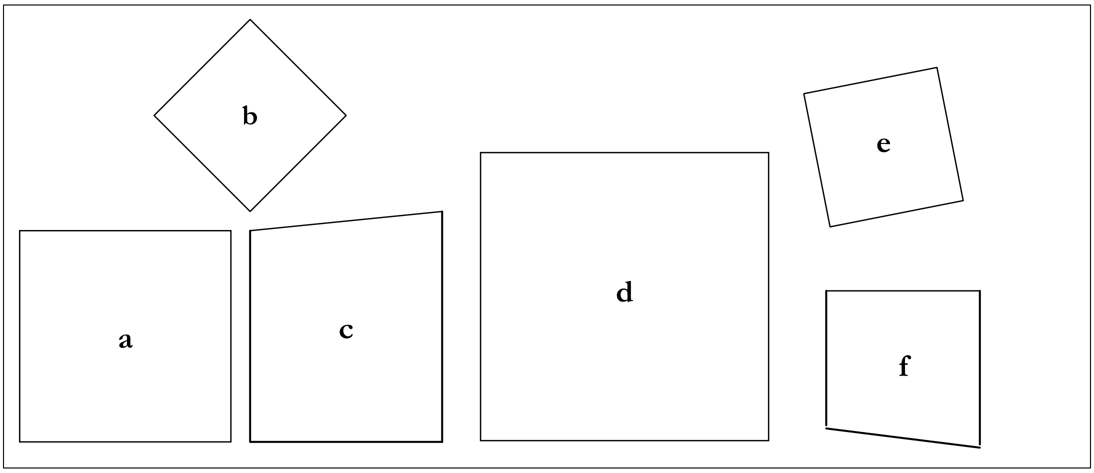


Figure 2.3
Recognition of a square as a rhombus

A teacher's misconception was found in a primary school in Padang, West Sumatera Indonesia, as can be seen below.

> *A teacher at a Grade 3 elementary school gave homework asking pupils to identify which of the figures below is a square*



> *When the teacher gave the answer to the pupils, she said that figures* ***b*** *and* ***e*** *are not square (because their appearance is not like figures* ***a*** *and* ***d****?), and she blamed the pupils whose answered that these figures were square.*

This finding shows that the teacher lacked spatial ability, especially in *'perceptual constancy'* (Del Grande, 1990; Del Grande & Morrow, 1993).

2.3.2 Curriculum implementation

Before discussing the implementation of mathematics curriculum in Indonesian primary schools, let us examine some directions for teachers mentioned in the GBBB:

- In the teaching learning process, teachers are advised to select and use strategies that could stimulate pupils' activities, mentally, physically and socially. In stimulating pupils' activities, the teacher could deliver mathematics problems that have divergent or convergent solutions or problems that require investigation.
- Teaching mathematics should be relevant with characteristics of each topic and the development of pupils' thinking. There should be synchronisation between teaching mathematical concepts, teaching skills and problem solving.

- Teaching mathematics has to start with concrete ideas and move to abstract ones, from easy problems to difficult ones, and from simple understanding to complex analysis.

No doubt that those are nice directions. In spite of the guidelines outlined above, in practice most teachers prefer traditional approach as it was shown earlier in Chapter 1 (see also Somerset, 1997). The teachers become the centres of almost all activities in the classrooms in which the pupils are treated as an 'empty box' that needs to be filled. This situation is certainly not conducive either for mathematics teaching or for the learning process. In general, the climate in Indonesian classrooms (see Fauzan, 2000; Fauzan, Slettenhaar & Plomp, 2002, 2002a; Somerset: 1997), is similar to that in several African countries as was summarised by de Feiter & Akker (1995) and Ottevanger (2001) as follows:

- students are passive throughout the lesson;
- 'chalk and talk' is the preferred teaching style;
- emphasis on factual knowledge;
- questions require only single words, often provided in chorus;
- lack of learning questioning;
- only correct answers are accepted and acted upon;
- whole-class activities of writing/there is no practical work carried out.

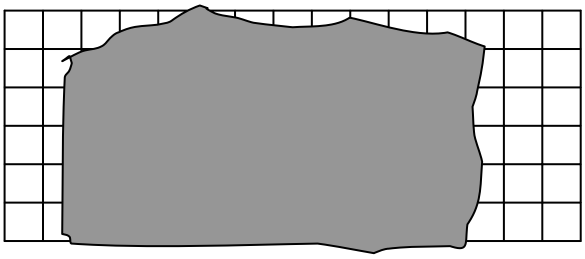
The impact of these situations is that most students are not learning the mathematics they need. They also do not have the opportunity to learn significant mathematics, and lack commitment or are not engaged by existing curricula. This is similar to what Battista (1999) mentioned about traditional mathematics instruction. He said, for most students, school mathematics is an endless sequence of memorising and forgetting facts and procedures that make little sense to them. For most teachers teaching mathematics is just a routine task in which the same topics are taught or re-taught year after year.

Several scientific studies have shown that traditional methods of teaching mathematics not only are ineffective but also seriously stunt the growth of students' mathematical reasoning and problem-solving skills. In addition, traditional methods ignore recommendations by professional organisations involved in mathematics education, and they ignore modern scientific research on how children learn mathematics. The innovation projects mentioned in section 2.2.4 are an example of these conditions. Several promising innovations have been undertaken in Indonesia, but there has been no significant impact on the way the teacher is teaching mathematics, as most of them still prefer to use traditional methods in the current practices.

Many teachers in Indonesian primary schools never pay much attention to how children learn mathematics. They focus more on what topics have to be taught and how to finish the topics in the allocated time. As we can see from vignette 2 mentioned in chapter 1, the teacher thought that what she did was the best for her pupils. In fact it was not, because the pupils are not the empty boxes that 'swallow' all things the teacher puts into them. They have their own ideas that need to be developed or listened to by the teachers.

Teachers need to stop thinking that they know everything and their pupils know nothing. Pupils do not come to school with empty minds. They have prior or informal knowledge resulting from social contact with their environment. Teachers have to consider the prior or informal knowledge of the students because it is a strong base on which to build new understanding (Horsley et al., 1998). In addition, teachers also should stop thinking that they are very important as the only source of knowledge. Briggs and Gagne in Rusyan (1992) mention that the important thing in teaching is not teacher effort to deliver the information/material, but how the students can learn from it based on goals. Teachers strive to influence students to study. Teachers are not the source of information but act as facilitator.

Besides teachers' lack of skills and knowledge about effective teaching methods (Hadi, 2002; Somerset 1997), the way the teachers present mathematics in the classrooms is strongly influenced by the textbooks. For most teachers the mathematics textbooks are the only instructional resources. Somerset (1997) says that many teachers, especially those who are insecure about their own mathematics knowledge, based their lessons closely on the material in the textbook they were using. What frequently happens is that teachers end up presenting their students with inaccurate mathematics because the mathematics in the textbooks are also inaccurate, or because of a lack of knowledge on the part of the teachers. Kerans (1995) found one of the examples for this case as follows:



Following what was written in a mathematics textbook published by a private publisher, a teacher told the pupils that the length of the shaded figure above was 10 (the number of square units in one row) and the width was 5 (the number of square units in one column), so the area was 10 x 5 = 50. We can see here that the goal of teaching this topic (in this case 'measuring an area') is no more than counting a 'number', meanwhile the essence of the topic (i.e. measurement is an approximation; area not only deals with regular shapes) is forgotten.

The third direction mentioned in GBPP implies that teachers need to be very careful in introducing new mathematics concepts to pupils. Because mathematics concepts are abstract, teachers have to be creative in finding ways to make those concepts real for pupils. One way the teachers can accomplish this is by using media (i.e. models of geometry objects) for mathematics instruction. But many teachers are not willing to make the effort to use media for their instruction. Most of them offer the excuse that it takes a long time to prepare the media, meanwhile a lot of topics have to be taught in a limited amount of time. In addition, the research shows that teachers suffer from a lack of knowledge and a lack of skill in creating and using media (Amin, 1995; Mukhni, 2002, Soedjadi, 1992). A principal in a primary school in Padang (through personal communication) admitted that there were a lot of media for mathematics instruction available in her school, but the teachers just left them unused. With the same excuse as mentioned before, many teachers skip practical works suggested in the textbooks (i.e. measuring perimeter by using wire).

2.3.3 Pupils' achievements

In general, the quality of mathematics instruction at all educational levels in Indonesia is very poor. One indicator of this is students' achievement in the national examination (Ebtanas). Even though almost all schools put a tremendous effort into increasing their students' achievement level in the Ebtanas (*note*: the

Ebtanas appears to be the only standard to measure the quality of the schools), the pupils' achievement in mathematics remains at a low level (Manan, 1998; www.depdiknas.co.id). The poor performance of Indonesian students can also be seen from the Third International Mathematics and Science Study (TIMSS) report (Mullis et al., 2000).

There is no data in national scale about pupils' achievement in geometry instruction. But some findings indicate that geometry tends to be the most difficult among the mathematics branches not only for students but also for teachers. For example, a junior high school teacher in Indonesia said that she did not present a particular geometry topic in her instruction because she did not understand the topic. According to Soedjadi (1991), geometry appears to be one of the most difficult parts of mathematics to learn. He found that most students face some difficulties in determining if an angle is a right angle or not; and recognising and knowing geometry objects, especially three dimensional geometry objects and their aspects. These conditions are found at both the elementary and the secondary school levels.

Fauzan (1996, 1998) found that the understanding of most students in senior high schools about geometry concepts (i.e. squares, parallelograms, and triangles) is very poor. They could not recognise those objects although they have already learned these concepts since they have been in primary school. Herawati (1994) found that Grade 5 pupils displayed weaknesses when trying to solve geometry problems, while Amin (1995) said that most teachers were having difficulties in teaching geometry topics. The poor performance of the students in geometry and negative attitude toward geometry as mentioned above became a big challenge for this study.

2.4 IMPLICATION TO THE STUDY

The previous sections have discussed several efforts to improve the quality of mathematics education in Indonesia. However, most of the efforts ended unsuccessfully. Mathematics curriculum and textbooks do not give opportunity for pupils to learn mathematics, but to remember mathematics. Meanwhile, teachers do not want to move from their traditional method, and pupils tend to dislike learning mathematics. These issues together with the fundamental problems mentioned in chapter 1 lead to the next questions:

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

The questions, which become the main theme in this study, are answered through developing and implementing RME-based curriculum. These efforts are relevant to what de Feiter (1998) says about three supports for successful implementation of an innovation in classroom practice:

- use of well tried exemplary materials that provide support for critical elements of proposed changes and that appropriately picture how to propose innovations work out in classroom practice,
- ample opportunity for teachers to practice innovation in safe environments with feedback on performance together with follow-up support after implementation attempts in school practice,
- creation of a supportive school environment, and provision of in-school support for teachers when they try out changes in their classrooms.

The next chapter discusses RME theory in which the important aspects of RME for instructional design as well as teaching learning process will be elaborated thoroughly. The information elaborated in this chapter will answer the two questions above. Further, the reader will also find the contrast between traditional mathematics education (as most of its conditions are described here) and RME.

CHAPTER 3
REALISTIC MATHEMATICS EDUCATION (RME)

The previous chapters described the motives for carrying out the study within the context of where it took place. Building on that, this chapter reviews the theory of Realistic Mathematics Education (RME) as the main theoretical framework for this study. The chapter begins with several notions about RME (section 3.2). Section 3.3 discusses the key principles of RME, while section 3.4 deals with the teaching and learning principles of RME. Section 3.5 presents realistic geometry and section 3.6 talks about the role of context in RME. In the latter the contrast between the contextual problems and the story problems is also reviewed. The last section (section 3.7) briefly discusses RME and the research trends in mathematics education.

3.1 INTRODUCTION

As a reaction to the *New Math* or *Mathematics Modern*, the *Wiskobas* project in the Netherlands developed the instructional theory called 'Realistic Mathematics Education (RME)' (see Freudenthal, 1973, 1991; van den Heuvel-Panhuizen, 1996; Gravemeijer, 1994, 1997; Klein, 1998; Streefland, 1991, 1991a; Treffers, 1987, 1991). The label 'realistic' is taken from a classification by Treffers (1987) that discerns four approaches in mathematics education: mechanistic, structuralistic, empiristic and realistic (these approaches will be discussed in section 3.3.1). Later on, based on Freudenthal's interpretation of mathematics as a human activity (Freudenthal, 1973), a realistic approach to mathematics education became known as Realistic Mathematics Education (RME). To give more insight into this theory the following section outlines some notions of RME.

3.2 SOME NOTIONS OF REALISTIC MATHEMATICS EDUCATION (RME)

The key idea of RME is that children should be given the opportunity to reinvent mathematics under the guidance of an adult (teacher). In addition, the formal mathematical knowledge can be developed from children's informal knowledge (Treffers, 1991a). It means that by performing some activities of solving contextual problems that are real for pupils, they can use their informal knowledge to reinvent mathematics. In this view mathematics education would be highly interactive in which the teachers would have to build upon the ideas of the students. It means they have to react based on what the students bring to the fore (Kooj, 1999).

Within a realistic approach mathematics is seen as an activity. Learning mathematics means doing mathematics, of which solving every day life problems (contextual problems) is an essential part (Gravemeijer, 1994). According to Freudenthal (1971), the activity that we perform in RME is:

> *An activity of solving problems, of looking for problems, and also an activity of organizing a subject matter. This can be a matter from reality, which has to be organized according to mathematical patterns if they have to be solved. It can also be a mathematical matter, new or old results, of your own or others, which have to be organized according to new ideas, to be better understood, in a broader context, or by an axiomatic approach.*

This organizing activity is called '*mathematizing*' (Gravemeijer, 1994; 1997; Treffers, 1991a).

Freudenthal mentions mathematizing as a key process in mathematics education because of two reasons. Firstly, mathematizing is not only the major activity of mathematicians but it also familiarizes the students with a mathematical approach to everyday life situations. For example, in the mathematical activity of solving contextual problems, it implies a mathematical attitude, encompasses knowing the possibilities and the limitations of a mathematical approach, knowing when a mathematical approach is appropriate and when it is not. Secondly, the final stage in mathematics is formalizing by way of axiomatizing. This end point should not be the starting point when we teach mathematics, as it is mostly found in traditional mathematics instruction. Freudenthal argues that starting with axioms is an anti-didactical inversion because the process by which the mathematicians come to their conclusions is the reverse. Related to this he suggests that mathematics education has to be organized as a process of guided reinvention, where students can experience a similar process to the process in which mathematics was invented by mathematicians.

Figure 3.1 of de Lange (1996) describes the process conceptual mathematization in RME. This figure also explains to us why real context is very important as a starting point in the learning of mathematics. De Lange says that the process of developing mathematical concepts and ideas starts from the real word, and at the end we need to reflect the solution back to the real world. So, what we do in mathematics education is to take things from the real world, mathematizing them, and then bring them back to the real world. All this process lead to *conceptual mathematization*. .

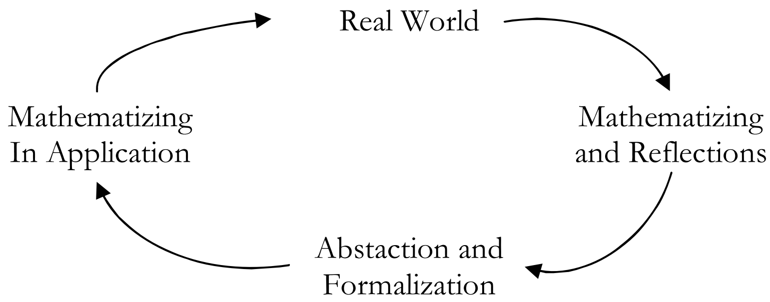


Figure 3.1
Conceptual mathematization

The following two sections discuss the RME's key principles for instructional design and the RME's learning and teaching principles. In these sections, some aspects of RME as described above are elaborated upon further.

3.3 RME'S KEY PRINCIPLES

According to Gravemeijer (1994, 1997) there are three key heuristic principles of RME for instructional design (see also Gravemeijer, Cobb, Bowers, and Whitenack, 2000) namely *guided reinvention through progressive mathematization, didactical phenomenology,* and *self developed models* or *emergent models*. These principles are discussed consecutively in more detail in the following sections.

3.3.1 Guided reinvention through progressive mathematization

According to de Lange (1987), in RME the real world problem is explored in the first place intuitively, with the view to mathematizing it. This means organizing and structuring the problem, trying to identify the mathematical aspects of the problem, to discover regularities. This initial exploration with a strong intuitive component should lead to the development, discovery or (re) invention of mathematical concepts. These criteria lead to the first key principle of RME for instructional design that is 'guided reinvention through progressive mathematizing'.

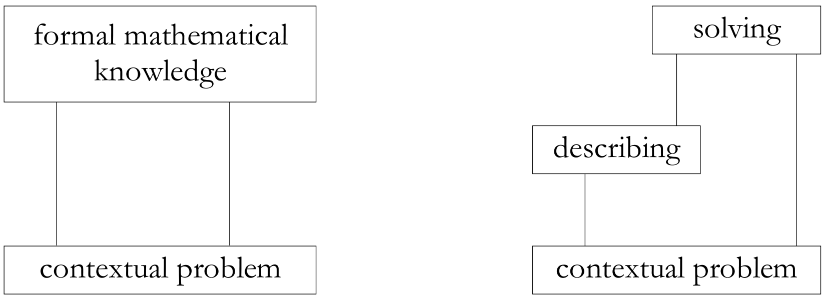
In the guided reinvention principle, the students should be given the opportunity to experience a process similar to that by which mathematics was invented (Gravemeijer 1994, 1999). With regard to this principle, a learning route has to be mapped out (by a developer or instructional designer) that allow the students to find the intended mathematics by themselves. When designing the learning route (Gravemeijer (1994) calls this *conjectured learning trajectory*), the developer/designer starts with a thought experiment, imagining a route by which he or she could have arrived at a solution him-or herself. Gravemeijer (1994) says that the conjectured learning trajectory should be emphasized on the nature of the learning process rather than on inventing mathematics concepts/results. It means we have to give students the opportunity to gain knowledge so that it becomes their own private knowledge, knowledge for which they themselves are responsible. This implies that in the teaching learning process students should be given the opportunity to build their own mathematical knowledge on the basis of such a learning process.

According to Gravemeijer (1994, 1997) there are two things that can be used to realize the reinvention principle. Firstly, from knowledge of the history of mathematics we can learn how certain knowledge developed. This may help the developer/instructional designer to lay out the intermediate steps, by which the intended mathematics could be reinvented. It means that students can learn from the work of mathematicians. Secondly, by giving a contextual problem that has various informal solution procedures, continued by mathematizing similar solution procedures, will also create the opportunity for the reinvention process. To do so the developer/instructional designers need to find contextual problems that allow for a wide variety of solution procedures, especially those which considered together already indicate a possible learning route through a process of progressive mathematization.

Gravemeijer (1999) sees the reinvention principle as long-term learning process in which the reinvention process evolves as one of gradual changes. The intermediate stages always have to be viewed in a long-term perspective, not as goals in themselves, and the focus has to be given on guided exploration. To realize this view, the developer/instructional designers need to design a sequence of appropriate contextual problems. What we mostly find in traditional mathematics instruction is in the contrary to this view. Here the learning path is structured in separate learning steps, in which each step can be mastered independently.

To understand the guided reinvention principle better, let us see the differences between the realistic approach and information processing regarding reinvention process. According to Gravemejer (1994) the information processing approach views mathematics as a ready-made system with general applicability, and mathematics instruction as breaking up formal mathematics knowledge into learning procedures and then learning to apply them. On the other hand, the realistic approach is emphasized on mathematizing. Mathematics is viewed as human activity and learning mathematics means doing mathematics in which solving the everyday problems is an essential part.

The different view of the two approaches is essentially reflected in the mathematical learning processes as shown in the next models in solving a contextual problem.



application of formal mathematics realistic problem-solving

Source: Gravemeijer, 1994.

Figure 3.2
Mathematical learning process in the information processing and realistic approaches

The first model describes the process of solving a contextual problem by using the formal mathematical knowledge. In the first step, the problem is translated to a mathematical problem (mathematical terms), then the mathematical problem is solved by using the relevant mathematical means. At the end, the mathematical solution is translated back into the original context. Gravemeijer criticizes this model because there is reducing information in the process of solving the problem. Transformation of a contextual problem into a mathematical problem causes a reduction of information because many aspects of the original problem will have been obliterated. When the mathematical solution is translated back into the original context, it involves an interpretation. On the other side, the aspects that were obliterated should be taken into account again. What frequently happens is that the suggestion obtained from mathematical solution does not really fit the original problem. Moreover, solving the problems by using this model is due to recognizing problem types and establishing standard routines.

In the second model, solving the problem also passes through three stages: describing the contextual problem more formally, solving the problem on this level, and then translating the solution back into the context. But because in the realistic approach mathematics is taught based on human activity, it makes that the three activities have a very different meaning than those in the first model. Gravemeijer describes the advantages of solving the problem by using this approach as follow:

- the problem is the actual aim rather than the use of a mathematical tool;
- solving the problem is done in an informal way rather than applying a standard procedure;
- the problem is described in a way that allow pupils to come to grips with it;
- by schematizing and identifying the central relations in the problem situation, pupils will understand the problem better;
- the description we provide can be sketchy and using self-invented symbol (it needs not be presented in commonly accepted mathematical language);
- the description also simplifies the problem by describing relations and distinguishing matters of major and minor importance;
- translation and interpretation of the solution are easier because the symbol are meaningful.

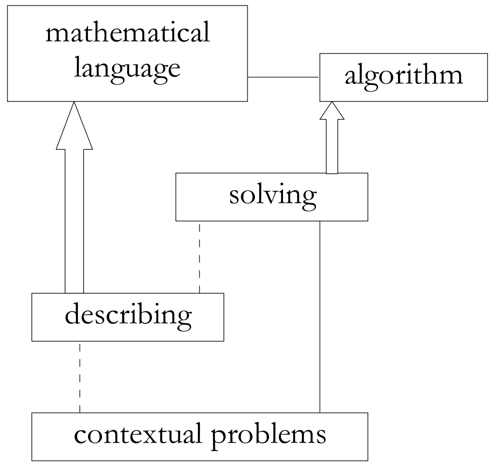
So far we can see that 'mathematizing' is a very important activity in RME. This activity mainly involves generalizing and formalizing (Gravemeijer, 1994). Formalizing includes modeling, symbolizing, schematizing and defining, and generalizing is to understand in a reflective sense. By solving the contextual problems in realistic approach students learn to mathematize contextual problems. This process is called mathematization (Treffers, 1987, 1991a).

As the process of mathematization is very important to develop knowledge from children's thinking (Freudenthal, 1968; Resnick, Bill & Lesgold, 1992; Trffers, 1991a), it is necessary to start the process by mathematizing those contextual problems that come from children's everyday-life reality. By doing that, children have the opportunity to solve the contextual problems using informal language (Treffers (1987, 1991a) calls this process as *horizontal mathematization*). In the long term, after the students have experienced similar processes (through simplifying and formalizing), the informal language will be developed into a more formal or standardized language. At the end of these processes the students will come to an algorithm. The process of mathematization of mathematical matter is called *vertical mathematization* (Treffers, 1987, 1991a). Freudenthal (1991) makes the distinction between horizontal and vertical mathematization:

> *"Horizontal mathematization leads from the world of life to the world of symbols. In the world of life one lives, acts (and suffers); in other one symbols are shaped, reshaped, and manipulated, mechanically, comprehendingly, reflectingly: this is vertical mathematization. The world of life is what is experienced as reality (in the sense I used the word before), as is symbol world with regard to abstraction".*

De Lange (1987) distinguishes between horizontal and vertical mathematization in more detail based on type of activities. The activities in horizontal mathematization involve identifying the specific mathematics in a general context; schematizing; formulating and visualizing a problem in different ways; discovering relations; discovering regularities; recognizing isomorphic aspects in different problems; transferring a real world problem to a mathematical problem; and transferring a real world problem to a known mathematical model. Meanwhile, in vertical mathematization the activities include representing a relation in a formula; proving regularities; refining and adjusting models; using different models; combining and integrating models; formulating a new mathematical concepts; generalizing

The process of horizontal and vertical mathematization is described in Figure 3.3. Horizontal mathematization takes place when pupils describe contextual problems using their informal strategies in order to solve them. If the informal strategies lead the pupils to solve the problems using mathematical language or to find an algorithm, then this process of movement shows a vertical mathematization.



Source: Gravemeijer, 1994.

Figure 3.3

Horizontal Mathematization (- - - - - - -); Vertical Mathematization (⇨)

Due to this learning process, if the students can (re) construct the formal mathematical knowledge, it means they do reinvention process. Gravemeijer (1994) schematizes this process in the next figure.

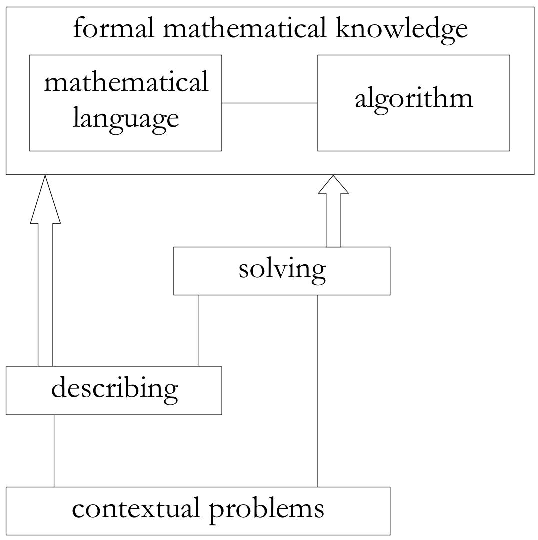


Figure 3.4

Reinvention process

Although in Figure 3.4 the reinvention process is presented using a one way arrow, in reality it is a repeated process. In other words, before reinventing the formal mathematical knowledge, pupils experience the processes of describing and solving the contextual problems that have similar procedure solutions. In these processes the pupils develop their informal strategies into mathematical language or algorithm.

The four approaches in mathematics education mentioned in section 3.1 are classified by Treffersr (1987) using criteria of horizontal and vertical mathematization. In the realistic approach, horizontal and vertical mathematizations are used to construct the long-term learning process. Here the students will start with contextual problems, idiosyncratic, informal knowledge and strategies. They then have to construct formal mathematics by mathematizing the contextual problems (horizontally) and by mathematizing solution procedures (vertically). The mechanistic approach is the opposite of the realistic approach because it lacks both the horizontal and vertical mathematization. The structuralistic approach only emphasizes on vertical mathematization, while the empiristic approach focuses on horizontal mathematization. These conditions can be summarized as follows:

	Horizontal Mathematization	**Vertical Mathematization**
Mechanistic Approach	–	–
Structuralistic Approach	–	+
Empiristic Approach	+	–
Realistic Approach	+	+

The sign '+' means much attention paid to that kind of mathematization, and the sign '–' means little or no attention at all (see De Lange, 1987).

3.3.2 Didactical Phenomenology

In contrast to the anti-didactic inversion (see section 3.2), Freudenthal (1983) advocated the *didactical phenomenology*. This implies that in learning mathematics we have to start from phenomena that are meaningful for the student, that beg to be organized and that stimulate learning processes. In didactical phenomenology, situations where a given mathematical topic is applied are to be investigated for two reasons (Gravemeijer, 1994, 1999). Firstly, to reveal the kind of applications that have to be anticipated in instruction. Secondly, to consider their suitability as points of impact for a process of progressive mathematization.

According to Gravemeijer (1994, 1999), the goal of a phenomenological investigation is to find problem situations for which situation-specific approaches can be generalized, and to find situations that can evoke paradigmatic solution procedures that can be taken as the basis for vertical mathematization. This goal is derived from the fact that mathematics is historically evolved from solving practical problems. In mathematics instruction we can realize this goal by finding the contextual problems that lead to this evolving process.

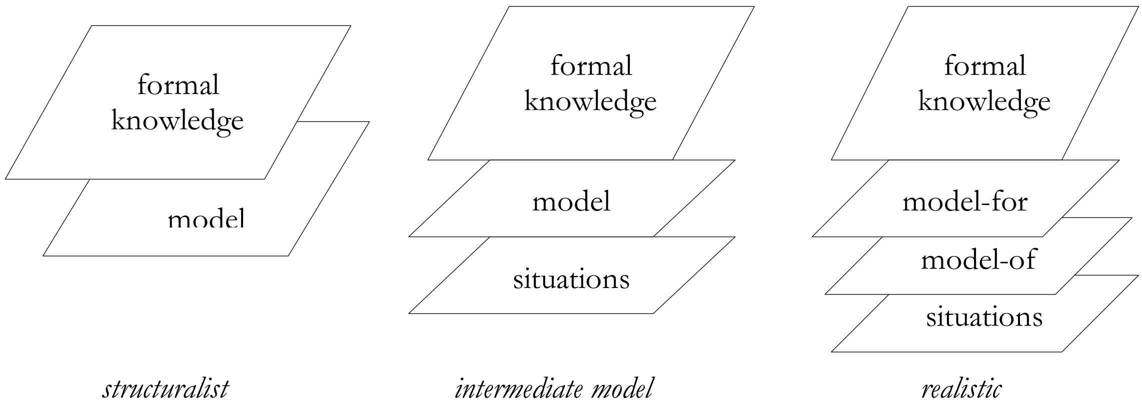
An implication of the didactical phenomenology principle is that the developer/ instructional designer has to provide students with contextual problems taken from phenomena that are real and meaningful for them. But sometimes mathematics educators misunderstand the label 'real' or 'realistic' in RME. They interpret it as referring to a 'really' real objects or situations in the surroundings. Considering this, it is important to notice the next statement from Gravemeijer (1999).

> *'The use of the label 'realistic' refers to a foundation of mathematical knowledge in situations that are experientially real to the students. Context problems in RME do not necessarily have to deal with authentic every-day life situations. What is central, is that the context in which a problem is situated is experientially real to students in that they can immediately act intelligently within this context. Of course the goal is that eventually mathematics itself can constitute experientially real context for the students.'*

3.3.3 Self-developed models

The third key principle for instructional design in RME is *self-developed models* or *emergent models* (Gravemeijer 1994, 1999). This principle plays an important role in bridging the gap between informal knowledge and formal knowledge. It implies that we have to give the opportunity to the students to use and develop their own models when they are solving the problems. At the beginning the students will develop a model which is familiar to them. After the process of generalizing and formalizing, the model gradually becomes an entity on its own. Gravemeijer (1994) calls this process a transition from *model-of* to *model-for*. After the transition, the model may be used as a model for mathematical reasoning (Gravemeijer, 1994, 1999; Treffers, 1991a).

To give a clearer meaning of models, Gravemeijer (1999) differentiates between embodiment and models. He says that embodiment are presented as pre-existing models in product-oriented mathematics education, while models emerge from the activities of the students themselves in realistic mathematics education. Related to this, Gravemeijer suggests that the primary aim of the use of models should not be regarded as something to illustrate mathematics from an expert point of view, but that they should support students in constructing mathematics starting from their own perspective. The next figure illustrates the use of models in three different approaches in mathematics education.



Source: Gravemeijer, 1994.
Figure 3. 5
The process of using models in three different approaches

At the beginning of this section the term *emergent models* was introduced. This term is used by Gravemeijer (1999) to indicate the character of the development of model-of to model-for. An RME model emerges from the informal solutions of the students when they solve the contextual problem. Firstly, the model is used to support informal strategies that correspond with situation-specific solution strategies. After the students experience similar solution procedures, the choice of a strategy is no longer dependent on its relation with the problem situation, but is much influenced by mathematical characteristics of the problem. Here the role of model begins to change because it gets a more general character. Finally the model becomes an entity on its own after a process of reification takes place. Gravemeijer (1999) argues that at this stage the model becomes more important as a base for mathematical reasoning than as a way to represent a contextual problem.

3.4 RME'S TEACHING AND LEARNING PRINCIPLES

The previous section has discussed the important principles in RME for instructional design. Suppose that we have designed curriculum material based on the RME theory, now comes the questions: how should the teaching learning process using this curriculum material be conducted; how should teachers present the curriculum in the classrooms; and how are students supposed to learn from the curriculum material? Related to these questions, Treffers (1991a) proposes five learning and teaching principles namely *constructing* and *concretizing*, *levels* and *models, reflection* and *special assignments, social context* and *interaction,* and *structuring* and *interweaving* (*Note:* in each pair, the learning principle is indicated first). These teaching and learning principles are parallel to five tenets mentioned by de Lange (1987): (1) *the use of real-life contexts*; (2) *the use of use models*; (3) *student's free production*; (4) *interaction*; (5) *intertwining*. The following parts discuss the RME's learning and teaching principles one by one.

1. *Constructing and concretizing*

   The first learning principle of RME is that learning mathematics is a constructive activity, something which contradicts the idea of learning as absorbing knowledge which is presented or transmitted (Treffers, 1991a). On the teaching idea, the instruction should start with a concrete orientation basis. In other words, the instruction has to be emphasized on a *phenomenological exploration* (Gravemeijer, 1994). From phenomena that need to be organized as a starting point, teachers can stimulate students to manipulate these means of organizing.

2. *Levels and models*

   In this principle, the learning of a mathematical concept or skill is viewed as a process which is often stretched out over the long term and which moves at various levels of abstraction (from informal to formal and from the intuitive level to the level of subject-matter systematics) (Treffers, 1991a). Now how to help bridge the gap between these various levels? Using the term *bridging by vertical instruments*. Gravemeijer (1994) advocates that a broad attention has to be given to visual models, model situations, and schemata that arise from problem solving activities because it will help students to move through these various levels.

3. *Reflection and special assignments*

   The third learning principle in RME is related to the raising of the level of the learning process. According to Graveimeijer (1994) and Treffers (1991a) the raising process is promoted through reflection, therefore serious attention has to be paid to a *student's own constructions* and *productions*. On the teaching principle: the students must constantly have the opportunity and be stimulated at important junctures in the course, to reflect on learning strands that have already been encountered and to anticipate what lies ahead (Treffers, 1991a). To realize this principle we have to provide students with special assignments, for example the conflict problems, those that can stimulate students' free productions

4. *Social context and interaction*

   The fourth learning principle is related to the importance of social context, as Treffers (1991a) says that learning is not a solo activity but it occurs in a society and is directed and stimulated by the socio-cultural context. By working in-groups for example, students have the opportunity for the exchange of ideas and arguments so that they can learn from others. This principle implies that mathematics education should by nature be interactive. It means *interactivity* that includes explicit negotiation, intervention, discussion, cooperation and evaluation become very essential elements in a constructive learning process (Gravemeijer (1994)

5. *Structuring and Interweaving*

   The last learning principle is connected to the first principle. According to Treffers (1991a) learning mathematics doe not consist of absorbing a collection of unrelated knowledge and skill elements, but is the construction of knowledge and skills to a structured entity. In addition, Gravemeijer (1994) says that the holistic approach, which incorporates applications, implies that learning strands can not be dealt with as separate entities; instead, an *intertwining* of learning strands is exploited in problem solving. These statements bring us to the teaching principle: the learning strands in mathematics must be intertwined with each other.

3.5 REALISTIC GEOMETRY

As this study is about developing and implementing the RME curriculum for topic geometry, this section discusses *realistic geometry,* which is included in RME theory. Realistic geometry deals with a kind of geometry instruction which differs largely from the well-known deductive geometry (Gravemeijer, 1990). The main focus of realistic geometry is not only to help pupils in grasping space as a goal of geometry itself but also to prepare students for more formal geometry.

There are six important aspects of realistic geometry that are developed for pupils age 4 – 14 namely sighting and projecting, orientating and locating, spatial reasoning, transforming, drawing and reconstructing and measuring and calculating (de Moor, 1991). A brief description of each of these aspects together with the examples of related activities are elaborated below. All figures presented in this section are taken from de Moor (1991)

- **Sighting and projecting**

  This aspect involves some activities with the main theme 'Looking at' (observing, perceiving, representing and explaining spatial objects and spatial phenomena). To perform these activities, some basic concepts are involved such as: point, straight line, direction, angle, distance, parallelism, intersecting and non-intersecting line in space, planes, etc., and also relations between these concepts.
  Many everyday experiences and simple experiments can be a source of sighting and projecting activities as can be seen from some examples given by de Moor (1991):
  - hide and seek and far near experiments (for pupils age 4-6);
  - hold the thumb in front of the eyes and alternately close one eye and then the other, why does the thumb jump from right to left and vice versa? (for pupils age 6-10);
  - when you are walking in the sun your shadow always has the same length. Why? (For pupils age 6-10).

- **Orientating and locating**

  According to de Moor (1991) orientating in every day life simply means that one knows where one is in the surrounding space and that one knows how to get from one point to another. In orientating pupils have possibilities to acquire concepts such as in front of/behind, up/down, far/near, etc. Meanwhile, locating means the (relative) position (and sometimes the time) of an object in a given space. Activities in locating involve drawing routes, maps, blueprints, graphs or spatial models.

- **Spatial reasoning**

  Spatial reasoning can be developed not only through Euclidean geometry, but it is also possible to reason logically (use common sense) without the explicit knowledge of formal logic. We can see this condition from the example in Figure 3.6. Here by using the block construction we can ask students to determine the exact composition of the construction from the given top, front and side view.

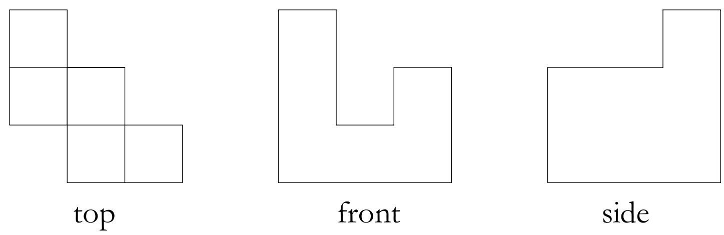


Figure 3.6
How was this constructed?

According to de Moor (1991), in this problem the aspect of reasoning has to do with the activity of combining certain facts because to answer the problem the students need to use 'if-then' logic. It means by working on this kind of problem the students are given the opportunity to use a typical mathematical (scientific) method at a level of their own, namely posing hypotheses, trying them out, refuting them and proving them (de Moor, 1991). The next problem is also useful for developing the spatial reasoning of students in primary education.

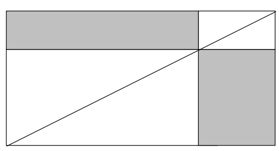


Figure 3.7
Why are the areas of the two shaded parts equal on the figure above?

- **Transforming**
  Transformations such as reflection, rotation and translation are important topics in geometry. However, the presentation of these topics in formal geometry is very deductive so that they only appear in secondary school or higher. In realistic geometry, transformations are presented to students at primary schools in which the skills and concepts are not taught directly or defined explicitly, but they are derived from the reality of our perception by means of adequate contexts and in an informal manner (de Moor, 1991). Many meaningful activities such as symmetry in line and plane, folding, translating, enlargement and reduction, and the use of a mirror can be used to stimulate students understanding about transformations. The next figure shows an example of the use of a mirror.

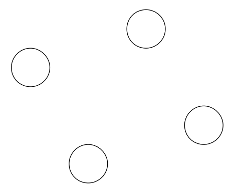


Figure 3.8
Using a mirror, make 8, 7 or 6 dots

- **Constructing and drawing**
  In Euclidean geometry construction means the drawing of figures with a ruler (with no scale) and a pair of compasses only (de Moor, 1991). In realistic geometry the meaning of construction is of broader context, that is fitting together two or three-dimensional figures under certain conditions. This can be realized by performing activities such as constructing blocks, working with cutouts, mosaics, and tangram. The aspect of drawing takes place by drawing on scale, designing pavements, drawing three-dimensional figures and finding locuses.

- **Measuring and calculating**
  Aspect measurement is already included in the origin of geometry, as we can see that the term 'geometry' came from the Greek: 'ge' (earth) and 'metrein' (measure). Here the practical measuring of the lengths, areas or volumes becomes the main focus. In realistic geometry, topic *measurement* is presented in a more informal way in which the use of formulas for measuring of the lengths,

areas and volumes does not become the main priority (see Gravemeijer, 1990). The next principles mentioned by de Moor (1991) for the topic *measuring area* show some important aspects of measurement that have not been touched in traditional geometry.

- The ability to restructure figures in such a manner that children become aware of the idea of conservation of area.

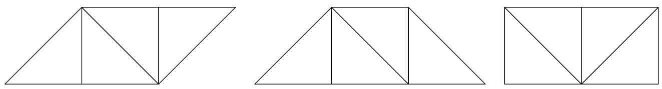


Figure 3.9
Conservation of area

- The replacing of a figure with a certain measure of area with a figure of 2 times, 3 times, ….its area (calculating with area)
- The completion of plane figures to a rectangle

Figure 3.10
Completion of figure

- Relating area of triangles to area of rectangles or parallelograms and vice versa

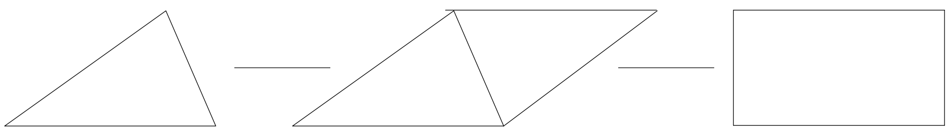


Figure 3.11
Triangle is a half of the rectangle or parallelogram

To end this section, let us see some important directions mentioned by de Moor regarding realistic geometry and its aspects. These were used as a guidance to develop and implement IRME curriculum in this study.

- The aspects of realistic geometry should not be considered as subjects on their own, and therefore not be taught as isolated topics. The various aspects are closely related and this intertwining constitutes the whole: realistic geometry.
- The realistic interpretation of geometry namely as investigation of the space in which we live and the phenomena that occur in it, make it possible to broaden our view of geometry compared with the traditional formalistic view. So, realistic geometry does not resemble individual paper and pencil work, nor is it a matter of the teacher doing the explaining and the pupil imitating the activity.
- Instruction in realistic geometry calls for work to be done in-groups, where investigation, experimentation, discussion and reflection are the core of the teaching learning process.

3.6 THE ROLE OF CONTEXT IN RME

As mentioned in section 3.2, solving the contextual problems is an essential part in RME. Before we talk further about the role of contextual problems, the concept of context will be presented. Then, the differences between traditional story problems and the contextual problems will also be discussed. The term *story problems* used here refer to the work of Figueiredo (1999), meaning all kinds of mathematical problems embedded in a context (story).

Roth (1996) mentions three different issues about 'context'. Firstly, context can relate to additional knowledge that is necessary to understand a mathematical story problem. The context can be the story that embeds the problem or all that goes without saying (does not have to be spelled out). Secondly, context refers to real-world phenomenon that can be modeled mathematically. For example, buying clothes as a physical context for linear equations (see De Lange, 1987). Thirdly, context is related to setting and situation. Setting refers to various physical sites of human activity, even a situation is all that 'surrounds' an activity and is therefore characterized by social, physical, historical and temporal aspects. Figueiredo (1999) says that context in a contextual problem refers to the first or second concept of context because the third one has more to do with social context of the activity of solving contextual problems. Before we discuss the contextual problems in RME, further let us look at the use of context in traditional mathematics.

Context in traditional story problems is frequently meaningless. This condition creates a set of believes, assumptions and strategies which constitute the students in solving story problems (Figueiredo, 1999) as follows:

- students assume that every problem makes sense;
- students do not question the correctness or completeness of the problems;
- students assume there is only one 'correct' answer to each problem;
- students use all the numbers given in the problem;
- students believe that if a mathematical operation works out without a remainder, you are probably on the right track;
- when you do not understand a problem, look at key words or previously solved problems in order to find the mathematical operation.

What Figueiredo mentioned above is in line with the findings from several studies (see Freudenthal, 1991; Reusser, 1988; Schoendfeld, 1989). The results of these studies show that primary and secondary school students ignore familiar aspects of reality, excluding common sense knowledge and everyday life experience when they solve story problems. In addition, Wyndhamn and Säljö (1997) say that, in solving story problems, students seem to follow rules and use symbols without reflecting on the specific context where they are used. They also only focus on the level of syntax of the problem, without paying enough attention to what the problem is really about. This condition is similar to what is found in Indonesian primary schools (see the discussion in Chapter 2 section 2.3).

Because of the meaninglessness of context in traditional story problems, students frequently solve problems without understanding them, they even solve unsolved story problems (see Reusser, 1988; Scoendfeld, 1989). Reusser (1988) gives a nice example for this case, where children were asked to solve the next story problem:

> *There are 125 sheep and 5 dogs in a flock. How old is the shepherd?*

One student answered the question as follow:

> *125 + 5 = 130… this is too big, and 125 – 5 = 120 is still too big…while… 125 : 5 = 25…that works…I think the shepherd is 25 years old.*

We can see that some conditions relating to traditional story problems mentioned by Figueiredo before are found in the student's answer. Here the student assumed that the problem made sense. He or she also used all the numbers mentioned in the problem without questioning the correctness of the problem.

In contrast to those in the traditional story problems, contexts in the contextual problems play a very important role. According to De Lange (1987), the role of context in RME is twofold. Firstly, the start of any sub-curriculum takes place in some real world situation. This real world is not restricted to the physical and social world (see also Gravemeijer, 1999). The 'inner' reality of mathematics or real world of the students' imagination as well provides source for developing mathematical concepts. The second role is in the applications: they uncover reality as source and domain of application. In other words De Lange mentions that the role of context in RME is not only as a source of conceptual mathematixation but also as a field of mathematical concepts. But not all contexts in the story problems can play these important roles. As Figueiredo (1999) argues, in order to allow students to engage in more meaningful story problems practices, the nature of contexts and how they need to be used must be different. For this purpose, Figueiredo mentions that contexts in RME must:

- be easy to imagine and recognize, and be appealing situations;
- be familiar to the students;
- be such that the problem itself can come to the fore out of the described situations;
- demand mathematical organization (progressive mathematization);
- not be separated from the process of problem solving, but it must lead students to arrive at a solution.

Based on the criteria above, contextual problems in RME fulfill a number of functions (see Figueiredo, 1999; Treffers & Goffree, 1985):

- help students to understand the purpose of the problem quickly;
- provide students with strategies based on their own experiences and informal knowledge;
- offer students more opportunities to demonstrate their abilities;
- invite students to solve the problems (motivational factor).

3.7 RME AND RESEARCH TRENDS IN MATHEMATICS EDUCATION

This section briefly discusses RME in relation to other research trends and theories in mathematics education. Based on the explanation presented in the previous section we can see that RME is a theory concerning mathematics education that deals with the following questions:

- What are the contents of mathematics that should be taught, together with a rationale of why those contents are important?
- How do pupils learn mathematics and how should mathematics be taught? (These imply the methods by which teachers should teach mathematics).

In addition, RME also includes a theoretical method of assessing students' learning capacity (see van den Heuvel-Panhuizen, 1996).
The first item above is a very important facet of RME, as other theories in mathematics education do not pay enough attention to this question. So far, theories and researches in the field of mathematics education have paid more attention to learning and teaching methods, while the investigation of *what content mathematics have to be taught* is seen as being the responsibility of curriculum designers/developers.

Although the RME theory was first developed more than 25 years ago, it is aligned with recent theoretical developments in mathematics education. According to Kwon (2002):

> *"A fundamental issue that differentiates RME from an exploratory approach is the manner in which it takes into account both of collective mathematical development of the classroom community and of the mathematical learning of the individual students who participate in it. Thus, RME is aligned with recent theoretical developments in mathematics education that emphasize the socially and culturally situated nature of mathematical activity."*

In RME pupils learn mathematics based on activities they experience in their daily life; pupils have a big opportunity to reinvent mathematical concepts and to construct their knowledge by themselves. These conditions are in line with constructivist theories (see Cobb, 1994; Cobb & Yackel, 1995; von Glaserveld, 1996; Simon, 1995). Gravemeijer (1994) says that the RME theory is compatible with the constructivist theories. Moreover, what de Moor (1991) says about realistic geometry indicates that RME is in line with the ideas of co-operative learning and collaborative learning (see Arends, 1997; Daniels, 1994; Slavin, 1983, 1995, 1997; Strijbos & Martens, 2001). He says that realistic geometry does not resemble individual paper and pencil work, nor is it a matter of the teacher doing the explaining and the pupil imitating the activity. Instruction in realistic geometry calls for work to be done in-groups, where investigation, experimentation, discussion and reflection are the core of the teaching learning process.

Furthermore, the ideas developed in RME are in agreement with the open-approach method developed in Japan (see Nohda, 2000), and they are also found in other sources such as in the project Mathematics in Context (MiC) (NSF, 1997), Everyday Mathematics (see www.sra4kids.com/everydaylearning), the Connected Mathematics Projects (CMP) (see http://www.mth.msu.edu/cmp), and the NCTM standards (NCTM, 1989). The NCTM standards set some new goals for students in learning mathematics namely *learning to value mathematics, becoming confident in one's own ability, becoming a mathematical problem solver, learning to communicate mathematically* and *learning to reason mathematically*. These are also the main intentions of RME, which achieves them through the three key heuristic principles (see section 3.3), and the five learning and teaching principles (see section 3.4).

CHAPTER 4
RESEARCH APPROACH

This study followed two development research approaches. The two approaches are elaborated upon further in section 4.2. The general design of the study is presented in section 4.3, followed by a discussion on the designs for the prototyping and assessment stages. Finally, section 4.4 discusses the evaluation activities.

4.1 INTRODUCTION

This study was about developing and implementing the IRME curriculum for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools. Through the development and implementation processes it was investigated: whether the RME approach could be utilized in Indonesia and the extent to which RME could address some problems in the geometry instruction in Indonesian primary schools. These processes, which took place from 1998 – 2001, were guided by the main research question:

> *What are the characteristics of a valid, practical and effective IRME curriculum for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary school?*

This research question was divided into three sub-research questions in order to keep the focus of the research in each stage of the study. These sub research questions will be outlined in section 4.3. Later on, by reflecting on the process of the development and implementation of the IRME curriculum, the study would come out with *the local instructional theory* for teaching topic Area and Perimeter in Indonesian primary schools and a design guideline for developing RME materials in Indonesia.

4.2 DEVELOPMENT RESEARCH

This study was built upon two "schools of thought" about development 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, 2002; 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, 1994, 1994a, 1999). In this study the two approaches were combined. First, the more generic approach from van den Akker and Richey & Nelson is elaborated upon in section 4.2.1. The FI-approach is discussed in section 4.2.2, and later on in section 4.3 it will be shown that this approach fits within the first approach. Then, the quality criteria of the IRME curriculum developed within the framework of this study are described in section 4.2.3.

4.2.1 The general concept of development research

Development research approach came to the fore because of dissatisfaction in traditional research approaches. As Richey (1997) mentions, the traditional view of research used to be discovery of knowledge, and development was a translation of that knowledge into a useful form in practice. In addition Richey says that a divide often exists between research and practice, either theory is too abstract to guide practice, or practice lacks suitable theory to follow. To some extent this gap is expected to be bridged through development research.

Educational development often takes place in a complex situation under uncertain circumstance, but with high ambition (see van den Akker, 1999; Ottevanger, 2001). So far the traditional research approaches do not address the questions of designers and developers in this field, as it does not usually take into account the complexity, for example the situations in the classrooms. For such situations, these approaches do not always provide sufficient support to design and development effort, as most results of traditional research come only with answers that are often too narrow, too superficial and too late to be useful (van den Akker, 1999). Related to this, van den Akker argues that development research could provide a useful alternative support for the complex situations where needs are diverse, problems ill defined and outcomes of interventions often unknown.

According to Seels & Richey (1994) development research is:

> *"The systematic study of designing, developing and evaluating instructional programs, process and products that must meet the criteria of internal consistency and effectiveness"*

Richey & Nelson (1996) mention that there are two types of developmental research. Type 1 research is the most context-specific type of inquiry and usually takes the form of a case study. In general, this type consists of studies that:

- describe and document a particular design, development, and/or evaluation project;
- emphasize entire models or specific development tasks and/or process;
- determine the effectiveness of instructional product or procedure.

Type 2 research typically addresses the validity and/or effectiveness of an existing or newly constructed development model, process, or technique.
In agreement with this classification, van den Akker (1999) distinguishes two types of development research in a more operational way:

- *Formative research:* research activities are carried out during the entire development process, aimed at optimizing the quality of product as well as generating and testing design principles.
- *Reconstructive studies*: research activities are conducted sometimes during but oftentimes after the development process, aimed at articulating and specifying design principles.

Considering that this study is aiming at developing a high quality IRME curriculum, it may be categorized as formative research or type 1 development research.

Formative research forms a blend of development as well as research (van den Akker, 1999; Nieveen, 1997; Ottevanger, 2001; Richey & Nelson, 1996; Walker & Bresler, 1993). Important activities in this 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) summarize the development and research activities for this type of research as follows:

- *Front-end analysis/ preliminary investigation.*
  According to van den Akker (1999), in this stage we conduct an intensive and systematic preliminary investigation of tasks, problems, and context. This includes searching for more accurate and explicit connections of that analysis with state-of the art knowledge from literatures. Some typical activities that can be done here are: literature review, consultation with experts, and analysis of available documents from previous studies, etc.
- *Prototype development*
  Here we apply the "state of the art knowledge" which is made explicit in a conceptual framework and included in the prototypes. The main characteristic of this stage is the cyclic process, which consists of analysis, design, development, implementation (van den Akker (1999) refers to this as the empirical testing), and evaluation.
- *Summative evaluation of the final products and reflection on the development methodology.*

Following these activities, the study was divided into three stages namely *front-end analysis*, *prototyping stage*, and *assessment stage*. Each of these stages will be discussed in section 4.3.

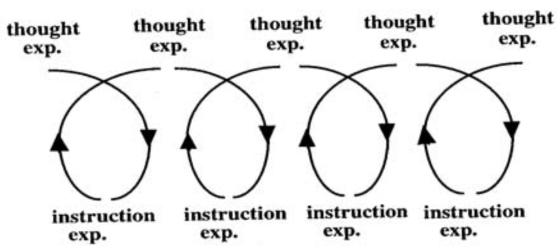
4.2.2 FI-approach for development research

As mentioned in Chapter 1, this study also followed a development research approach developed by mathematics educators in Freudental Institute (FI), the Netherlands (see Freudenthal, 1991; Gravemeijer, 1994, 1994a, 1999). This approach played a very important role in developing the content of IRME curriculum, especially in sequencing the learning routes. The most important thing here is that the approach gave a direction towards developing a local instructional theory for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools (see Chapter 3 and Chapter 5).
Freudenthal (1991, p. 161), in relation to the development of RME, defines development 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"*

If we compare this definition to those mentioned in the previous section, we can see that they are in agreement with each other. The two schools of thought mention that development research consists of two main activities, development and research in which the research process and the development process are merged into one enterprise. During this joint process, development and research can contribute to each other. These activities contribute to two aspects: product improvement and related knowledge growth. In this study it refers to the improvement of the RME-curriculum and to the development of the local instructional theory.

The FI-approach of development research developed within the area of mathematics education. Gravemeijer (1999) says that in this approach researchers direct their attention to developing instructional sequences in learning mathematics. To do so, they start with thought experiment, 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 (see Figure 1.1 in Chapter1) are connected. This situation leads to the description that development can be seen as a cumulative cyclic process, as it is shown in Figure 4.1.



Source: Gravemeijer, 1999.

Figure 4.1
Development research as a cyclic process of thought and instruction experiments

The cycles of the thought and instruction experiment described above indicate the activities carried out on a daily basis in 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 experiment are tested through the second instruction experiment on the next day. This process is continued until the learning sequences, consisting of a number of lessons for teaching a mathematics topic that work well, are developed. The process sometimes leads to the repetition of a lesson (the same lesson is taught in some consecutive days). However, this process could not be fully applied in Indonesian primary schools because the schools have to finish the curriculum on time (because of the centralized system). Considering this reason, the cycles of thought and instruction experiments in this study do not present the daily activities (see the detail in section 4.3).

Based on the explanation in sections 4.2.1 and 4.2.2, and by referring to the work of Nieeven (1997) and Ottevanger (2001), the focus, aims and projected results of the development and research activities in this study can be summarized as follows:

Table 4.1
The development and research activities

Type	**Development Research Type I + FI Development Research**
Main focus	Development of and research on the IRME curriculum (student book and teacher guide) and testing of the characteristics.
Aims	To develop a high quality IRME curriculum that is suitable for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools.
Results	A high quality IRME curriculum Lesson learned about: Characteristics of high quality IRME curriculum. Development process of the IRME curriculum. 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

4.2.3 Quality Criteria

As can be seen from Table 4.1, one of the expected results of this study is a high quality IRME curriculum. It leads to the question, what are the criteria for the high quality? According to Nieveen (1997, 1999), such a curriculum can be assessed on three quality criteria namely *validity*, *practicality* and *effectiveness*. In this study these criteria are defined as follows:

- *Validity* refers to the extent that the design of the intervention should 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.

In clarifying the concept of these quality criteria Nieveen (1999) suggests the use of the typology of curriculum representations proposed by Goodlad, Klein & Tye (1979) and adapted by van den Akker (c.f. Nieveen, 1999). These representations can be seen in Table 4.2.

Table 4.2
The typology of curriculum representations

Curriculum Representation	
Ideal	Reflects the original assumptions, visions and intentions that are laid down in a curriculum document.
Formal	Reflects the concrete curriculum documents such as student materials, teacher guides and policy documents. The combination of the ideal and formal curriculum is called ***intended curriculum***.
Perceived	Represents the curriculum as interpreted by it users
Operational	Reflects the actual instructional process as it realized (often referred to curriculum in action or enacted curriculum).
Experiential	Reflects the curriculum as the students experience it.
Attained	Represents the learning results of the students.

Source: Nieveen, 1999.

Table 4.3 below presents the application of the typology of curriculum representations proposed by Nieveen (1999) in assessing the three quality criteria. This scheme was also suitable for this research. The use of this scheme in assessing the validity, practicality and effectiveness of the IRME curriculum will be elaborated upon in section 4.3.2.

Table 4.3
Assessing the quality criteria using curriculum representations

	Quality Criteria		
	Validity	***Practicality***	***Effectiveness***
Representations	Intended (ideal+formal): - State of the art - Internally consistent	Consistency between: - Intended and perceived - Intended and operational	Consistency between: - Intended and experiential - Intended and attained

Source: Nieveen, 1999.

4.3 THE DEVELOPMENT AND IMPLEMENTATION OF THE IRME CURRICULUM

As mentioned at the end of section 4.2.1, the processes of the development and implementation of the IRME curriculum in this study were conducted in three stages, as presented in Figure 4.1. These processes were realized in a four-year research, which included three field-works in Indonesian primary schools.

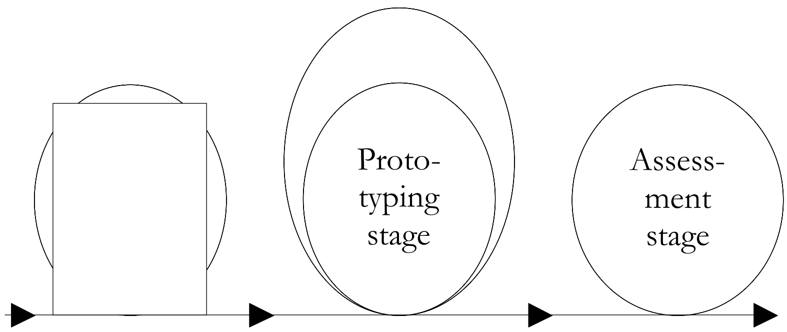


Figure 4.2
The general research design

In the design, the prototyping stage is presented in two cycles to indicate that there were two consecutive prototypes of the IRME curriculum 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. The detail concerning the evaluation activities will be presented in section 4.4.

The next sections discuss each stage of the study, starting with the front-end analysis (section 4.3.1), then the prototyping stage is outlined in section 4.3.2, and finally the assessment stage is presented in section 4.3.3.

4.3.1 Front-end analysis

The purpose of front-end analysis is to get a picture of the starting point and the ending point of the study. The work done in this stage included context and problem analysis, literature review, and analysis of available and promising examples. The main focus of these activities was to collect data and information in order to answer the next questions:

- What are the characteristics of a high quality IRME curriculum for geometry instruction that could promote not only pupils' understanding but also pupils' attitude in learning mathematics?
- How to develop and implement such a curriculum?
- How to support teachers in implementing the IRME curriculum?

The results of this stage were presented in Chapter 2 (see also Fauzan, 1999), and later on they will be discussed further in Chapter 5.

The results of the literature review on the RME theory (will be presented in Chapter 3) gave the direction in how to develop and implement such curriculum material. Considering the timing of this study and its relation to on-going curriculum in Indonesian primary schools, it was decided that the best option would be to develop the IRME curriculum on the topic *Area and Perimeter* for pupils at Grade 4.

In designing the content of the IRME curriculum, the analysis of available and promising examples was done by studying some related documents. The first step was by analyzing the contents of the Indonesian curriculum and textbooks on the topic *Area and Perimeter*, in order to ensure that the IRME curriculum suited the on-going curriculum. The next step was the study of the realistic geometry textbooks developed from the Wiskobas project in the Netherlands (see Gravemeijer, 1994; Klein, 1999; Treffers, 1991). Another document that inspired the development process of the IRME curriculum was 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 roles of all documents mentioned here in designing the IRME curriculum for learning and teaching the topic Area and Perimeter will be discussed extensively in Chapter 5.

4.3.2 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.

The prototyping approach was used in this study because this approach gives the opportunity to develop an IRME curriculum fitting the Indonesian context (see, Goodrum, Dorsey & Schwen, 1993; Nieveen, 1997; Shneiderman, 1992; Tessmer, 1994). Two prototypes of the IRME curriculum 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 consists of a student book and teacher guide. The way that the prototypes were developed followed the approach of *evolutionary* prototyping from Smith (1991) in which, a prototype was continually refined (based on reflections of developers and users on the prototype and formative evaluation results) until the requirements of *the final version* of the IRME curriculum was reached. This final version was investigated in the assessment stage.

According to van den Akker (1999), formative evaluation plays a very important role in development research, especially in formative research because it provides the information that feeds the cyclic process of developers during the subsequent loops of the design and development trajectory. Following this suggestion, several formative evaluation activities were conducted in refining the prototypes of the IRME curriculum. These activities, together with the purposes and methods of the evaluation, will be discussed in section 4.4. The formative evaluations in this study also followed the process as described in Figure 4.1. The latter was mainly focused on developing the local instructional theory for learning and teaching the topic Area and Perimeter.

The next sub sections briefly discuss the prototypes of the IRME curriculum, while the detail regarding the development and implementation of these prototypes will be elaborated upon further in Chapter 6 and 7.

Prototype 1 of the IRME curriculum

Based on the results of the front-end analysis stage, the first draft of the IRME curriculum was designed for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools. This work was followed by a series of discussions conducted with the Dutch RME experts and the Indonesian subject matter experts, during which this first draft was reviewed. The reviewing process consisted of a cyclical process of *experts' review* and *consideration*. The consideration means that the author improved the first draft of the IRME curriculum based on the results of the experts' review. The latter activity resulted in the first prototype of the IRME curriculum that was ready to be implemented in the classrooms. The development and implementation of prototype 1 of the IRME curriculum is summarized in Figure 4.3.

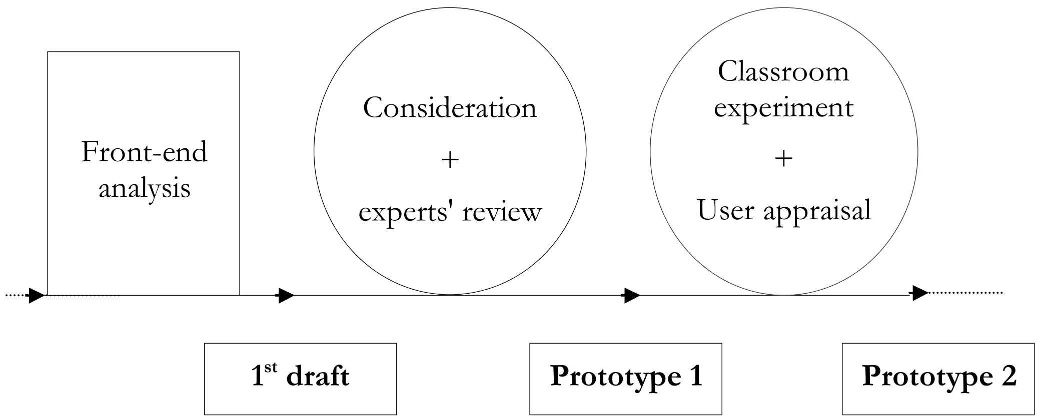


Figure 4.3
The development and implementation of prototype 1 of the IRME curriculum

The main focus of developing prototype 1 was to reach a valid IRME curriculum. This activity was guided by the next research question:

> *What are the characteristics of a valid IRME curriculum for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools?*

Using the criteria of the validity presented in section 4.2.3, the IRME curriculum is considered to be valid if it includes "state of the art knowledge" (content validity) and the various components in the IRME curriculum should be internally consistent (construct validity). The content and construct validity mentioned here referred to the RME theory point of view. The investigation into the content validity of the RME- based curriculum was focused on the following issues:

- Does the content of the IRME curriculum include the subjects/topics that are supposed to be taught for topic Area and Perimeter?
- Does the content of the IRME curriculum reflect the RME's key principles?
- Does the IRME curriculum reflect the RME's teaching and learning principle
- Does the IRME curriculum reflect the important aspects of realistic geometry?

Meanwhile, the construct validity or the internal consistency of the IRME curriculum dealt with the following questions:

- Is the content of the IRME curriculum sequenced properly?
- Are the goals/objectives in each lesson clearly stated?
- Are the relevance and importance of the topics explicit?
- Is the content well chosen to meet the objectives/goals described in the beginning of each lesson?

To reach these criteria, the IRME curriculum was developed by following and considering the RME' key principles, RME' teaching learning principles, some important aspects in realistic geometry (see Chapter 3), Freudenthal's steps for teaching measurements (will be discussed in Chapter 5), and some documents mentioned at the end of section 4.3.1. These factors when applied together shaped the characteristics of the IRME curriculum and played very important roles in the developing of the local instructional theory in this study. The characteristics of the IRME curriculum and the developing of the local instructional theory for learning and teaching the topic Area and Perimeter will be discussed in Chapter 5.

As mentioned, the Dutch RME experts and the Indonesian subject matter experts reviewed the first draft of the IRME curriculum. The reviewing process was focused on the content and construct validity of the IRME curriculum, and it resulted in the first prototype of the IRME curriculum. Prototype 1 of the IRME curriculum was implemented in the classrooms in order to test whether the conjectured learning trajectory worked as intended. It meant that the learning sequence might change if the data from the classroom experiments led to the need for changes. This implied that the validity of the IRME curriculum might have to be evaluated further. This activity took place in the next step of the study as described below.

Prototype 2 of the IRME curriculum

The results of the classroom experiments as described in the previous section led to the development and implementation of the second prototype of the IRME curriculum. The activities that took place in developing and implementing prototype 2 of the IRME curriculum followed the next design.

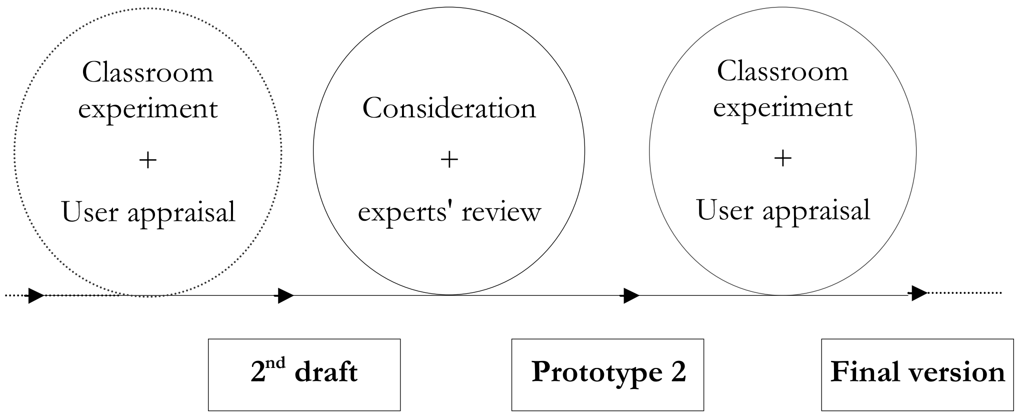


Figure 4.4
The development and implementation of prototype 2 of the IRME curriculum

Prototype 1 of the IRME curriculum was revised by reflecting on the results of the implementation. The outcome of this activity was the second draft of the IRME curriculum. After the validity of the draft was discussed once more with the Dutch RME experts and the Indonesian subject matter experts, it became prototype 2 of the IRME curriculum.

The main focus of the development and implementation of prototype 2 was to investigate the validity and the practicality of the IRME curriculum. 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 IRME curriculum needed to be researched further. The research question for this stage of the study was:

What are the characteristics of a valid and practical IRME curriculum 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 in normal conditions. It means that the IRME curriculum should meet the needs and wishes of pupils and teachers at Grade 4 in Indonesian primary schools. Moreover, the IRME curriculum should be considered by experts to be an appropriate and usable material for learning and teaching the topic Area and Perimeter. In other words Nieveen (1999) says that the practicality takes place if there is a consistency between the intended and perceived curriculum, and between the intended and operational curriculum. The two consistencies were elaborated upon the following questions:

- Has IRME curriculum potential for developing student's understanding?
- Has IRME curriculum potential for developing student's activity and creativity?
- Has IRME curriculum potential for developing student's motivation?
- Has IRME curriculum potential for creating student-centered learning?
- Is the student book easy to use?
- Is the teacher guide useful for teachers?
- Is the teacher guide easy to use?
- Is the time mentioned in each lesson enough?
- Do pupils learn as intended?
- Do teachers use the teacher guide as intended?

The term "as intended" in the last question refers to the RME's teaching and learning principles mentioned in Chapter 3.

Although the main focus of developing prototype 2 was to investigate the practicality and the validity of the IRME curriculum, some effects of using the curriculum in the classroom experiments were also documented (these will be discussed in the next section). The reasons for taking this step, instead of waiting until the IRME curriculum reached the validity and practicality criteria, was because every teaching learning process has an instruction effect on pupils. Besides, the nature of the cyclic processes in developing the IRME curriculum (see the designs above) made it possible to investigate the three quality criteria at the same time. It means, in this study the three quality criteria could not be seen as a strict hierarchy.

4.3.3 The assessment stage

During the prototyping stage, the main focus of the development and formative evaluation activities was on improving the validity and practicality of the curriculum materials. These activities resulted in a final version of the IRME curriculum for learning and teaching the topic Area and Perimeter. Based on the results of those activities in the prototyping stage, it was assumed that the content of the IRME curriculum was valid, and it was also considered to be practical for learning and teaching the topic Area and Perimeter. However, the data that supported the conclusion about the practicality of the curriculum materials were collected from a small number of target users (teachers and pupils), and also the formative evaluation was conducted in a rather informal way. In order to gain further insights about the practicality of the curriculum materials, in this stage the evaluations were conducted with a wider group of target users, in a more formal way. In addition, some of the information regarding the effectiveness of the IRME curriculum that was collected during the prototyping stage involved small numbers of target users. Therefore, in the assessment stage, the evaluation of the effectiveness of the IRME curriculum was conducted in a broader context. The research activities in the assessment stage are presented in the following design:

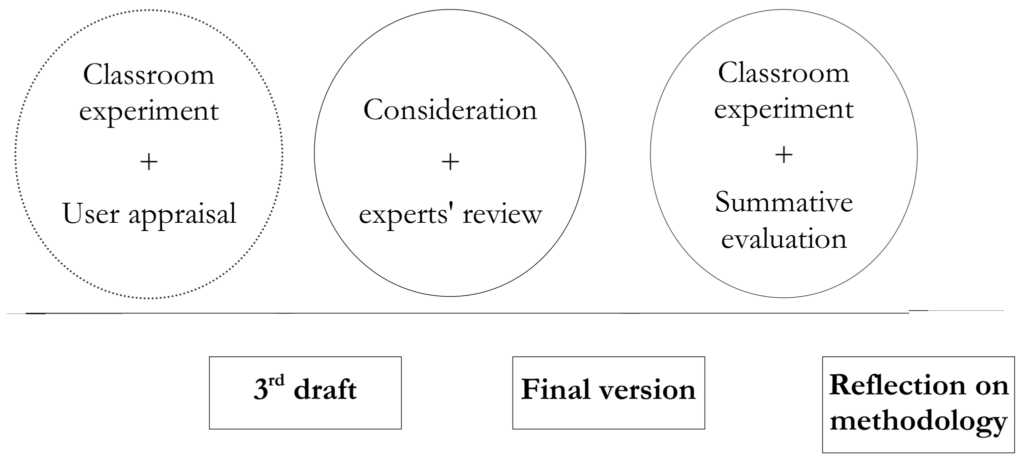


Figure 4.5
The development and implementation of the final version of the IRME curriculum

The research question for the assessment stage was:

> *What are the characteristics of a practical and effective IRME curriculum for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools?*

The IRME curriculum reached the effectiveness criteria if it could give positive impacts to the pupils at Grade 4 in Indonesian primary schools in learning the topic Area and Perimeter. Referring to the criteria mentioned in Table 4.3, the IRME curriculum was called effective if there was consistency between the ideal and experiential curriculum and between the ideal and attained curriculum. These criteria were measured using four of five levels of effectiveness mentioned by Kirckpatrick (1987) and Guskey (1999, 2000) namely *participants' reaction*, *participants' learning*, *participant's 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 IRME curriculum because it was not applicable to this study. The levels of effectiveness in this study were elaborated upon by posing the following questions:

- ***Participants' Reactions***:
  Did the pupils and teachers like the IRME curriculum?
  Was their time well spent?
  Was the IRME curriculum useful?
- ***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?
  What was the impact of the IRME curriculum on the pupils' performance and achievement?

The learning outcomes in this study referred to two aspects: cognitive and affective. The cognitive aspect included pupils' achievement and reasoning, while the affective aspect involved pupils' motivation, activity, and creativity. The RME theory described in Chapter 3 explained that 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 IRME curriculum would increase pupils' achievement. Moreover, in solving a contextual problem pupils are always stimulated to explain "*what do they do and why?*" This requirement was assumed to have potential to promote pupils' reasoning.

Many researches suggest that both cognitive and affective variables should be taken into consideration to describe how students solve mathematics problems (see Boekaerts, 1992, 1995, 1997; Klein, 1998; Schoenfeld, 1992; Vermeer, 1997). Schoenfeld (1992) says that doing mathematics can be viewed as a social activity, with roots in the cultural and social environment. It implies that student's behavior in doing mathematics tasks is strongly influenced by the context of where and how learning takes place. This is in line with Boekaerts (1997) who says that the social and didactical context in which learning takes place plays an important role in how students judge a learning situation or problem posed to them.

As discussed before in Chapter 3, RME is very different from traditional mathematics education. In RME pupils have more freedom in learning mathematics. For example, when solving a contextual problem, pupils may come up with informal solutions or solutions which are different from their teacher's solutions. So, RME gives pupils an opportunity to learn mathematics in the way they like. Therefore it was expected to see differences in appraisals before and after the pupils learned mathematics using RME curriculum. In addition, by providing contextual problems that had more than one correct solution (the principle of students' free production) the pupils were stimulated to be more creative.

The investigation on pupils' activity was based on De Moor (1991) argument about realistic geometry. He says that realistic geometry does not resemble individual paper and pencil work, nor is it a matter of the teacher doing the explaining and the pupil imitating the activity. Instruction in realistic geometry calls for work to be done in-groups, where investigation, experimentation, discussion and reflection are the core of the teaching learning process. Based on this statement it was argued that pupils would become involved actively in the learning and teaching process that used the IRME curriculum.

4.4 THE EVALUATION ACTIVITIES

In this study the author took the roles of developer, researcher and teacher (*note*: four teachers involved in the assessment stage). This situation could cause a bias in forming the conclusions of the study, so this was solved by conducting triangulation. According to Denzin (in Husen, 1994) triangulation is the application and combination of several research methodologies in the study of the same phenomenon. The purpose of triangulation is to overcome the weaknesses or biases of using a single method or single measurement instruments. Denzin says that there are four basic types of triangulation: (1) *data triangulation*; (2) *investigator triangulation*; (3) *theory triangulation*; (4) *methodological triangulation*. In practice the researcher frequently combines one type with the others, which is called multiple triangulation.

Referring to the work of Denzin, three types of triangulation were applied in this study. The first was *data triangulation* in which the data of the same phenomenon, for example the effect of the IRME curriculum on the pupils, was studied in different time*s*, places and from different subjects. The second type of triangulation namely *investigator triangulation* was realized by using multiple sources to evaluate the same phenomenon. For example, the practicality of the IRME curriculum was investigated by interviewing Dutch RME experts, Indonesian subject matter experts, inspector, principals and teachers, and the classroom experiments were also observed by multiple observers. Finally, *methodological triangulation* was applied in this study by combining some methods in investigating the same phenomena. For example, pupils' reaction to the IRME curriculum was evaluated by conducting the interviews with the pupils and the classroom observations.

The following sections discuss the evaluation activities that were conducted during the study in more detail. Section 4.4.1 presents the activities to evaluate the validity of the IRME curriculum, while section 4.4.3 deals with the evaluation of the practicality. Finally, section 4.4.4 outlines the activities in evaluating the effectiveness.

4.4.1 The validity of the IRME curriculum

The validity of the IRME curriculum, including the content and construct validity, and the conjectured learning trajectory, was investigated by conducting a series of interviews and discussions with the Dutch RME experts and the Indonesian subject matter experts. Interview and discussion were chosen because these methods gave more opportunity to investigate the validity of every single part of the content of the IRME curriculum.

The instrument used for the evaluation activities was the interview guideline (see appendix E). To ensure the validity of the data gathering from these activities, the interviews and discussions with the experts in each stage of the study were conducted more than one time. In this case, the improvements made by the author on the IRME curriculum based on the results of the interviews and discussions were discussed again with the experts to gain their agreement.

After the experts had agreed on the validity of the IRME curriculum, the investigation was continued by conducting the classroom experiments to test the conjectured learning trajectory to ascertain whether it worked as intended. Some observers such as the teachers, student teachers and a Dutch RME expert evaluated these activities (this will be discussed in more detail in Chapter 6 and 7). The instrument used for observing the classroom experiments was the observation scheme (see Appendix D) which was developed using the RME characteristics as its basis.

Some activities were conducted in order to gather the good quality data from the classroom experiments. Firstly, the observers (excluding the Dutch RME expert) were trained before conducting the observations. Then, at least two observers observed every classroom experiment. Finally, after finishing the classroom experiments, the teachers, the observers and the author discussed what had happened in the classrooms. The last activity was also conducted to reduce the bias in interpreting the findings because of the conflict of interest of being a teacher, researcher and developer at the same time. In addition, the presence of the RME expert in observing some classroom experiments, and the discussions conducted with two RME experts afterwards also helped to keep the objectivity of the data gathering from the classroom practices.

4.4.2 The practicality of the IRME curriculum

As mentioned in section 4.3.2, the practicality of the IRME curriculum was about the consistency between the intended and perceived curriculum, and between the intended and operational curriculum. To investigate the first consistency, the interviews and discussions were carried out with the Dutch RME experts, Indonesian subject matter experts, teachers, principals, inspector and pupils. The interview guideline for conducting interviews and discussions is presented in Appendix E.

The consistency between the intended and operational IRME curriculum was investigated by carrying out the classroom observations. The activities and instruments used here were similar to those in the previous section. The detail regarding the evaluation activities of the practicality of the IRME curriculum will be discussed in Chapter 6, 7 and 8.

4.4.3 The effectiveness of the IRME curriculum

The effectiveness of the IRME curriculum was evaluated using several instruments. Firstly, the *participants' reactions* were evaluated by conducting the interviews with some pupils and teachers. Then, *the participant's learning* and *the participant's use of new knowledge and skills* were measured using the observation scheme, assessments (see Appendix A), and pupils' portfolios. Thirdly, *the learning outcomes* were evaluated using the pre-tests and post-tests (see Appendix C), motivation questionnaire, pupils' portfolios, assessments and observation scheme. The motivation questionnaire used in this study was developed by Blöte (1993). The detail of the evaluation activities is presented in Table 4.4, while the use of the instruments for the evaluation activities can be seen in Chapter 6, 7 and 8.

Table 4.4
Evaluation activities

	Object Evaluation (What?)	The Purposes of Evaluation (Why?)	Evaluation Activities (Method (How?))	Instruments
PROTOTYPE 1	Validity of the IRME curriculum, focused on the content and construct validity, and developing local instructional theory.	To test the characteristics of the IRME curriculum whether they met criteria as mentioned in section 4.3.2.	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 IRME curriculum.	To assess whether the pupils and teachers found that the IRME curriculum was promising.	Classroom observations, interviews with pupils and teachers	Observation scheme, interview guidelines.
Prototype 2	Practicality of the curriculum materials, Focused on consistency between: Intended curriculum and perceived curriculum, intended curriculum and operational curriculum, intended curriculum and experiential curriculum.	To check whether the learning and teaching process using the IRME curriculum met the criteria described in section 4.3.2.	Interview and discussion with the Dutch RME experts, Indonesian subject matter experts, teachers, principals, inspector and pupils, and classroom observations.	Interview guidelines, observation scheme.
	Validity of IRME curriculum (continued)	To test the characteristics of the IRME curriculum to see whether they met criteria as mentioned in section 4.3.2.	Interview and discussion with the Dutch RME experts and the Indonesian subject matter experts, classroom observations.	Interview guidelines, observation scheme.
	Effectiveness of IRME curriculum in small scale, focused on consistency between: Intended curriculum and experiential curriculum, intended curriculum and attained curriculum,	To gain information regarding the impact of the IRME curriculum on the pupils for each level of effectiveness mentioned in section 4.3.3.	Interview with teachers and pupils, classroom observations, pre-test and post-test, assessments, and analyzing pupil's portfolios.	Interview guidelines, observation scheme, and test and assessment materials.

To be continued

Table 4.4 *(Continued)*

Final Version	Effectiveness of IRME curriculum focused on consistency between: Intended curriculum and experiential curriculum, intended curriculum and attained curriculum.	To gain more insight regarding the impact of the IRME curricu-lum on the pupils for each level of effective-ness mentioned in section 4.3.3	Interview with teachers and pupils, classroom observations, pre-test and post-test, assessments, and analyzing pupil's portfolios. Pre-test and Post-test	Interview guidelines, observation scheme, test and assessment materials, and questionnaire.
	Practicality of the RME-curriculum (continued)	To gain more insight into whether the learning and teaching process using the IRME curriculum met the criteria described in section 4.3.2.	Interview with teachers and pupils, and classroom observations.	Interview guidelines, observation scheme.
	Teachers ability to implement the IRME curriculum.	To gain information as to whether the teachers could implement the IRME curriculum as intended.	Classroom observation and interviews with teachers	Observation scheme, interview guideline.

CHAPTER 5
THE CHARACTERISTICS OF THE IRME CURRICULUM

What characteristics the IRME curriculum should have in order to prove that RME could be utilised in Indonesia and could address some problems in the geometry instruction was the main issue in this study. The characteristics of the IRME curriculum for learning and teaching the topic Area and Perimeter were designed by referring to several sources. The rationale used for designing the characteristics was primarily argumentative. Three aspects, namely pupils' understanding, the applicability of the content, and the guided reinvention principle, were considered as very important aspects in designing the characteristics of the IRME curriculum. 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. By sequencing the learning trajectory in such a way, and by considering the applicability of the content, it is argued in this study that the pupils would learn the topic Area and Perimeter better.

5.1 INTRODUCTION

As mentioned in Chapter 1, one of the aims of this study was to develop a local instructional theory for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools. This chapter discusses the process of developing the characteristics of IRME curriculum as the embryo of the local instructional theory. The chapter begins with the description of the Indonesian curriculum regarding the topic Area and Perimeter (section 5.2). Section 5.3 is about designing the IRME curriculum in which the vision and goals of the IRME curriculum, and the conjectured learning trajectory for learning and teaching the topic Area and Perimeter will be described. The content of the IRME curriculum is presented in section 5.4, while section 5.5 outlines the implementation of the RME key principles in the IRME curriculum.

5.2 THE TOPICS AREA AND PERIMETER IN THE INDONESIAN CURRICULUM

The Indonesian curriculum for primary schools pays only minimal attention to the concepts of Area and Perimeter. The concept of area is mostly seen as "length times width' or counting the square centimeters in a rectangle or square. These conditions give no idea of the concept of area, in its meaning of extent of surface. Nor does it indicate how area is measured (in square units) (see Romberg, 1997). The teaching about Area and Perimeter in Indonesian primary schools are just merely applying formulas (see the examples in Chapter 2).

The topics about Area and Perimeter in the Indonesian curriculum is spread over different grades, as the curriculum follows a spiral approach, (see: www.pkur.pdk.go.id/gbpp_sd and Appendix F). This condition can be seen from the illustration in Table 5.1.

Table 5.1
Topics about Area and Perimeter in the Indonesian curriculum for primary schools

Topic	Cawu	Grade
Comparing and ordering the areas of 2-dimentional geometry objects	I	1
Perimeter of squares and rectangles	II	4
Area of squares and rectangles	II	4
Area of triangles	I	5
Area of parallelograms	I	6

Note: One academic year is divided into trimesters/three Caturwulan (Cawu).

By spreading the topics in this way, most pupils and teachers have difficulty in seeing the connection between one topic and another (see Vignette 3 in Chapter 1). The next criticisms that can be addressed to the Indonesian curriculum for elementary schools regarding topic Area and Perimeter are:

- The goals of teaching the unit 'comparing and ordering area' are not clear, in relation to building an understanding of the concept of area. Here pupils are only asked to choose if figure A is bigger or smaller than figure B, or to determine the smallest/ biggest geometry objects, without asking further explanations which are very important for making pupils aware of the notions of area.

- Not clear why the topic 'areas of rectangles', 'areas of triangles' and 'areas of parallelograms' have to be separated, while areas of triangles are better understood as one-half of area of quadrangles. In this case, if we teach area of rectangles in Grade 4, the pupils then have to wait for two years until they learn about area of parallelograms by which time they may have lost the connection between the areas of the two geometry objects.
- Not clear why the topic 'perimeter and area' has to be separated, while they are interconnected with each other.
- The learning of the topic 'measurement units' is nothing more than remembering the structures such as 1cm = 10mm, 1m = 100cm, or 1 cm^2 = 100 mm^2. Because of that, based on classroom observations, most pupils have no idea of the relative sizes of those measurement units.
- There is some practical work in the curriculum regarding topic Area and Perimeter. For examples, in Grade 3: constructing a new square/rectangle from the smaller squares/rectangles; in Grade 4: measuring geometry objects using a measurement unit. But as mentioned in Chapter 2, many teachers are not willing to make the effort to do the practical work in their instruction because it is time consuming. So, pupils acquire almost all knowledge about Area and Perimeter by memorizing concepts and drilling (applying the formulas).

In contrast to this criticism, the discussion in the following section will show the RME point of view for teaching the topic Area and Perimeter.

5.3 DESIGNING THE IRME CURRICULUM

Two literatures were used as the main sources for designing the content of the IRME curriculum, namely the paper entitled "Reallotment" 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 paper Reallotment reflects the RME theory on teaching the topic Area and Perimeter as developed in the project Wiskobas in the Netherlands (see Freudenthal 1973, 1991; Gravemeijer, 1994; van den Heuvel-Panhuizen, 1996). Meanwhile, the book used in the project MiC was designed based on Gravemeijer's work. The idea of learning and teaching the topic Area and Perimeter described in the sources outlined above is in line with that mentioned in the National Council of Teachers of Mathematics (NCTM) standards (see NCTM, 2000).

Contrary to the traditional mathematics point of view (see section 5.2 and Chapter 2), Gravemeijer (1992) mentions two orientations of the teaching topic Area and Perimeter, namely the *general* and *specific* orientation. The general orientation means that the concept of Area and Perimeter be broadened to other shapes, including irregular shapes and surfaces of 3-dimensional objects. The specific orientation refers to the abilities that are very important for pupils to acquire when they learn the topic Area and Perimeter. For examples, pupils should be able to compare areas of shapes by using reallotment or addition strategies.

The vision and goals of the IRME curriculum were mainly built upon Gravemeijer's ideas and those from the book Reallotment used in the project MiC (NSF, 1997). The sequence of the content of the IRME curriculum was an adaptation of the latter source. The following sections (5.3.1 and 5.3.2) will discuss the vision and goals together with the rationales behind them. Section 5.3.3 presents the conjectured learning trajectory for learning and teaching the topic Area and Perimeter, while the content of the IRME curriculum is presented in section 5.3.4.

5.3.1 The vision of the IRME curriculum

As mentioned in section 5.2 the Indonesian curriculum only deals with the minimal concepts of Area and Perimeter. Reflecting on this situation and referring to Gravemeijer's idea, the vision of the IRME curriculum is to broaden the concept of Area and Perimeter. It is argued in this study that by broadening the concepts of Area and Perimeter to other shapes such as irregular shapes or surfaces of 3-dimensional objects, or to other magnitudes such as weight and costs, pupils will understand the concepts of Area and Perimeter better.

The rationale for the broadening of the concepts is 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. In addition, studying the surfaces of 3-dimentional objects may help to prevent the pupils from misunderstanding the concept of area, as frequently happens that the study of rectangular shapes causes many children to think that area is always the product of two lengths. By relating the concepts of Area and Perimeter to other magnitudes that are familiar to the pupils, it gives them the opportunity to learn the concepts in a more meaningful way. Moreover, it may also help the pupils to realise that the concepts of Area and Perimeter are useful for them in their daily life, so that they become more motivated to learn the topic.

The vision of the IRME curriculum was elaborated further by broadening the concepts of Area and Perimeter through the following aspects:

- *Relating Area and Perimeter to other "magnitudes' such as costs, weight, paint, rice field, cake and fence.*

  The concepts Area and Perimeter are frequently involved in our daily activities. For example, when we talk about the costs for covering the floor with carpet or fencing the garden with a new fence, we need the information about the areas of the floor or the perimeter of the garden before doing the calculation for the costs. Farmers also need to know the areas of their rice fields before deciding on how much seed they will need to buy when they want to plant the rice on their fields. Based on these conditions, in the IRME curriculum it is considered to be important to relate the concepts of Area and Perimeter to other magnitudes such as *costs, weight, paint, rice field, cake* and *fence.* By learning the concepts through contextual problems that pupils are familiar with, it is assumed that pupils will understand the concepts better.
- *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. For example, a triangle or hexagon tile are used as a measurement unit to determine the number of tiles that are needed in a tiling work; a tree has a function as a measurement unit when we are counting the number of trees in a forest.

  Introducing the exchange of measurement units as a counting strategy would be useful for helping pupils to understand:
  - that the measurement units do not have to be the choice of squares as part of standardization;
  - the concept of area as the number of measurement units that covers a surface;
  - the formulas for the areas of squares and rectangles as length times width;
  - the role of measurement units in determining areas: the bigger the measurement units that are used to determine the areas the smaller the number of measurement units that are needed, and vice versa.

- *Investigating the relation between Area and Perimeter*
  According to Gravemeijer (1992), there is a strong belief that Area and Perimeter are directly proportional to each other, in which people think that the bigger the perimeters the bigger the areas, or vice versa. Meanwhile, Romberg (1997) states that a common difficulty regarding perimeter and area is to understand that for a given area, many perimeters are possible, and vice versa. In addition, it is frequently found that pupils mix the concepts of Area and Perimeter. From an observation in a primary school in Indonesia, it was found that some pupils had counted the perimeters to answer the questions about areas. To prevent pupils from this confusion and to invalidate the belief mentioned by Gravemeijer, in the IRME curriculum the concepts of Area and Perimeter are taught consecutively. It is argued in this study that this condition will not only help pupils to understand these concepts better, but also make them aware of the effect that a systematic change in dimension has on Area and Perimeter. The decision to teach the topic Area and Perimeter consecutively was also supported by some mathematics educators (based on personal communication via e-mail with the members of Teacher2Teacher: (see http://mathforum.org/t2t/). The concept of area is not a prerequisite for learning the concept of perimeter, and vice versa. It implies that one can be taught before another. In the IRME curriculum the concept of area is taught before the concept of perimeter.
- *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)*
  Referring to what Romberg (1997) mentioned before, 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. 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 IRME curriculum some geometry activities are involved such as *re-shaping*: cutting a figure into pieces and reallocating these pieces to get another shape; a shape of which it is easier to find the area (Gravemeijer, 1992), and *tessellation*. Re-shaping is considered as an important activity in the IRME curriculum 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. Besides, we use re-shaping in many activities of measuring areas in our daily life, for example in measuring irregular or circular shapes. 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.

5.3.2 The Goals of the IRME curriculum

In relation to the vision as described in the previous section, the goals of the IRME curriculum were developed. The goals were built upon the Gravemeijer's idea mentioned in the paper *Reallotment* (1992), and focused on certain abilities that are important for pupils to acquire when they are taught the topic Area and Perimeter. These goals are defined as follows:

1. At least pupils will be able to compare areas of shapes by:
   - tracing, cutting and pasting,
   - using grid paper (counting the number of grids + approximation),
   - using reallotment strategy.
2. In a higher level, pupils will be able to
   - determine the areas by using the formulas,
   - interpret the areas of triangles as a half of the areas of rectangles/ parallelograms,
   - understand the concept that areas of rectangles and parrallelograms will be the same if they have the same lengths and heights
   - determine areas using addition and substraction strategy.
   - understand the effect of the systematic changes on the Area and Perimeter

These goals are elaborated upon further in each unit in the IRME curriculum (see Appendix A).

5.3.3 The conjectured of the learning trajectory for the topic Area and Perimeter

This section presents the conjectured learning trajectory (see Gravemeijer, 1994, 1999), which describes how the content of the IRME curriculum is designed and sequenced so that pupils would learn the topic Area and Perimeter as intended according to RME point of view. After the cyclical processes of the implementation of the IRME curriculum in the classrooms and formative evaluations (see Chapter 4), the conjectured-learning trajectory would become a local instructional theory for learning and teaching the topic Area and Perimeter in Indonesian primary schools.

The content of the IRME curriculum was designed based on the vision and goals as mentioned in the previous sections. It implies that all the contextual problems in the IRME curriculum were designed based on the aspects presented in sections 5.3.1 and 5.3.2. The rationale for choosing the contextual problems in the IRME curriculum will be elaborated upon further in section 5.3.4.

As mentioned before, the sequence of the content of the IRME curriculum was an adaptation of the book Reallotment (see NSF, 1997). The sequence was based on the Fredudenthal's steps for teaching measurement, which are also in line with the NCTM standards (2000). Freudenthal (cf. Gravemeijer, 1992) says that there are six steps that have to be followed when we want to design and/or teach about measurement namely *comparing, ordering, combining two non-standard measurement units, using one non-standard unit, using one standard unit,* and *application.* These steps are in a hierarchical order. However, in practice we may combine one step with others. For example, we can compare the areas of two shapes by comparing the number of measurement units that cover each shape.

When we analyse the order of the steps then we can see here the intention of the guided reinvention (see Chapter 3). Besides, the steps are also suited to the phenomena of measurement activities in our daily life, in which we will find that the hierarchical order of the steps tends to be self-evident. This was the main reason to apply the steps to the designing of the conjectured of the learning trajectory for the topic Area and Perimeter in the IRME curriculum. The following parts will discuss each of Freudenthals'steps and the rationale behind them.

Comparing

The idea about measurement in reality starts with comparing. For example, when we ask a pupil to take one of two pieces of cake (see figure above), then his or her mind and eyes seem to be automatically comparing one piece of cake to another. It means that the idea such as one is bigger/smaller than the other, or one is better than the other will come to the fore. Although when we only see one piece of cake, our mind will refer to our previous experiences to say something about the piece of cake, based on a certain category of measurement.

Ordering

When the number of pieces of cake is more than two, e.g. there are three pieces of cake, then the same situation occurs in our mind as mentioned before. Our mind will compare the three pieces, and at the end we will come to conclusions, for example: one piece is the biggest, one is the smallest and the other one is in between. What happens here is that we are ordering the object that we observe using certain categories of measurement.

Combining two non-standard measurement units

The need for measurement units occurs naturally when we deal with measurement activities in our daily life. One finding of this study that will be discussed in Chapter 7 proved this assumption. The finding showed that pupils used the grids on their exercise book to compare the areas of two shapes while they had not learnt about measurement units yet. At that time pupils were supposed to use other strategies such as tracing, or cutting and pasting to compare the areas of the shapes. However, a group of pupils had the idea to place the holes (which resulted after they had cut out the figures of the shapes) over the top of the grids (on their exercise book) and then to count the number of grids covered by the holes. These pupils used that strategy because they needed a point of reference (a measurement unit) to compare the two shapes.

The idea of using two different non-standard units is found in many cases in our daily life. For example, people used their feet and arms to measure length, before the standard measurement units were developed.

Using one non-standard unit

When we see the pattern of a tessellation on the floor or the pattern of the figures on wallpaper, and when our mind starts counting by iterating the number of the tiles or figures, it means that we use the tile or figure as a measurement unit. Using non-standard units for measurement activities will give pupils a strong basis in understanding the standard measurement units. Besides, it also helps pupils to realize that results of measurements are never exact. In measuring areas, the use of non-standard measurement units such as a triangle or hexagon tile, will make pupils aware that a measurement unit is not only squares.

Using a standard measurement unit

The change from the use of non-standard to standard units is because of the following reasons:

- The need to have more accurate results of measurement activities.
- The development of using tools for measurement.
- The results of measurement should be interpreted in the same meaning and should be acceptable everywhere.

One important aspect in using the standard measurement units for measurement is *refinement*: the changing from one standard measurement unit to another. The refinement becomes very important because of the practical reasons. Measurement activities in our daily life deal with many different objects that have different sizes. Sometimes we need to relate or to compare a result of one measure to another. In this case, we need an understanding about the refinement of measurement units.

Application

This step is related to the idea of applying the measurement activities in interpreting the phenomena in our everyday life. For example, we can apply the concept of area to reason about a population density in one region.

From the explanation above, we can see that the Freudenthal's steps suit the phenomena about measurements in our daily life. By sequencing the topic Area and Perimeter using these steps, pupils were expected to understand the concepts involved in the topic better. The role of the steps in the IRME curriculum is elaborated upon_further in the following section.

5.4 THE CONTENT OF THE IRME CURRICULUM

The term *IRME curriculum* includes both the approach and the materials (teacher guide and student book). The approach refers to the ways the IRME curriculum was designed and implemented in the teaching learning process which are based on the RME theory. Meanwhile, the materials involve *the teacher guide*: a guide provided for teachers to teach the topic Area and Perimeter in the classroom practices, and *the student book*: a book that contains a number of contextual problems provided for pupils. By working on the contextual problems pupils are expected to learn the topic Area and Perimeter as intended.

Based on the vision and goals of the IRME curriculum, the Freudenthal steps for teaching measurement, and also the time available for the classroom experiments in the Indonesian primary schools, five units for learning and teaching the topic Area and Perimeter were designed. The units were *the size of shapes, area 1, area 2, measuring area,* and *perimeter and area*. The remainder of this section describes the content of the teacher guide (section 5.4.1) and student book (section 5.4.2). In the latter, each unit will be discussed further.

5.4.1 The teacher guide

In order to support teachers so that they will be able to teach the units in the IRME curriculum as intended, several components were designed for the teacher guide (see Appendix A). The components were designed by referring to the unit *Reallotment* in the project MiC (see NSF, 1997).

a. *Goals*: describes the goals that need to be achieved in teaching a unit. These goals are a refinement of the general goals mentioned in section 5.3.2.
b. *Pupils' activities*: describes the intended activities the pupils should perform during the teaching learning process in order to achieve the goals. These activities are designed based on the RME's learning principles (see Chapter 3).
c. *Pacing*: indicates the time that is needed to teach one unit.
d. *About the mathematics*: explains the important mathematics concepts involved in a unit. This part also explains why the concepts are important, and how one concept relates to others.
e. *Materials*: describes the materials, tools, or media needed for the teaching and learning processes.

f. *Homework*: contains the contextual problems that have to be solved by pupils as homework .
g. *Planning assessment*: contains the contextual problems that will be used to assess pupils' achievement after they have been taught a unit.

As mentioned in the previous section, there are five units in the IRME curriculum. These units are divided into ten lessons: *the size of shapes* (2 lessons)*, area 1* (3 lessons)*, area 2* (3 lessons)*, measuring area* (1 lesson)*,* and *perimeter and area* (1 lesson). In each lesson there are explanations about *the overview of the lesson*, *materials*, *about the mathematics*, and *planning instruction*. The planning instruction describes the intended approaches or activities the teachers should perform in the teaching learning processes. These approaches or activities are constructed based on the RME's teaching principles.

The teacher guide also contains the student book and the comments about the contextual problems. The comments for a contextual problem vary between one and the others, but they mostly include: the hints that the pupils may need, the different possible solutions of the contextual problems, a follow up that teachers may do based on the solutions of the pupils, or warning for teachers regarding unexpected answers from the pupils.

5.4.2 The student book

The student book (see Appendix A) contains a number of contextual problems that are sequenced in ten lessons based on the vision and goals of the IRME curriculum, and Freudenthal's steps. Part of the contextual problems in the IRME curriculum for learning the topic Area and Perimeter were created by the author, while the rest were adopted from and inspired by some resources such as: the paper Reallotment (Gravemeijer, 1992), the book Reallotment in the project MiC (1989), the Wiskobas Bulletin (ter Heege & de Moor, 1977, 1978), and the article Realistic Geometry (de Moor, 1991).

The way the content of the IRME curriculum is sequenced is adapted from the book Reallotment used in the project MiC. Both follow Freudenthal's steps, which are ordered based on the intention of reinvention principles. Nevertheless, there were some differences between them such as:

- The number of topics in the IRME curriculum was less than those in the Reallotment book. Some topics such as the relation between perimeter, area and volume, and measuring using metric units were not included in the IRME curriculum.
- The content in the IRME curriculum was also more restricted. For example, topic about tessellation was not explored widely, while topic perimeter only discussed perimeter of squares and rectangles. The main reason for restricting the content of the IRME curriculum was because of the time constraint (it was not possible to interfere in the school for a long period) and to make the content more relevant to ongoing curriculum in Indonesian primary schools.

The following parts discuss each unit in the IRME curriculum for learning the topic Area and Perimeter. The conjectured-learning trajectory discussed in section 5.3.3 is elaborated upon further in these parts. Moreover, the reasons behind the design of the contextual problems are also explained explicitly.

Unit 1: The Size of shapes

This unit was about comparing, ordering, and estimating the sizes of various geometry shapes. The goals that needed to be achieved through this unit were that pupils would be able to:

- Compare the areas of shapes using a variety of strategies and non-standard measuring units.
- Estimate and compute the areas of geometric figures.
- Estimate and compute the prices of things by using area comparison.

Following the steps mentioned by Freudenthal in the previous section, and the orientations proposed by Gravemiejer (see section 5.3), the unit begins with comparing the areas of real objects that have irregular shapes such as cakes, rice fields and forests. The unit also relates the concept of area to various magnitudes such as cakes, paint, prices, tiles, rice fields, and forests, and includes some geometry activities such as tessellation, re-shaping, and adding and subtracting between shapes.

The main intention when designing the content of the unit was to give the opportunity to the pupils so that they could use their informal knowledge of specific situations in solving the contextual problems. The specific situations mean situations which are experientially real that the pupils can immediately act upon and reason sensibly in those situations. The reasons for choosing the irregular shapes taken from pupils' daily life are not only to show them that the concept of area mostly deals with irregular shapes, but also to make them aware of the idea of approximation (measurement is never exact) and compensation. For example, the first contextual problem in lesson 1 (see Appendix A) asks pupils to compare two pieces of cake that are almost similar in area. The first piece of cake is longer, while the second one is wider. This condition stimulates pupils to think about the idea of approximation and compensation. They would think about: how much longer is the first piece of cake than the second one, and how much wider is the second piece than the first one; what will happen if the longer part of the first cake is cut then put on top of the wider part of the second cake?

Although the pupils work in this unit on various notions of areas such as determining: the bigger cakes, the forest that has more trees, the rice field that produces more rice and the prices of tiles, the term *area* itself is not introduced yet. Nevertheless, the concept of *area* – the number of measuring units needed to cover a shape- is implicitly introduced. The mathematical term *area* is introduced in unit 2 after pupils have experienced filling the interior of a two-dimensional shape. From here we can see that RME gives pupils the opportunity to learn the concept of area informally, even without ever mentioning or using the term "area".

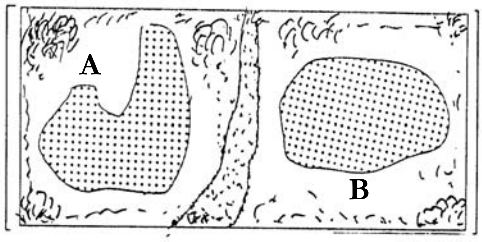
Through this unit pupils develop and use various strategies such as cutting & pasting, counting, using non-standard measurement units, and reallotment, to compare the areas of different-sized shapes. The strategies pupils use are not only important in developing their understanding of area and their ability to determine area, but also to give them a foundation that would help them to better understand how formal area formulas are derived. The following paragraphs describe the usefullness of those strategies.

The simplest strategy for comparing the size of two shapes is by tracing one shape then putting it on top of the other, or cutting one shape then putting it on top of the others, to see whether or not it can cover the other shape. This activity is useful in helping pupils to grasp the idea about area and to make them aware of the idea of approximation and compensation as explained before. Moreover, this strategy is also useful in developing pupil's critical thinking because after putting one shape on top of the other they have to argue about the shape that has more area by observing carefully the parts that are not overlapped.

Pupils also use several non-standard units of measurement such as dots, object patterns and tiles, to compare the area of shapes (they estimate or count the numbers of dots or objects in two or three shapes). The use of the non-standard units would broaden the pupils' knowledge of the notions of area especially in realizing that the area is not only the matter of length times width or the number of square units that cover a shape. Through the following example (contextual problems 2 in Appendix A) we can see the role of using non-standard measurement units in helping pupils to understand how formal area formulas are derived.

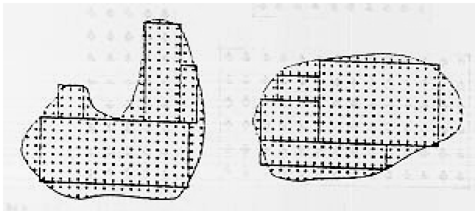
Rice fields

The figure below shows two ricefields separated by a road. Both rice fields are planted with the same rice and they are given the same fertiliser. The dots on the figure represent rice clusters. Use the worksheet to determine which rice field produces more rice?



Source: Mathematics in Context, unit Rreallotment, 1997.

Although this problem could be solved using cutting and pasting strategy, the dots on the shapes would stimulate pupils to use counting strategy. This contextual problem challenges pupils to find the number of dots in each shape without counting them one by one. The challenge leads them to use the counting strategy as it shown in Figure 5.1.



Source: Mathematics in Context, unit Rreallotment, 1997.

Figure 5.1
Counting the dots efficiently

Another important aspect of the first unit in the IRME curriculum is that pupils should develop an understanding of the concept of *reallotment*, 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 tesselations, pupils will better undertand 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.

Gravemeijer (1992) differentiates the reallotment into types: local reallotment (Figure 5.2a) and global reallotment (Figure 5.2b)

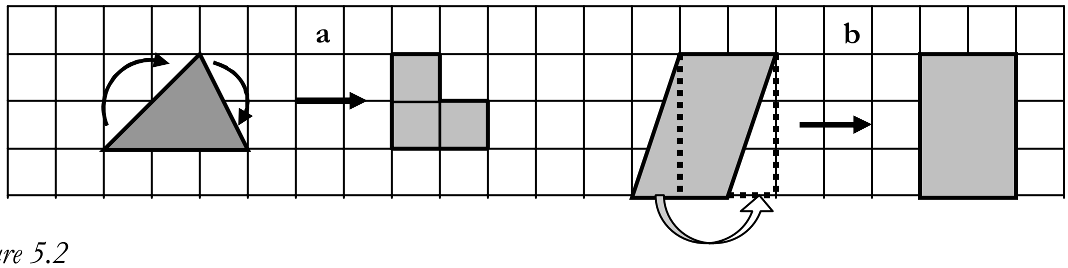


Figure 5.2
Local and global reallotment

From Figure 5.2b we can see that this kind of problem gives the direction for pupils to understand that the area of a rectangle and parallelogram that have the same base and height will be the same.

Based on the explanation about the content and the activites that the pupils perform in the first unit of the IRME curriculum, we can summarize the usefullness of the unit as follows:

- Giving the opportunity to the pupils to learn the concept of area informally
- Encourage pupils to focus on the concept of area;
- Develop critical thinking and reasoning of the pupils because they have to explain their strategies and answers;
- Stimulate pupils' activity and creativity because they have more opportunities to solve mathematical problems using their own ideas. These opportunities also give more confidence to pupils in learning mathematics.
- Stimulate pupils to solve the contextual problems because they are working with those that they are familiar with.
- Making pupils aware of the various notions about area, and that area is not only using formula or counting the number of square units that cover a shape.

Unit 2: Area 1

The goals of this unit are to guide pupils to:

- understand which measurement units that are appropriate to estimate and to measure the area;
- find the concept of area as the number of measurement units that are needed to cover a shape.

However all the ideas involved in unit 1, such as dealing with irregular shapes, reallotment strategies, relating the concept of area to other magnitudes, were still continued in this unit. Further, pupils would also have the opportunity to use other strategies in determining the areas such as: subtraction; constructing a grid; relating one problem to another; or dividing one shape into a series of smaller rectangles and triangles, calculating the areas of these smaller shapes, and sometimes adding areas to equal the shaded area.

To achieve the first aims mentioned above, pupils would work on some contextual problems that give them the opportunity to experience several non-standard measurements. This activity would help them to understand not only the measurement units that are appropriate to estimate and to measure the area but also the concept of area as the number of measurement units needed to cover a shape.

The activities the pupils perform to create rectangles or squares using small square units will enhance pupils understanding of the concept of area and the formula for finding the areas of those objects. Besides, this activity will also help pupils to realize that objects that have the same areas may be different in shape. Later on, this understanding will lead pupils to be aware that shapes that have the same areas may have different perimeters.

In unit 2, the pupils would also deal with the contextual problems that lead them closer to discovering a method or formula to find the area of a triangle. The formula itself will be introduced in lesson 8. It is important that the pupils see that the area of a right angled triangle is exactly one-half of the area of a rectangle that has sides of the same lengths as is shown in the following figure. By dividing the figure into two smaller triangles (at the same time we also divide the rectangle that encloses the triangle into two smaller rectangles) we can see that the area of each smaller triangle is a half of the area of a smaller rectangle. It implies that the area of the original triangle is half of the area of that of the rectangle that enclosed it.

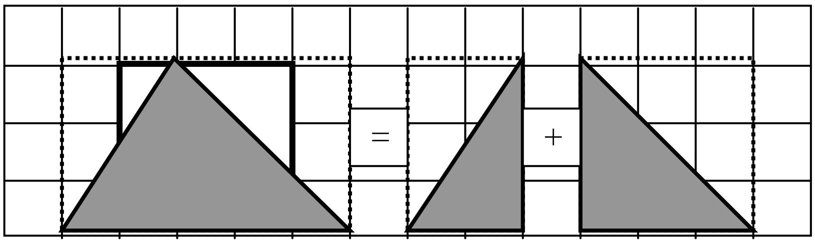
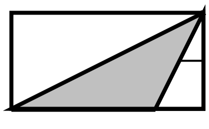


Figure 5.3
The area of a triangle as a half of the area of a rectangle

The area of the shaded triangle can also be found directly by subtracting the unshaded areas from the total area of the rectangle. However, it should be remembered that the statement *the area of a triangle is one-half of the area of the enclosing rectangle* is not always valid, as we can see from the following figure:



It was argued in the IRME curriculum that by experiencing this kind of contextual problem, pupils would better understand the area of triangles.

Unit 3: Area 2

This unit aims at giving pupils experiences so that they will be able to generalize formulas and procedures for determining the areas of rectangles, squares, parallelogram and triangles. To achieve this aim pupils will perform various activities such as:

- Transform a parallelogram into a rectangle in order to find its area. They use different strategies to reshape a parallelogram, such as cutting and pasting one triangular section of the parallelogram to make a rectangle.
- Create a rectangle or parallelogram by doubling a triangle and create parallelograms from a rectangle.
- Create different shapes having equal areas.

The strategies for estimating and calculating area that pupils develop in unit 2 are made more explicit in this section. The areas of rectangles, triangles, parallelograms can be found with counting, realloting, and subtracting strategies. The use of base and height measurements leads to formulas for the areas of rectangles, triangles, and parallelograms. To derive the formula for the area of a parallelogram from the area of a rectangle, several strategies can be used, such as reshaping by cutting and pasting or shifting. The area of triangle can be found with a subtraction strategy or by halving the area of a corresponding rectangle or parallelogram.

The areas of most parallelograms can be found using the compensating strategy: cutting and pasting triangular sections of the parallelogram to reshape the figure into a rectangle, as it was shown in Figure 5.2b. Sometime we need to do these tasks twice, but the strategy of framing the parallelogram within a rectangle and subtracting the remaining parts can always be used.

In one of the activities pupils in this unit would show that a diagonal of a rectangle or parallelogram divides the rectangle or parallelogram into two congruent triangles (see contextual problem 2 in unit 3, Appendix A). Therefore every triangle can be considered as half of a rectangle or parallelogram. This activity illustrates one of the properties of area: no matter how a shape is rearranged, the area of the shape remains the same. Pupils may be aware that the height and base of each figure in this activity also remain the same. However, it is more important for pupils in this unit to understand the concept of area as it relates to rectangles, parallelograms and triangles than to use rules or formulas for finding the areas of these shapes.

Unit 4: Measuring Area

The goals of this unit were to guide pupils to understand:

- The units and tools that are appropriate to estimate and measure Area and Perimeter.
- The structure and use of standard system of measurement.

The development of points of reference for measurement units is very important for pupils. They should have an idea about the relative sizes of one centimeter, one meter, etc., in order to estimate the sizes of objects and to convert between one unit and the others. For example, if pupils have points of reference for one meter and one centimeter, they can estimate that there are 100 centimeters in one meter. Realistic problems presented in this unit would also help pupils to investigate the relationships among measurement units.

Another important point in this unit is to make pupils aware of the concept of measurement units for area. It is frequently found that teachers tell pupils that 1 square centimeter is the result of 1 centimeter times 1 centimeter, or 12 square centimeter is a result of 3 x 4 and centimeter times centimeter, when they teach about measurement units for area. However, it does not make any sense for pupils to multiply centimeter by centimeter. To prevent the pupils from this situation, they need to experience creating several different shapes using standard measurement units. For example, by asking pupils to create a rectangle that has an area of 12 square centimeters, they would realize that they need 12 units of 1-centimeter square to perform this task.

Unit 5: Perimeter and Area

Through this unit pupils are expected to be able to:

- Find the formulas for determining perimeter of a square and rectangle.
- Analyse the effect of systematic change in dimension on Area and Perimeter.
- Use the concepts of Area and Perimeter to solve realistic problems.

In this unit the concept of perimeter was introduced in the same way as that for the concept of area. Using the contexts such as trails and fences the pupils performed the activities that would help them to understand and keep focussed on the concept of perimeter. In contextual problems 4 and 5 unit 5 (see Appendix A), pupils would find that figures with identical perimeters could have different areas and that figures with identical areas could have different perimeters. One important activity in this unit (through contextual problem 6 in Appendix A) would also be useful to prevent the pupils from the common misconception that Area and Perimeter are directly proportional. Finally, this unit also discusses the perimeters of some real objects that lead pupils in finding the formulas for the perimeters of squares and rectangles.

5.5 THE IMPLEMENTATION OF RME'S KEY PRINCIPLES IN THE IRME CURRICULUM

The IRME curriculum was designed based on the RME approach. So that it reflects three key principles of RME: guided reinvention and progressive mathematizing, didactical phenomenology and emergent models (Gravemeijer: 1994, 1999). The following sections describe how these principles had been applied in the IRME curriculum.

5.5.1 Guided reinvention through progressive mathematization

The role of guided reinvention principle was reflected in the activities that were provided for the pupils in solving the contextual problems. In this case, the pupils were given the opportunity to experience the processes of discovering the geometry concepts involved in the IRME curriculum by themselves. For example, before the pupils construe the concept of area as the number of measurement units that cover a shape, they experienced how to solve a series of the contextual problems that lead them to construe the concept. Firstly, they were working on the contextual problems that could be solved using their informal knowledge (see contextual problems 1 and 2 in unit 1, Appendix A). At this stage the pupils dealt with the concept of area intuitively. Then, they solved the contextual problems that involved measurement units (see contextual problems 3 - 5 in unit 1, Appendix A). These problems stimulated the pupils to use counting strategy (to mathematize the problems). Finally, the pupils created the shapes using the small square units (see contextual problems 10-15 in unit 2, Appendix A) that helped them to undersatnd the concept of area.

5.5.2 Didactical phenomenology

Based on the vision discussed in section 5.3, we can see that the principle of the didactical phenomenology was applied in the IRME curriculum. By broadening the concepts of Area and Perimeter in such a way, it implied that all the contextual problems in the RME-based curriculum should be designed based on certain phenomena that are meaningful for the pupils. Moreover, the explanation in the previous section also indicated that the contexts in the contextual problems not only have to be meaningfull but also have to give the pupils the opportunity to mathematize them. This condition is in line with the intention of the didactical phenomenology mentioned by Gravemeijer (1994, 1999). He mentions that the goal of a phenomenological investigation is to find contextual problems for which a situation-specific approach can be generalized, and to find contexts that lead to similar solution procedures that can be taken as the basis for vertical mathematization.

5.5.3 Emerging models

The grid (counting the number of squares in a grid) may be used as the model for learning about area in the IRME curriculum. At the beginning counting squares in a grid comes to the fore as a model of iterating some measurement units such as dots, trees and tiles. Later, counting squares in a grid starts to function as a model for reasoning about the areas of various shapes such as square, rectangle, triangle and parallelogram. In this case the formulas of these shapes will be understood on the basis of the imagery of constructing a measurement unit and a grid on the basis of that measurement unit, and counting the number of the measurement units in that grid in an efficient manner (via repeated addition or multiplication)

CHAPTER 6
PROTOTYPE 1 OF THE IRME CURRICULUM

This chapter presents the development and implementation of prototype 1 of the IRME curriculum. First, the research question and the summary of the evaluation activities are presented in section 6.2. Then, the development process from the first draft into prototype 1 of the IRME curriculum is described in section 6.2. Section 6.3 discusses the implementation of prototype 1 in two primary schools in Indonesia. Finally, section 6.4 presents some conclusions and the implication to the next stage of the study.

6.1 INTRODUCTION

The first draft of the IRME curriculum was designed based on the results of the front-end analysis stage. The characteristics of the first draft can be seen in Chapter 5. After the first draft was improved based on the results of the discussions and interviews with the Dutch RME experts and Indonesian subject matter experts, it became prototype 1 of the IRME curriculum. This chapter discusses the development of the first draft into prototype 1, followed by the implementation of prototype 1 of the IRME curriculum in the classrooms.

The focus of the study in this stage was to investigate the validity of the IRME curriculum. The investigation involved two main activities: expert validation of the characteristics of the IRME curriculum and the testing of these characteristics through classroom experiments. The two activities were guided by the following research question:

What are the characteristics of a valid IRME curriculum for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools?

Nevertheless, some aspects of the practicality and effectiveness of the IRME curriculum were also evaluated in this stage. The main aim of this activity was to get the first impression on the pupils' reactions when they were taught using the RME approach. The evaluation of these aspects was performed in a rather informal way in this stage of the study. The evaluation activities that were conducted in developing and implementing prototype 1 of the IRME curriculum are summarized in Table 6.1.

Table 6.1
The evaluation activities for the development and implementation of prototype 1

Object Evaluation	Data Collection (Method)	Instruments
The validity of the IRME curriculum: ▪ *Validating the characteristics/content and construct validity* ▪ *Testing the characteristics*	Interview and discussion with the Dutch RME experts and Indonesian subject matter experts, classroom observations, analyzing pupil's portfolios.	Interview guideline, observation scheme.
The practicality of the IRME curriculum: ▪ *Is the student book easy to use?* ▪ *Do pupils learn as intended?* ▪ *Is the time mentioned in each lesson enough?*	Interview and discussion with Indonesian subject matter experts, teachers and pupils, and classroom observation.	Interview guideline, observation scheme.
The effectiveness of the IRME curriculum: ▪ *Did the pupils like the student book?* ▪ *Was their time well spent?* ▪ *Did the IRME curriculum affect pupils' understanding, reasoning, activity, creativity, and motivation?*	Interview with teachers and pupils, classroom obser-vation, analyzing pupils' portfolios, and post-test.	Interview guide-lines, observation scheme, and test material.

6.2 THE DEVELOPMENT OF PROTOTYPE 1

The development process from the first draft into prototype 1 of the IRME curriculum involved a cyclical process consisting of *experts' review* and *consideration*. The term expert refers to two types of people namely the Dutch RME experts and the Indonesian subject matter experts. Meanwhile, the term consideration means the process of improvement on the IRME curriculum based on the results of the experts' review (see also Chapter 4). The cyclical process is described in the following design:

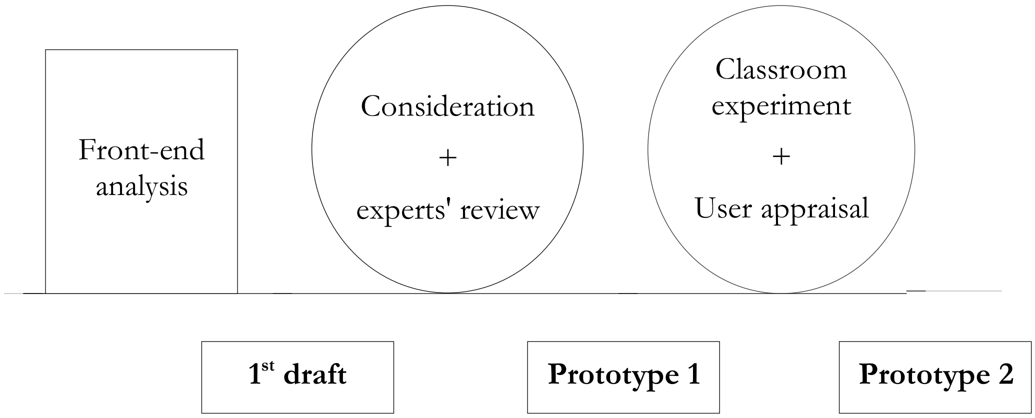


Figure 6.1
The development of prototype 1 of the IRME curriculum

After having developed the first draft of the IRME curriculum on the basis of the literature relating to RME, the validation of this draft, consisting of content and construct validity, was performed through a series of interviews and discussions with two Dutch RME experts. The interviews and discussions were conducted through face to face meetings and via e-mails and focused on the aspects mentioned in Chapter 4 section 4.3.2. During the discussions, each contextual problem in the student book and each component in the teacher guide (see Chapter 5, section 5.4) were discussed thoroughly and repeatedly.

Based on the results of the interviews and discussions, it was concluded that the RME experts approved of the content and the construct validity of the IRME curriculum as well as the conjectured 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. The recommendations of the RME experts are summarized in Table 6.2.

Table 6.2
The recommendations of the RME experts on the validity of the IRME curriculum

The contextual problems that needed to be improved involved the concepts:	The recommendations of the RME experts
Area of a triangle as half of area of a parallelogram or rectangle	Provide more contextual problems about the related concept
The *height* of a triangle or parallelogram	Provide more contextual problems to help pupils to realize that the height of a triangle or parallelogram is not always vertical or horizontal
The formulas for areas of squares, triangles, rectangles and parallelogram.	Give more opportunity for pupils to construe the formulas
Concept of measurement unit	Consider the right time and how to introduce the standard measurement units

After the discussions with the RME experts, the first draft of the IRME curriculum was also reviewed by four subject matter experts from Indonesia and two primary school teachers. Three of the subject matter experts had experience in writing mathematics textbooks for Indonesian schools. The reviewing activity was focused on the appropriateness (i.e. language, figures, and lay out) of the IRME curriculum for pupils at Grade 4 in Indonesian primary schools. The results of the reviewing process are presented in Table 6.3.

Table 6.3
The recommendations of the Indonesian subject matter experts on the validity of the IRME curriculum

Aspects that needed to be changed	The recommendations of the subject matter experts
Language	▪ To simplify of the wording used in the contextual problems, to make them easier for pupils at grade 4. ▪ To present some contextual problems in more effective sentences.
Figures	▪ To improve the clearness of some figures. ▪ To shade some the figures.
Preface	▪ To complete the explanation about the content of the student book on the preface, in order to give the readers a clear picture of what the student book is about and how to use the book.

The reviewing processes of the first draft as described above resulted in prototype 1 of the IRME curriculum, which was then implemented in the classroom experiments. The implementation of the prototype is discussed in the following section.

6.3 THE IMPLEMENTATION OF PROTOTYPE 1

Prototype 1 of the IRME curriculum was implemented in two primary schools namely SD N Ketintang I Surabaya (school 1) and SD N Percobaan Surabaya (school 2) during Fieldwork I of the study. Fieldwork I was conducted in Indonesia from September 1999 until February 2001. The activities that took place during this period are summarized in Table 6.4.

Table 6.4
The activities in Fieldwork I

Activities	**Time**
1. Research preparation	September 1999
2. Finding the schools for the implementation	September 1999
3. Obtaining the permission of the research	1-7 October 1999
4. Giving a short training for the observers	8 October 1999
5. Classroom experiments in school 1	11 – 30 October 1999
6. Classroom experiments in school 2	1 – 20 November 1999
7. Interview with the teachers and pupils	22 – 27 November 1999
8. Data analysis	December 1999 – January 2000

The two schools were chosen with considerations:

- As this was the first experience of teaching mathematics using the RME approach in Indonesia, it was preferred to implement prototype 1 in a small number of schools to get more insight from the research.
- The two schools chosen had different conditions. The pupils from school 1 were very heterogeneous in mathematical ability (based on their previous results), 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.
- The willingness of the two schools, especially the teachers and principals, for a collaboration.

As no teacher in Indonesia had experience in teaching IRME curriculum the author taught the pupils himself in the two schools, with the teachers taking the role of observers (*Note:* in remainder of this chapter, the term *teacher* refers to the author, while the real teachers are called *classroom teachers*). Before the classroom teachers observed the classroom experiments, they received a short training about the RME theory and to brief on the important aspects to be observed by them (see Appendix D). A Dutch RME expert also observed and supervised the teacher during the classroom experiments in school 1.

During and after each lesson the teacher made observation notes about what happened in the classrooms when the pupils were working on the contextual problems. The notes were made for each contextual problem, and focused on the conjectured learning trajectory and objects of evaluation mentioned in Table 6.1. Meanwhile, the classroom teachers filled the observation scheme (see Appendix D) which was focused on the teacher and pupils activities during the teaching and learning processes.

The implementation of prototype 1 of the IRME curriculum aimed at testing the characteristics and investigating whether the conjectured learning trajectory worked as intended. The implementation process followed the design presented in Figure 6.2. The term 'user' in this design refers to the pupils.

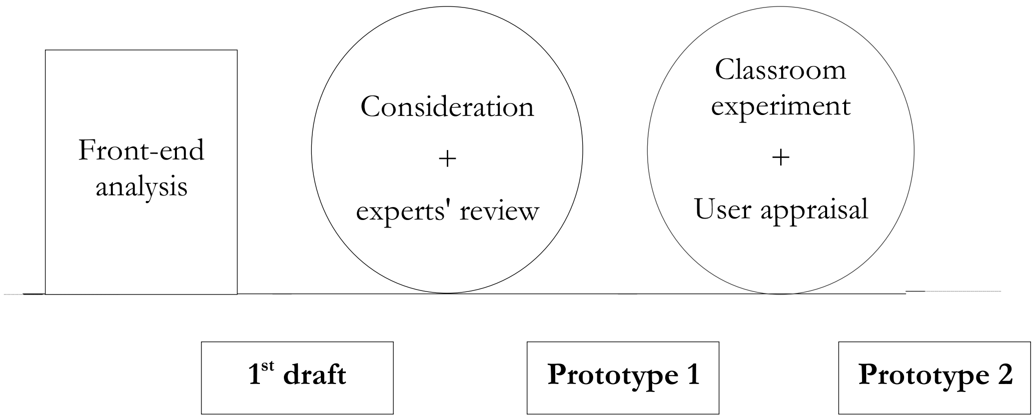


Figure 6.2
The implementation of prototype 1 of the IRME curriculum

Because of the potentials and characteristics of the IRME curriculum (see Chapter 3 and 5), in the teaching learning process pupils were expected not only to master the mathematical concepts but also to pay much attention to the process related. They were expected to know how to work in-groups, be active and creative in construing the concepts and developing their model in solving a contextual problem, and understand the importance of giving an explanation for a solution. As there was no information at all about how Indonesian pupils would react on RME-approach, the data collection was also focused on pupils' activities and reactions when they dealt with such a new approach.

With regard to teaching based on the RME approach, teachers were expected to be able to direct the pupils to solve the contextual problems, encourage the pupils when they were working in group, react to the pupils' contribution, and guide the classroom discussions. Considering that the teacher was inexperienced in teaching mathematics using the RME approach, the intention was focused on the improving of the teacher skills and roles (see the RME's learning and teaching principles in Chapter 5) in the first week of the classroom experiments in school 1. This had been done by having discussions with the Dutch RME expert and the classroom teachers after each lesson. The discussions, in term of reflection, were focused on what happened in the classroom. The following sections will consecutively discuss the classroom experiments in the two primary schools.

6.3.1 The implementation of prototype 1 in school 1

SD N Ketintang I is located on Ketintang Street No. 163 Surabaya, East Java, Indonesia. The neighbourhood of the school is not really appropriate for the teaching learning process because the school building is adjacent to a busy street with a high level of traffic noise. Moreover, there are three different elementary schools in the same building and some of the rooms are in the process of being renovated. Because of the renovation, the learning and teaching process for the pupils at the grade 4 had to be conducted in the afternoon. The numbers of pupils at grade 4 SD N Ketintang I were 37, and the group were heterogeneous in their mathematics ability.

The following sections present the results of the classroom experiments from the first two lessons, structured as follows: planning for the lesson, what happened in the classroom, and the lesson learnt from the classroom experiment.

Planning for lesson 1

The unit for the first lesson was *the sizes of shapes* in which pupils would compare and order the sizes of various shapes. To undertake these activities, the teacher prepared materials such as: worksheet for the pupils to work on the contextual problems (see the examples of worksheets in Appendix B), tracing papers, drawing papers, and scissors. Each pupil was also provided with a grid exercise book for writing his or her results in. An important goal of the lesson was to see how pupils would react and act to the change in roles: from passive listening and making exercises towards active working on mathematics tasks. In this meeting pupils worked in-groups of 4, in which pupils who sat next to each other were in the same group. The pupils were grouped to make it easier to observe their activities (the size of the class was big), and as the RME approach was new to the pupils, it was assumed that the pupils would understand the contextual problems better if they worked in-groups.

What happened in the classroom?

At the beginning the teacher explained what the lesson was about, the expectations from the lesson (the changes of pupils' and teacher's role, compared to the traditional method), what activities the pupils would do, and the nature of the materials that were provided for their use. This was what happened when the pupils dealt with the first contextual problem:

The outline of the hands

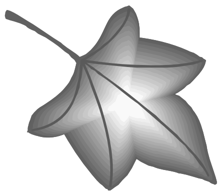
Draw the outline of your hand on a piece of paper then find out who has the smallest hand's outline? Explain your answer!

After reading the contextual problem the pupils kept silent. It seemed they did not know what to do and were waiting for instruction. The teacher tried to explain and encouraged them to use any materials in order to solve the problem, but none of the pupils started to work. Because of that, the teacher explained how to draw the outline of a hand on a piece of drawing paper/tracing paper. Then, the teacher gave the pupils a clue on how to use those drawings to find the member of each group who had the smallest hand outline 'by putting one drawing on top of the others'. Some groups were not interested and just observed their drawings then decided about their answers without giving any reasoning. When the teacher asked them '*how do you know it is the smallest?*', they just looked at each other. Because most pupils were still confused, the teacher asked them to cut out their drawings in order to make it easier to compare their drawings. All groups did this but only two groups (out of ten) succeeded in this task.

The same conditions as those explained before were found when the pupils worked on the following contextual problem.

Leaves

Look at the figure of two dry leaves below. Suppose that one side of each leaf will be painted to make a decoration, which leaf needs more paint? Explain your reason!



Cotton Leaf

Kembang Sepatu Leaf

The pupils were still waiting for the instructions about what they should do, so the teacher told them that they could use any of the strategies used in the previous contextual problems. In addition, there were no pupils who used the context of painting in giving the answer. Most of them just said that one leaf was bigger than the other without any reason.

Working in-group was not running smoothly because only one or two pupils in each group were working seriously, while the others were waiting for the answers. Moreover, the pupils in the mixed groups (boys and girls) did not enjoy working together.

Some lesson learnt from lesson 1

From the first lesson, the following points emerged as lessons learned:

- The pupils were not used to story problems so they experienced difficulties in grasping the whole idea mentioned in the contextual problems. Initially the teacher thought the problem was because of poor reading ability. After asking some pupils randomly it was discovered that the problem was not in reading but that the pupils almost never worked on story problems.
- Most pupils had a very dependent attitude. They very much lacked the ability to take initiative, and were not self-confident in solving the contextual problems.

Every time they finished a task, they always asked the teacher to come closer and check whether what they had done was correct or not. Reflecting on the results of the context analysis described in Chapter 2, the dependent attitude of the pupils was probably because they were used to a situation in which the teacher would first give them an example, after which they would do tasks similar to that in the example.

- It was difficult to organize the class because of the pupils shouting many times asking for help. The classroom was also too small so that the teacher could not move easily from one group to another to give guidance.
- In solving a contextual problem, the pupils could not explain what they did, how they did it, or why they did it, neither orally nor in writing. Most of the questions that the teacher asked were answered by silence, smiles or by one or two words. For example: "how do you know that your hand outline are larger than that of any of your friend? Almost all pupils said that *my hand outline looks larger*. Moreover, the pupils were only interested in the final results, and did not like to write down the process that led to the results. As discussed in Chapter 1 and 2, the mathematical problems in the mathematics textbooks in Indonesia lack the question *why?* Teachers also rarely ask pupils to explain their answer and are more interested in the final results of the pupils' work, so that pupils do not have the opportunity to argue or to come up with their own ideas that are different to what their teachers say. We could argue that these situations lead to the pupils' weaknesses in reasoning.
- Based on the interviews with the classroom teachers after the lesson, it was discovered that they almost never apply working in small groups in the teaching learning process. It seems that this was the reason why the majority of pupils got confused when the teacher asked them to work in-groups for the first time. According to the classroom teachers the problem in the mixed groups (boys and girls) was because of the pupils' culture. In their everyday life, it is rare for boys and girls to take part in activities together. So they were shy when working together in one group.
- Some pupils were not motivated to solve the contextual problems, and were just waiting for correct answers from their friends.
- The introduction given by the teacher to stimulate the pupils to solve the contextual problems was not satisfactory.

Planning for lesson 2

Lesson 2 was still about comparing and ordering the size of shapes, so that the tasks in this lesson were similar to those in lesson 1. Dealing with the problems that were discovered before, the plan for this lesson was as follows:

- Using Overhead Projector (OHP) to attract the pupils and to focus their attention to the process of solving the contextual problems.
- Minimize the intervention of the teacher in order to reduce the dependent attitude of the pupils.
- Making agreements on not shouting, but to put a hand in the air when wanting to say something.
- In grouping the pupils, allowing them to choose their friends themselves.

What happened in the classroom?

Most of the planning did not go well. As it was the first time the pupils followed an instruction using OHP, some of them came closer to see the OHP and played with its light, and the others were laughing at shadows moving on the screen. Pupils from other grades who did not have lessons at that time stood in front of the door and made noise, because they were curious, especially about the use of OHP and the presence of the Dutch RME expert in the classroom.

Most pupils still asked *what should we do now and next?* The teacher tried to motivate them to think for themselves by giving hints and/or raising stimulating questions. This effort worked for most of the pupils, but still did not work for some pupils who were very weak in basic mathematical concepts. Later on it was discovered that these pupils could not draw a simple geometry object, still used their fingers to count 3 x 4, and did not know the results of 8 x 7, a half of 6, a half of 9, etc. These pupils really needed guidance step by step in solving a contextual problem.

The frequency of pupils' shouting out asking for help and clues was reduced, although sometimes they forgot the rule. The motivation of most pupils to work in-groups increased, and they also started to give the explanations for their solutions orally as well as in writing, although most of those reasons were not relevant to the questions. Furthermore, it was found pupils' tended just to get the results and did not pay attention to the process in solving a problem. For example, some groups preferred dividing the tasks among the group members in order to get the answers as soon as possible, rather than having a discussion to find the answers together.

Some lesson learnt from lesson 2

The lesson learned from lesson 2 can be summarized as follows:

- The pupils started to give the reason for their solutions orally as well as in written form, although most of those reasons were still weak and sometimes they were not related to the questions mentioned in the contextual problems. The pupils tended to give a reason by repeating or using the same words that they used previously, every time they answered a question. For example, *A is bigger than B because A is bigger*, or *A is bigger than B because when I measure, it was bigger*. Occasionally, if they were asked to explain their answers orally, they could not do it directly, but then they needed to look into their exercise books and read what they had written there word for word.

  The examples below show the reasons of the pupils when they were solving some of the contextual problems in the student book.

Hand and foot outlines
Draw the outlines of your hand and foot on a piece of paper, then compare which one is the biggest? Explain your reason!

  All pupils said that the foot outlines were bigger than the hand outlines because:

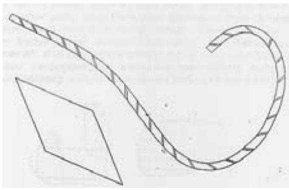
  - *The foot outlines are bigger than the hand outlines*
  - *When I measured it was bigger*
  - *The foot has more area.*
  - *It has more than hand outlines*
  - *Between the foot outlines and the hand outlines, the foot outlines were bigger*
  - *It can walk further*
  - *20,5 cm x 8 cm = 164 cm*
  - *14,5 cm x 8 cm = 116 cm*
  - *So, 164 cm is bigger than 116 cm*

  The above examples show that some pupils just repeated their answers when giving the reasons, and others gave irrelevant reasons. The last example was from a pupil who was in Grade 4 for the second time. He learned the formula to determine the areas of rectangles as length times width in the previous year, then used it to solve this contextual problem.

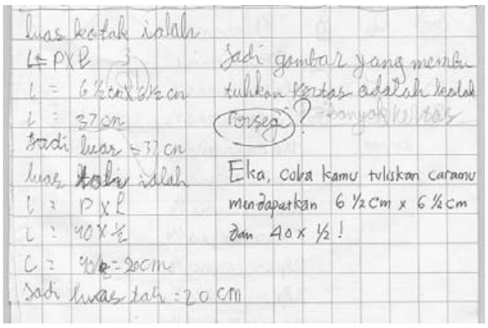
Pupils' work on contextual problems also showed their weakness in *reasoning*, as can be seen from the following example:

Decorations

Ani wants to make two decorations by using paper, as it is shown in the figure below. According to you, which decoration needs more paper? Use the worksheet 3, then explain your strategy in answering this problem.



A pupil said that the figure on the right side (*he called it: stick*) was the one that needed more paper *because it was longer and circular*. Another pupil gave an answer as follows:



The area of box is:
A = l x w
A = 6 ½ cm x 6 ½ cm
A = 37 cm
Thus, area = 37 cm

The area of string is:
A = l x w
A = 40 x ½
A = 40/2 = 20 cm
Thus, the area of string: 20 cm

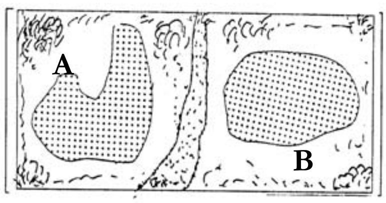
So, the figure that needs more paper is the square box

The pupil assumed that the figure on the left was a box (square box) and that the figure on the right was a string in the form of a rectangle so she used the formula to determine the area of a square/rectangle to solve the problem. When the teacher asked the pupil to explain how she got the number 6 ½ cm x 6 ½ cm and 40 x ½, she could not explain.

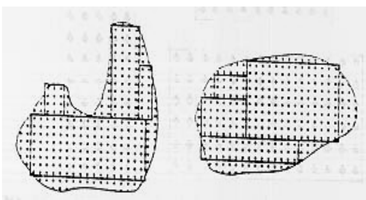
- The teacher had not yet been successful in stimulating pupils' activity and creativity to find and use various strategies in solving the contextual problems. In lesson 2 the pupils were also provided with grid transparencies to solve the problems, but most of the time they only used this tool for finding the answers. For example, there were various strategies that the pupils could use in solving the following contextual problem:

Rice fields

The figure below shows two rice fields separated by a road. Both rice fields are planted with the same rice and they are given the same fertiliser. The dots on the figure represent rice clusters. Use the worksheet to determine which rice field produces more rice?



The pupils could solve this problem by drawing one of the figures using tracing paper then putting it on top of another. They also could use cutting and pasting strategy or smart counting. However, no pupil used those strategies. There were some groups that cut out one of the figures, and could easily have found the answer by putting it on top of the uncut figure, but they did not do it, and used the grid transparency instead. So, their effort to cut out the figures was useless. Some pupils used counting strategy by counting the dots in the rice fields one by one. Although the teacher challenged them to use a more efficient way in counting the dots, for example by drawing squares or rectangles as it is shown in the figures below, no pupil did this.

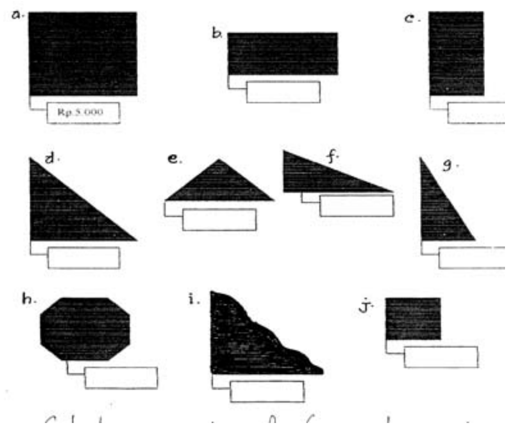


The reason why almost all pupils stuck to one kind of strategy (using grid transparencies) was probably because if they used grid transparencies, they got the solutions in terms of numbers (the number of grids), and they could compare the numbers to compare the areas. The pupils thought that this strategy was easier for them to give the reasons rather than creating/writing explanations when they were using other strategies. Nevertheless, this situation indicated the development of pupils' understanding about the concept of area as a number of measurement units that cover a surface.

In solving the contextual problems pupils tended to think convergently (just paying attention to one direction), as can be seen when they were working on the following contextual problem.

Wingko Babat

Yono's father sells Wingko Babat in a shop. He asks Yono to price each piece of Wingko Babat that will be sold. A reasonable price for the big square piece (figure ***a*** *below) is Rp. 5.000. Help Yono to decide on the prices of the other pieces of Wingko Babat. (Remember: the thickness of all Wingko Babat is the same). Use the worksheet 6 to explain you answer.*



The teacher tried to stimulate the pupils to find the relation between one figure and the others (not only to the figure **a**) in order to make it easier to find the answers. For example, by asking them to observe the relation between the figures such as **f** and **b** or **c** (wingko babat **f** as a half of wingko babat **b** or **c**) , **j** and **b** or **c**, **e** and **d.** However, only a few pupils did it, and others used the figure **a** as a directive in answering the questions. For the latter group of pupils, their strategy in solving the problem caused difficulties for themselves because it was not easy to find, for example, the price of wingko babat **e**, **f**, or **g** by comparing it with the wingko babat **a**. It seemed that the pupils used figure **a** as a directive because it was the only figure with the given price. The teacher also found some pupils that had used drawing and tracing papers to find the answers because they could not do it by making direct comparison. They drew the figures one by one and compared them to figure **a** to get the results. Although the pupils were asked to explain how they got the answers, most them just put the results in their exercise book without any explanation.

- Pupils' tendency just to get the results and not pay attention to the process was still strong. When working group they preferred dividing the tasks among the group members in order to get the answers as soon as possible rather than having a discussion to find the answer together. If one group explained their answers, some pupils did not pay attention to them and continued with their activities. Once more, this was probably an effect of the traditional way of teaching and National Evaluation System in Indonesia, and the teacher found it was difficult to change this attitude.
- Another problem was that, the pupils always asked the teacher to put the mark on their exercise books for every exercise or homework that they did. They also asked the teacher to discuss the solution of exercises or homework classically so that they could check if their answer was correct or wrong, then express their happiness if their answers were correct. The pupils would be less motivated if the teacher only gave the marks on their exercise books without discussing the answers classically. Besides being an effect of the traditional way of teaching, this condition is also influenced by a habit in which the parents always ask their children about the mark that they got in the school every time they go back home.
- The frequency of pupils shouting when asking for help/clues was reduced, although sometimes they forgot the rule and the teacher had to remind them again.
- Working in-group was not really comfortable for some pupils. The reason was because not all the members of the groups had equal in solving the contextual problems.
- The teacher effort, to attract the pupils' interest by explaining the contextual problems orally plus additional explanation about the context, did not influence the pupils very much. Some pupils were still unmotivated to solve the contextual problems.

- The time for the classroom discussions was frequently insufficient because in general the pupils needed more time to solve the contextual problems than predicted.
- Despite some problems as described above, the observation scheme (see Appendix D) completed by the classroom teachers for the first two lessons showed that the learning and teaching process was running well. They mentioned that the pupils' performance regarding some aspects such as *asking questions or giving responses to questions*, *mentioning their ideas*, and *the pupils' enthusiasm in the learning and teaching process* was good. They also reported that the teacher performed well in *stimulating the pupils, guiding the pupils when they worked in-groups, guiding the classroom discussions*, etc. These results were probably influenced by the culture of the teachers in as much as they tend to say positive things about research conducted in their schools, instead of being critical.

The results from lessons 3 - 10

The experiences gained from the two lessons showed that the pupils needed time to get used to the new approach (RME). Therefore some more work had to be done, especially in finding ways on how to:

- Attract the pupils' interest so that they would be highly motivated in following all activities in the teaching learning process.
- Stimulate the pupils to become more active and creative in raising ideas and finding various strategies in order to solve the contextual problems.
- Develop pupils' reasoning.
- Reduce the negative tendencies of the pupils (i.e. dependent atttitude, result oriented).

Below is a summary of the work done in lessons 3 –10 to achieve the above aims and the impact that this had.

Firstly, some thought was given on how to stimulate the pupils to be highly motivated in solving the contextual problem. In the third meeting, the teacher read the contextual problems to the pupils instead of just letting them read and solve the contextual problems by themselves. Sometimes the teacher changed the context (to differ slightly from those in their book) to make the problems more interesting so that the pupils could understand the problem and then feel more able, or have more motivation, to solve them. After reading a contextual problem, the teacher took some time to raise questions such as *who can explain what the problem is about? Who has got an idea on how to solve the problem? Who has a different idea?* This tactic worked well. The pupils started to give their contributions on how to solve a problem, although their opinions were frequently not relevant. However, by encouraging a democratic atmosphere (by not just saying right or wrong to what the pupils said) in the classroom, the pupils were not afraid anymore to mention their ideas. Teaching in this way resulted in some of the contextual problems not being solved by the pupils, because of the time constraints, but in this case it was considered that the understanding was more important than the number of the contextual problems that could be solved and/or taught.

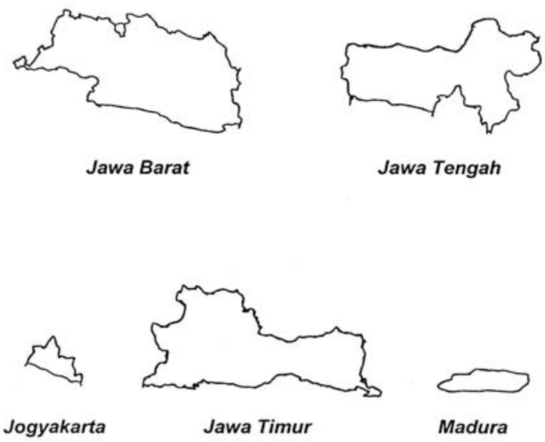
The tactic mentioned above was also useful in reducing the dependent attitude of the pupils, and in stimulating the pupils to become more active and creative in raising ideas and finding various strategies in solving the contextual problems. This was because they were given a big opportunity to express their original ideas or different ideas to those expressed by their friends. The democratic situation in the classroom also motivated the pupils when they solved the contextual problems in-groups, although there were a few pupils that still did not really enjoy working together.

The positive impact of this approach was found in lesson 4. In this lesson the pupils worked in-groups of 4 in which one member in each group was made responsible for writing the answers on the blackboard after the group had finished solving the contextual problems. The next example shows the result of pupils' works in lesson 4.

The Provinces in Java Island

The figures below are drawings of some provinces in Java Island and a drawing of Madura Island. Cut the drawing of Madura Island from the worksheet then use it to estimate and answer the next questions.

a. How many times would Madura Island fit into the area of West Java?
b. How many times would Madura Island fit into the area of Central Java?
c. How many times would Madura Island fit into the area of East Java?
d. How many times would Madura Island fit into the area of Jogyakarta?



. introduceert probleem. Hij wil ze weer in groepen laten werken.
L de vier delen van Java
zet op 't bord een schema: Ze gebruiken knopen

	Jawa Barat	Java Tengah	Java Timur	Jogyakarta
1) Santi dkk	8	7	8	1
2) Rinon dkk	10	8	7	1/2
3) Astrid dkk	9	7	8	1
4) Retno dkk	10	8	8	1/2
5) Dian dkk	10	7	7	1/2
6) Bayu A. dkk	8	~~8~~ 7	~~5~~ 7	1/2
7) Cholifi dkk	12	9	5	1
8) Kalifi dkk	10	7	12 !	3 !

L dan kawan-kawan ('en anderen')

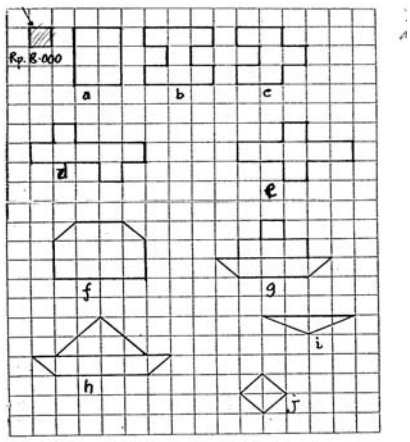
The teacher observed that most pupils were very enthusiastic in completing this task, probably because the context was familiar and therefore very interesting for them. Each group had a discussion to find the answers instead of dividing the tasks among the group members (as they did before). They were happy when they finished one task then could show the result on the blackboard immediately (the groups competed with each other). After all groups had written their answer on the blackboard, a discussion was conducted, especially concerning the results of group 8 for questions **c** and **d** which were not accurate. The discussion, as well as the answers of other groups, helped them to realize their mistakes.

Secondly, some thought was applied as to how to encourage the pupils to give an explanation for their answers. The teacher succeeded in stimulating the pupils to change their tendency just to get results without paying attention to the process, after applying some rules in the class. The pupils were told that they would get a maximum mark if they could solve the contextual problems correctly and show or explain the process and reasons in solving the problems. Moreover, the teacher also wrote notes in pupils' exercise books, asking them to explain the processes and reasons every time they worked on their homework. After analyzing the pupils' exercises book, it was found that this action had an impact in that the pupils started to give explanations or reasons. The reasons given by the pupils were very weak at the beginning in which most of the reasons were irrelevant to the questions, but after a few meetings most pupils showed an improvement in reasoning.

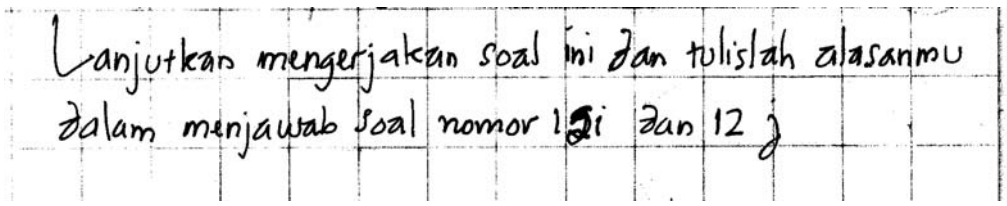
The following example describes the comment of the teacher in a pupil's exercise book, followed by the pupil's reaction afterwards.

Tiles

Below are drawings of tiles of various different shapes. If the small square tile costs Rp. 8.000, figure out fair prices for the other tiles. Use the worksheet 7 to help you to explain your strategies in finding the answers.



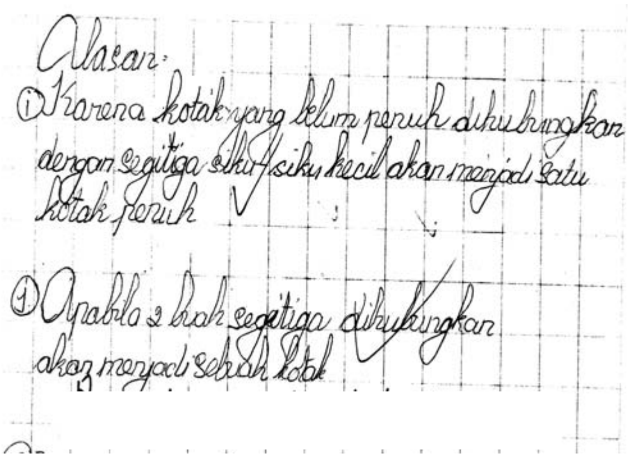
Teacher's comment:


Lanjutkan mengerjakan soal ini dan tulislah alasanmu dalam menjawab soal nomor 12i dan 12 j

Continue your work on this contextual problem and write your reasons in answering problems 12j and 12j

Pupil's answer: i. Rp. 16.000, j. Rp. 16.000

The reason given by the pupil shows that she understood the concept of reallotmen:



Reason:

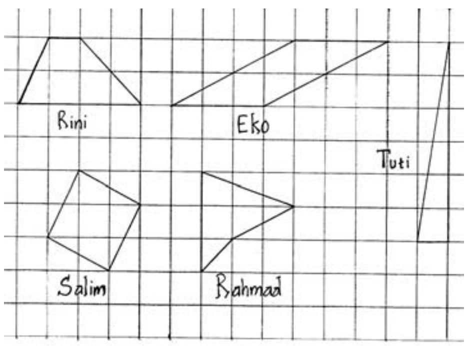
i) *Because the grid that is not yet complete is connected with the small right triangle, it will become one complete grid.*

j) *If two triangles are connected then they will become one grid.*

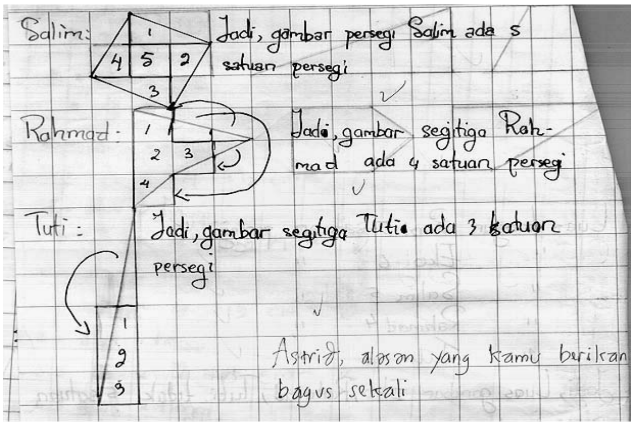
The next paragraphs show an improvement of a pupil (A) in reasoning.

In the first two meetings, pupil A was very weak in reasoning. Every time she compared *the size of shapes* she wrote '……. *is bigger than……., because it looks bigger* or *when I measure it, it is bigger*'. In the third meeting she wrote the same sentences '*when I compare it, and tried to trace it, I found……*' eight times in solving the contextual problems. However, in the seventh meeting she came up with a good idea when she worked on the contextual problem below:

> *Rini, Eko, Tuti Salim and Rahmad drew the shapes below. Did they draw shapes with an area of five square units? Explain your answers.*



By using reallotment strategy pupil A found that the Salim's drawing was 5 square units, Rahmads' was 4 units square units, and Tutis' was 3 square units.



After taking the two actions as discussed above, the constraints mentioned earlier in this section were solved and the teaching learning process progressed better than before. Later on, using an overhead projector was also useful to attract pupils' attention not only before they solved the problems but also during their discussions about the results. It was observed that the contextual problems in the student book were also playing an important role in stimulating the changes that were happening. Moreover, the supervision gave by the Dutch RME expert as well as the discussion with the classroom teachers after each lesson also helped the teacher to grasp the ideas of being a teacher based on the RME point of view.

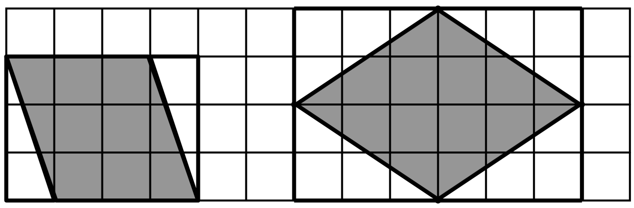
Some lesson learnt from lessons 3 -10

As was discussed before some negative impacts of the traditional way of teaching were found in lessons1 and 2. Later on it was also discovered the weak understanding of the pupils of the mathematics concepts they had learned. Before the teacher taught the topic perimeter and area the pupils had already learned about measurement units of length such as kilometer, hectometer, decimeter, meter, centimeter, millimeter. When the teacher asked the pupils, they knew by heart the relationships between one measurement unit to the others. For example, they knew that 1 kilometer = 1000 meter, 1 meter = 100 centimeter, 1 centimeter = 10 millimeter, etc. However, the pupils probably only learned the concepts by memorising and drilling, and they had never actually experienced the manipulation of objects that have relative size one meter or one centimeter length, etc. This fact was highlighted by some of the strange answers that were found in the pupils' workbooks after they had worked with the contextual problems in the student book. Some examples of these answers are listed below:

- a blackboard is about 4 kilometers in length.
- my photo is about 2 meters in width.
- my pencil is about I kilometer in length.
- my eraser is about 1 meter high.

Some interesting facts were also found which related to pupils' and parents' attitude. Firstly, in checking the solutions of the exercises or homework, the pupils preferred to do it classically so that they could express their happiness (by shouting) if their answers were correct. They also asked me to put the mark on their exercise book every time they finished an exercise or homework. This was not only for the pride of the pupils themselves (especially when they get 10/10) but also because the parents always ask about the marks that the children have got every time they come back home from the school.

Secondly, some parents helped their children to do their homework, but the main reason for this was only to increase the mark of the pupils (the marks for the homework used to be considered in determining the final mark). They did not pay attention to the pupils' understanding, because when the teacher asked the pupils about what their parents had told them they could not explain. Below is an example of what the parents taught to their children.



To determine the areas of shaded figures above, the parents told the children to use the formulas of parallelogram (for the figure on the left hand side) and kite (for the figure on the right hand side). It seemed that the parents only think about topic 'area' as merely applying the formulas (at this moment the pupils have not learned the formulas yet). In fact, the problems could be solved easily using reallotment or halving strategy (without knowing the formulas).

6.3.2 The implementation in school 2

SD Percobaan Negeri Surabaya was located in Surabaya State University's complex. This school had many teachers so that every teacher only teaches one subject matter. In conducting teaching learning process, pupils in each grade were divided into three groups (classes) based on their ability, namely higher (class A), middle (class B) and lower (class C) group. Each group followed the instruction in different classrooms and they also had different timetables for mathematics lessons.

The implementation of the curriculum in this school was conducted in the higher and middle group. Each group had 17 pupils. This choice was based on the consideration of the classroom teacher that the lower group was not ready yet to learn topic perimeter and area at that time (they had not finished learning the previous topic).

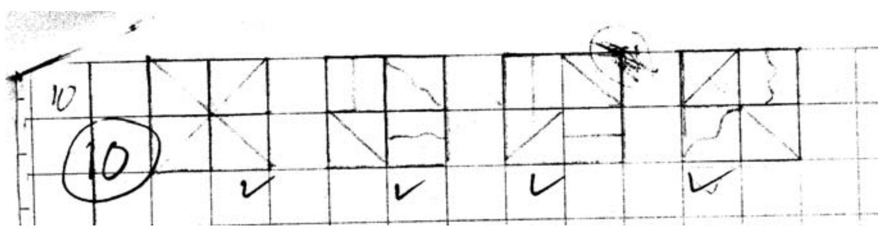
The classroom experiments in school 2 were performed three weeks after those in school 1 were started. Initially the author planned to make some changes on the prototype 1 of the RME-based curriculum based on the findings in school 1, before implementing the prototype in school 2. Because the conditions of the two schools were different, it was decided not to make any changes. It was also assumed at that time that the differences between the two schools would lead to different findings.

The following paragraphs outline the results from the classroom experiments in school 2. There is no detailed description of the classroom events (like for school 1) presented here, but just the summary of the findings.

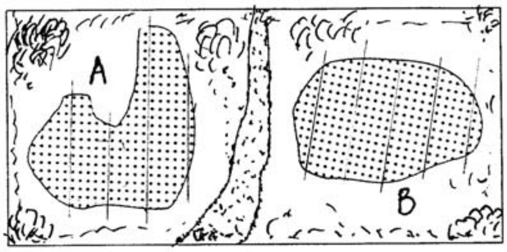
- In the first week of the classroom experiments, the pupils in the middle group had the same very dependent attitude as those in school 1. Most of the time they were waiting for the instructions before solving the contextual problems. However, the pupils in the higher group were more active and not so dependent. If they had difficulties in solving a contextual problem then they would raise questions to the teacher. In general, the teacher could play his role as motivator and coordinator during teaching learning process in the higher group.
- The pupils in the higher group enjoyed working in pairs or groups. They preferred to perform all activities in pairs or groups. The situation in the middle group was similar to that in school 1. Some pupils did not like to work in-groups, there was even one that did not want to work with any other pupils.

- At the beginning most pupils also lacked reasoning abilities, which meant that they could not give the reasons for what they did in solving a contextual problem. Sometimes they could give the reasons or the explanations orally, but then they got into difficulties when they tried to write them down in their exercise books. This situation occurred probably because the traditional teaching learning process never gave them the opportunity to develop their reasoning. However, after working on the contextual problems for several days, they started to show a positive change in reasoning.
- The activity and creativity of the pupils in the higher group was better than those in the midle group and school 1. They actively participated in the classroom discussions, and were always eager to find the different solutions of the contextual problems. As a result, almost all the possible solutions mentioned in the teacher guide were found by the pupils. For example: for contextual problem 4 (lesson 1) the pupils came up with three different strategies. Some pupils cut out the figures then put one on top of the other and looked for overlapping sections. Then they came to the conclusion: *the cotton leaf is bigger because the rest* (after they put the cotton leaf on top of the Kembang Sepatu leaf) *is more*. Some other pupils used a grid transparency to find a larger leaf. The other pupils drew the figures of leaves on their exercise books then counted the number of grids for each leaf.

  The next example shows the creativity of a pupil when she worked on contextual problem 9 in lesson 2. In this problem the pupils were asked to divide a square into eight equal parts. The second and the fourth figures drawn by the pupil show how creative she was in creating those figures. She knew that each part of the figures were the same in area even if the shapes of some parts were irregular.



More evidence of pupils' creativity can bee seen from the pupil's answers on the contextual problems about *the rice field* (see page 119). There were some pupils who used their own counting strategy in solving the problem which was different to the strategies mentioned in the teacher guide (see Appendix A), as it is shown on the figure below.



- As was found in school 1, the pupils here also had a lack of understanding of the previous concepts, especially the concept of measurement units. These findings strengthen the conjecture mentioned before that the teaching learning process in the traditional way did not succeed in developing pupils' reasoning and understanding, and that the pupils mostly learned the geometry concepts by remembering them, without an adequate understanding.

6.4 THE CONCLUSIONS OF THE DEVELOPMENT AND IMPLEMENTATION OF PROTOTYPE 1

This section presents some conclusions of the development and implementation of prototype 1 of the IRME curriculum. The conclusions about the validity, practicality and effectiveness of prototype 1 are presented consecutively in sections 6.4.1, 6.4.2 and 6.4.3. Some important aspects discovered from the classroom experiments in the two schools are outlined in section 6.4.4. These aspects are important as a lesson learned for the development and implementation of prototype 2 of the IRME curriculum. They may also be useful for teachers who want to apply the RME approach in their teaching practices. Finally, section 6.4.5 discusses the implication of the results in this stage to the next round of the study.

6.4.1 The validity of prototype 1 of the IRME curriculum

As discussed in section 6.2, the content and the construct validity of prototype 1 of the IRME curriculum were considered to be valid by the experts, before the prototype was implemented in the classroom experiments. It means the characteristics of the IRME curriculum (see Chapter 5) met the criteria of the validity mentioned in Chapter 4, section 4.3.2. Based on the observation notes made by the teacher during the classroom experiments, and after analyzing the pupils' portfolio, it was concluded that the conjecture learning trajectory for learning the topic Area and Perimeter in general worked as intended. However, the following findings from the classroom experiments suggested that some improvements that will be discussed in section 6.4.5, need to be done on the content of the IRME curriculum, especially on the contextual problems.

- The pupils, especially those in school 1 and the middle group in school 2, could not finish working on the given contextual problems because of several problems regarding the pupils' attitude (see section 6.3), and the time constraint.
- There were some contexts that were not used by the pupils when they were solving some contextual problems (i.e. the context on contextual problem 4, lesson 1). Perhaps this was because the statement in those problems did not guide the pupils to use the contexts.

The changes on the contextual problems implied that the learning trajectory might be changed as well. Therefore the validity of the IRME curriculum would be evaluated further in the next stage of the study. This activity will be elaborated upon Chapter 7.

6.4.2 The practicality of prototype 1 of the IRME curriculum

The investigation of the practicality of the IRME curriculum was focused on three issues:

- Is the student book easy to use?
- Do pupils learn as intended?
- Is the time mentioned in each lesson enough?

The first issue was evaluated by conducting the interviews with 4 subject matter experts, 2 teachers and 13 pupils (small group evaluation). The pupils were chosen purposively in which 7 of them were from upper groups (in mathematics ability) and the rest were from the lower group. Despite some changes suggested by the subject matter experts on the student book (see Table 6.2), all of them and also the teachers agreed that the student book was easy to use. Meanwhile, the pupils said that they did not have difficulty in using the student book both when they were working in the schools as well as doing their homework. Some pupils were also asked to read the contextual problems in the student book, after that they were asked to explain what they had read. All of them could explain correctly what the contextual problems were about.

The other two issues were investigated through classroom observations. As was explained in the previous sections, at the beginning most pupils did not learn as intended according to the RME point of view. It happened because the pupils were not used to the RME approach, and also because of their negative attitudes in learning mathematics. After the teacher took some action as discussed in section 6.3.1, the majority of the pupils learned as intended, and the two teachers approved this development. Nevertheless, there were 4 pupils in school 1 and 2 pupils in school 2 who found it difficult to make progress. These pupils lacked knowledge of the basic concepts, were very passive, and needed step by step guidance in solving the contextual problems.

The findings from the classroom observations showed that the time for the classroom discussions was frequently not sufficient because in general the pupils needed more time to solve the contextual problems than was predicted. Moreover, the problems regarding the pupils' attitudes that were found at the beginning of the classroom experiments also took time to handle, and this meant that the pacing planned for each lesson was insufficient. This finding would be taken into account in improving the IRME curriculum (see section 6.4.5).

6.3.3 The effectiveness of prototype 1 of the IRME curriculum

The aspects of the effectiveness that were investigated in this stage involved the following issues:

- Did the pupils like the IRME curriculum?
- Was their time well spent?
- Did IRME curriculum affect pupils' understanding, reasoning, activity, creativity and motivation?

The first issue was evaluated by interviewing the 13 pupils (7 pupils from the upper groups, and 6 pupils from the lower groups). They were asked to mentioned their opinion about the student book, the activities that they had been performed in solving the contextual problems, and the way the teaching learning process had been conducted (see the interview guideline in Appendix E). All pupils said that they liked the student book, and enjoyed the activities and the way the teacher taught them, but only 3 pupils from upper groups that could explain the reasons for their opinions. These pupils valued the working groups and the way the teacher guided them in solving the contextual problems as can be seen from the following statements from pupil 1 and 2, and a protocol from the interview with pupil 3.

Pupil 1: *I like working in-groups because we can share the ideas with our friends. If I don't know the answer, maybe my friends know. So we can help each other.*

Pupil 2: *(continuing pupil 1) I also like working in-groups in case my friends are willing to work together. But some of them are just waiting for the answers.*

Pupil 3: *I enjoy the lessons because I can ask the teacher if I don't understand. Most of the time I can solve the contextual problems myself, but if I have problem I can ask the teacher for a clue.*

Teacher: *How about the classroom teacher before?*

Pupil 3: *Usually he only gives the problems then ask the pupils to solve the problems by themselves. Then when the pupils finish working they can bring their work to the classroom teacher to get a mark*

Teacher: *Has your teacher ever walked around when you are working on the problems?*

Pupil 3: *Almost never.*

Although the pupils did not explain in great detail why they liked the student book and the way the teaching learning processes were conducted, based on the classroom observations the author argues that to some extent it was happened because of the RME approach. The student book was very different with the mathematics textbook used in Indonesian elementary school. The changes in the content (from theoretical to contextual problems) and the atmosphere in teaching leaning process (from teacher centre to pupil centre) created a more dynamic teaching learning process. The RME approach also gave the pupils more opportunity to learn geometry concepts using their own informal knowledge.

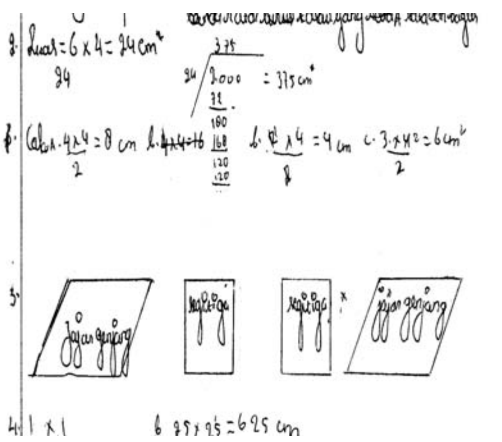
These aspects were probably the reasons why the pupils like the IRME curriculum. Regarding the second issue, at the beginning most pupils could not spend their time well in learning the topic Area and Perimeter. They got confused in solving the contextual problems, and most of the times were just waiting for instructions from the teacher about what to do. Some pupils were also just waiting for the correct answers in working groups. However, after the stimulation given by the teacher (see section 6.2.1), and after the pupils got used to the new approach, they were able to focus their attention on the tasks given to them.

The following parts outline the affect of the IRME curriculum on the pupils' performance, especially pupils' understanding, pupils' reasoning, pupils' activity and creativity and pupils' motivation. These aspects were investigated through the classroom observations, the interviews with pupils and teachers, analysing pupils' portfolios, and giving a post-test. Considering that the evaluation was conducted in a rather informal way, some conclusions presented here are rather judgmental, and this condition would be improved when designing the evaluation activities for the next round of the study (see Chapter 7 and 8).

- *pupils' understanding*

  The pupils' understanding on the topic Area and Perimeter was only evaluated by giving a post-test after the classroom experiments. All the item tests were on contextual problems (see Appendix C). The results of the test were not satisfying enough in which the average of the pupils' achievement was 5,66 in scale 1 – 10.

  The same test was also given to the pupils at Grade 5 in an elementary school in West Sumatera (N*ote:* the test was not given to the pupils at grade 4 because they had not learned about the areas of triangles and parallelogram yet). The aim of this activity was not to compare the achievements between the two groups, but to explore how the pupils that had been taught in the traditional method solved the contextual problems. When the author asked, all pupils in Grade 5 knew by heart the formulas to determine the area of rectangles and triangles. However, almost all of them could not solve the item tests correctly, and none of them could give a reason for their answers (they were very weak in reasoning). It was also found from the pupils' answers that most pupils learned geometry concepts without understanding. The following example shows the answer of a pupil on the test.



Comments:

- *The pupil solved the first two problems wrongly using the formulas. Meanwhile, the problems could be solved without knowing the formulas.*

- *For the third problem the pupil labeled the two figures in the middle as triangles*

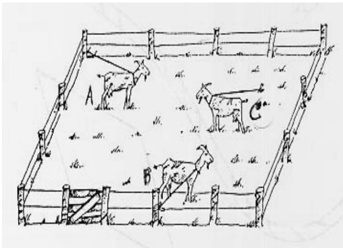
The classroom teacher from Grade 5 said that the bad results were because her pupils were not used to the contextual problems. But, based on the conditions described above the author argues that the reason for these findings was because when the pupils were taught about Area and Perimeter they only practiced with the problems in which they could use the formulas precisely.

- *pupils' reasoning*

  Some of the affects of the IRME curriculum on pupils' reasoning were discussed in section 6.3. This part describes another potential of the IRME curriculum in stimulating pupils' reasoning. As explained in Chapter 5, the contextual problems in the student book gave the opportunity to the pupils to use their informal knowledge and different strategies in solving the problems. This condition made it possible for the pupils to reason with different kinds of reasoning. Nevertheless, all pupils were expected to reason mathematically. The different reasons given by the different pupils can be seen when they solved the following contextual problem:

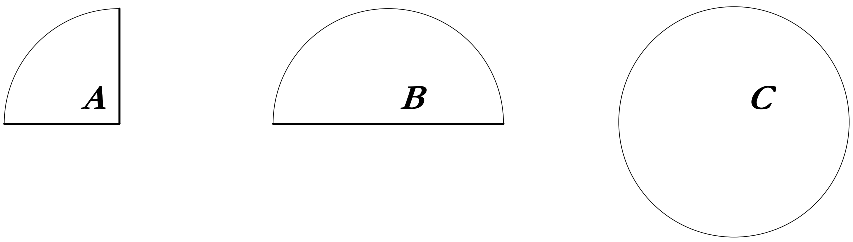
Goats and Grass

The next figure shows three goats in one fenced grass field. If the grass grows in the same condition throughout the field's area, which goat gets more grass? Explain your answer!



All pupils said that goat C got more grass, and their reasons could be grouped as follows:

- *there was more grass around goat C*
- *the goat C was tied in the middle, the others at the fence*
- *the goat C can go to the left, right, behind, and front*
- *the goat C can in all direction.*
- two pupils came up with a very good answer in which they drew the region where each goat could eat the grass as seen below:



- *goat A eats the grass in the area of ¼ circle*
- *goat B eats the grass in the area of ½ circle*
- *goat C eats the grass in the area of one circle*

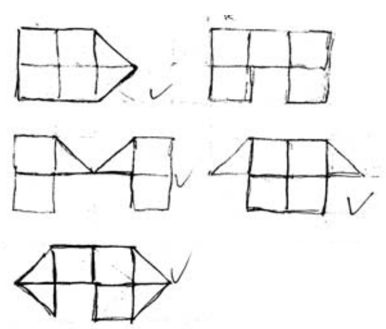
The last answer was the one was expected answer as the pupils reasoned mathematically. We can see here that the two pupils used their mathematical knowledge in giving the reasoning. By discussing all kind of reasons from the pupils classically, they could learn from each other.

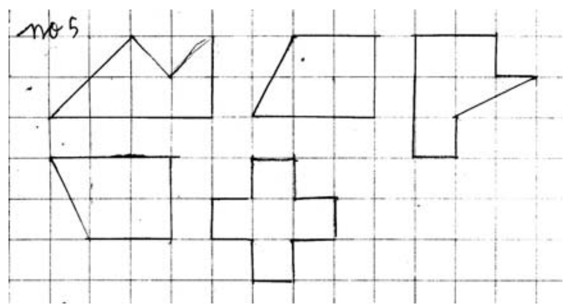
- *pupils' activity and creativity*

  The IRME could stimulate the pupils to become more active and creative in the geometry teaching learning process. Most pupils that were very dependent at the beginning started to raise questions; give responses to the questions; give a contribution/idea in solving a contextual problem. The classroom teachers admitted that the attitude of the pupils was changing in a positive way in that they were not afraid anymore to raise questions.

  In relation to the RME characteristic namely students free production, the contextual problems in the student book could stimulate pupils' creativity because they encouraged the pupils came up with different kinds of solutions. At the beginning most pupils stuck to one kind of solution, but later on they came up with many creative ideas. The pupils from the higher group in SD Percobaan Surabaya on most occasions found all the different possible solutions provided in the teacher guide.

  The following example show the creativity of the pupils in solving a contextual problem in which they were asked to draw five different shapes in which each figure had an area of five square units. The answers of two different pupils show that none of the shapes that they drew are the same. This example not only shows pupils' creativity but also an understanding that different shapes may have the same areas.





- *pupils' motivation*

  The effect of the IRME curriculum on the pupils' motivation in this part of the study was only evaluated through the classroom observations. The observations were focused on the pupils' activities in solving the contextual problems both individually and in groups. At the beginning the pupils in school 1 and the middle group in school 2 were unmotivated in solving the contextual problems. They mostly waited for the instructions from the teacher and always asked about what to do. They also did not enjoy working in-groups and just waited for the correct answers from their friends. However, from the discussion in section 6.2, we can see that the pupils became highly motivated when they worked on the special task in which the context in the problems was very familiar to them. This finding lead to a conclusion that the familiarity of the context played an important role in stimulating pupils' motivation to work on the contextual problems. This was still a premature conclusion, and it would be investigated further in the next round of the study.

In addition to the findings described above, Table 6.5 below presents the full summary of the results of the classroom observations conducted by the two classroom teachers. Although, as mentioned before, the classroom teachers tended to give positive information in filling in the observation scheme, nevertheless, the results presented here strengthen the positive findings discussed earlier.

Table 6.5
The results of the classroom observations

Aspects that were observed	Results
Pupils' activities in:	
- Paying attention/ responding to teacher's explanation.	Good
- Paying attention/ responding to their friends' contributions.	Good
- Communicating their ideas.	Rather Good
- Working in-groups.	Good
- Raising questions to the teacher.	Good
Teacher's activities in:	
- Introducing the contextual problems.	Good
- Asking the pupils questions.	Good
- Responding to pupils' contribution.	Good
- Observing pupils' activities.	Good
- Stimulating pupils' participation and motivation.	Good
- Guiding pupils' activities (individually or in-groups).	Good
- Guiding classroom discussions.	Good
Some comments of the classroom teachers:	
- The learning and teaching process was running smoothly.	
- The classroom climate was conducive, and the pupils' highly motivated.	
- Majority of the pupils followed the learning and teaching process with enthusiasm.	
- Most pupils could mention their own ideas.	
- These lessons were useful.	
- The interaction between the teacher and the pupils appeared to be good.	
- These lessons had the potential to stimulate the pupils to be critical and creative.	

There were several problems found at the beginning of the classroom experiments, especially in school 1 and the middle group in school 2 such as:

- Dependent attitude of the pupils
- Pupils were not used to work on the contextual problems
- Pupils' tendency to get the result without paying attention to the process
- Pupils were not used to working in-groups
- Pupils' lack of motivation, activity, creativity, and reasoning

However, after the action taken by the teacher in overcoming the problems and after the pupils got used to the RME approach, some changes toward a positive direction on pupils' attitude, pupils' understanding, motivation, activity, creativity, and reasoning were found. The contextual problems in the student book and the teaching method performed during by the teacher the classroom experiments played very important roles for these changes.

6.4.4 Some important findings from the classroom experiments

This section summarizes some important findings from the classroom experiments as a lesson learned for further development and implementation in the next round of the study. Considering that the conditions of the schools in Indonesia are rather similar in general, these findings may also useful for teachers if they want to apply the RME approaches in their teaching practices.

- It is important to tell pupils at the beginning about the changing of their and teacher's roles in the teaching learning process compared to those in the traditional way of teaching.
- The teacher needs to explain clearly the expectations of the IRME curriculum to pupils regarding what activities the pupils need to perform, what kind of answers they have to give in solving the contextual problems.
- Regarding the negative attitude of the pupils that were found at the beginning of the classroom experiments, the following activities may help in changing their attitudes:
  - Creating a challenging introduction before the pupils solved the contextual problems so that the pupils felt excited and responsible to solve them.
  - Creating a democratic atmosphere in the classrooms so that the pupils are not afraid to be actively engaged in the teaching learning process. The democratic condition means that the pupils feel free to be active in the learning teaching process without feeling afraid to make mistakes, if they want to ask questions or to answer questions. There were two conditions that probably resulted from the traditional way of teaching that prevented the pupils from being active. Firstly, only the correct answers were expected. If a pupil came up with an incorrect answer, there was no response or follow up from the teacher. Secondly, most of the time other pupils laughed at pupils who came up with the incorrect answer. Telling the pupils that we can

learn from the incorrect answers, or by giving a positive response to the pupils who gave an incorrect answer might solve these problems.
- Applying some rules on how to ask questions (i.e. raising hands instead of shouting) and how to respond to the questions may contribute to creating an atmosphere of learning and task orientation. Informing the pupils of the consequence if they do not behave or act according to the expectations (i.e. they will get better marks if they give the reasons for their answers) may also help to reduce the negative attitude of the pupils.

- As some parents helped pupils to work on the homework, it is also important to inform the parents about the changes from a traditional mathematics approach to the RME approach.
- It took some time for the pupils and the teacher to adapt the RME approach. It was realized that the presence of the RME Dutch expert and observers helped the teacher to get used to the new teaching style and also to overcome the problems occurred in the classrooms.

6.5 THE IMPLICATION TO THE NEXT ROUND OF THE STUDY

There were two implications of the results in this stage to the next round of the study: the improvement on the content of the IRME curriculum and on the evaluation.

- In general the pupils needed more time than was predicted in solving the contextual problems. It meant that the time allowed for the classroom discussions was mostly insufficient. Meanwhile, the classroom discussion was a very important activity in the IRME curriculum. Moreover, there were some contexts in the contextual problems that were not used by the pupils when they solved the problems. Because of these conditions the number of the contextual problems in the IRME curriculum had to be reduced, and some contexts needed to be changed. Reducing or changing the contextual problems implied that the learning trajectory might be changed as well. Therefore the investigation of the validity of the IRME curriculum would be continued when developing and implementing prototype 2 of the IRME curriculum. The changes that would be made and re-evaluation of the validity will be discussed in Chapter 7.
- The evaluation of the practicality and effectiveness of the IRME curriculum was conducted in a rather informal way. In the next round of the study, the evaluation would be conducted in a more formal way using more adequate instruments.

CHAPTER 7

PROTOTYPE 2 OF THE IRME CURRICULUM

This chapter summarizes the results from the development and implementation of prototype 2 of the IRME curriculum. Most of the findings in this stage of the study were similar to those in the developing and implementing of prototype 1 (see Chapter 6) so that the similar parts will only be discussed briefly. The beginning of the chapter re-introduces the research question and the planning of the evaluation activities of this part of the study (section 7.1). The development of prototype 2 of the IRME curriculum is discussed in section 7.2, followed by a discussion of the implementation processes that were conducted during Fieldwork II (section 7.3). Section 7.4 outlines the outcome of the study, while section 7.5 presents some conclusions and the implication to the assessment stage.

7.1 INTRODUCTION

Prototype 2 of the IRME curriculum was designed based on the results of the implementation of prototype 1. This chapter describes the development of prototype 1 into prototype 2 and the implementation of prototype 2 in two Indonesian primary schools. The main focus of the research in this stage was to investigate the validity and the practicality of the IRME curriculum.

As mentioned in the last section of Chapter 6, some of the results from the implementation of prototype 1 led to the improvement of the content of the IRME curriculum. This implied that the content and construct validity of the IRME curriculum had to be re-evaluated by experts and the learning trajectory for learning the topic Area and Perimeter had to be re-investigated through the classroom experiments. Few aspects of the practicality of the IRME curriculum were also evaluated during Fieldwork I. In this stage, the aspects of the practicality that have been evaluated were broadened, and the number of experts and users who evaluated the practicality were also more than those in Fieldwork I.

This purpose was realized by formulating the following research question:

What are the characteristics of a valid and practical IRME curriculum for the geometry instruction topic Area and Perimeter at grade 4 in Indonesian elementary schools?

By implementing the prototype 2 of the IRME curriculum in the classroom practices, there was the opportunity to investigate some aspects of the effectiveness such as pupils' reaction and pupils' learning outcomes, therefore these aspects were also evaluated during the classroom experiments. Table 7.1 below summarizes the evaluation activities on the validity, practicality and effectiveness of prototype 2 of the IRME curriculum.

Table 7.1
The evaluation activities for the development and implementation of prototype 2

Object Evaluation	**Data Collection (Method)**	**Instruments**
The validity of the IRME curriculum: ▪ Validating the characteris tics/content and construct validity (see Chapter 4, section 4.3.2) ▪ testing the characteristics	Interview and discussion with the Dutch RME experts and Indonesian subject matter experts, classroom observations, analysing pupil's portfolios.	Interview guidelines, observation scheme.
The practicality of the IRME curriculum focused on the aspects mentioned in Chapter 4, section 4.3.2	Interview and discussion with the Dutch RME experts, Indonesian subject matter experts, teachers, principals, inspector and pupils, and classroom observations.	Interview guideline, observation scheme.
The effectiveness of the IRME curriculum focused on the aspects mentioned in Chapter 4, section 4.3.3)	Interview with teachers and pupils, classroom observations, pre-test and post-test, assessments, and analysing pupil's portfolios.	Interview guidelines, observation scheme, and test and assessment materials.

7.2 THE DEVELOPMENT OF PROTOTYPE 2

This section discusses the development of the second draft of the IRME curriculum into prototype 2. This second draft of the IRME curriculum was designed based on the results of the classroom experiments during Fieldwork I. Prototype 1 and the second draft differed on some aspects such as:

- The number of the contextual problems was reduced by skipping some of the contextual problems regarding the tessellations, without changing the learning trajectory. The learning trajectory was not changed because the function of the contextual problems that were skipped could be covered by the others. Besides, as Gravemeijer (1994) says, the tessellations are just like an excursion in geometry.
- Some contexts in the contextual problems were changed especially those that were not used by the pupils when they solved the contextual problems.
- There was an enrichment section in each lesson that was provided for smart pupils who could finish solving the given contextual problems earlier than other pupils.
- There were the letters to the pupils and parents printed at the beginning of the student book, so that they could have a general idea about the new approach.

The development of the second draft into prototype 2 of the IRME curriculum followed a cyclical process as described in Figure 7.1.

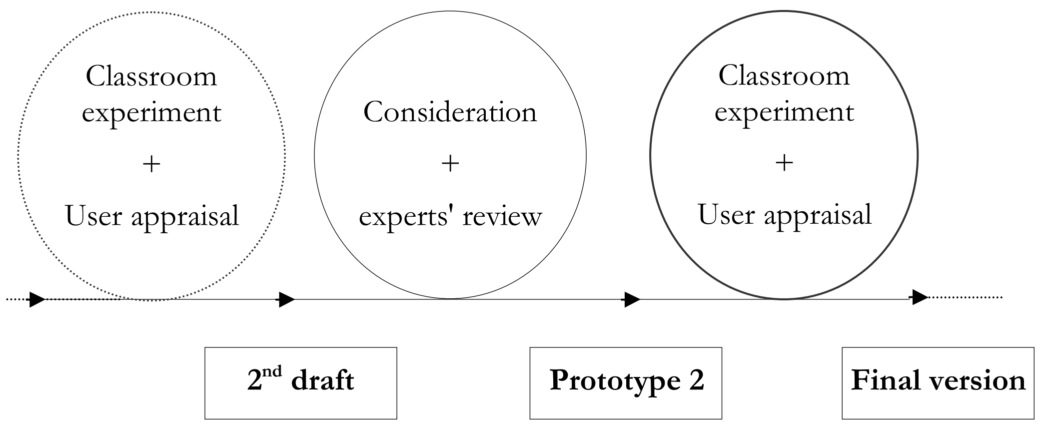


Figure 7.1
The development of prototype 2 of the IRME curriculum

During the cyclical process, the content and the construct validity of the second draft were evaluated by three Dutch RME experts. The evaluation was performed by asking the experts some questions regarding the aspects of the validity (see Chapter 4, section 4.3.2 and Appendix E) and also by conducting a series of discussions. However, only one expert (called *expert 1*) answered the questions in writing and the other two (called *expert 2 and 3*) preferred to have only a discussion. Expert 1 answered all the questions with a "OK", which meant he approved the content and the construct validity of the second draft of the IRME curriculum.

In the discussions with expert 2, he mentioned some important points that should be included in the topic Area and Perimeter such as *relating Area and Perimeter to other magnitudes*, *reshaping, adding and subtracting area*, by referring to the book used in the project Wiskobas (see Chapter 5). These important points were included in the IRME curriculum because the same book was used as a reference in designing the curriculum, and expert 2 approved of this condition.

The discussions with expert 3 were conducted several times. In general he approved the content and the construct validity of the IRME curriculum. Nevertheless, he gave the following suggestions. The first two points were related to the teacher guide, while the others concerned the student book.

- Be aware about developing concepts or strategies in solving the contextual problems.
- It has to be clear how the strategies and concepts are related to each other?
- Add the contextual problems that would show the idea of approximation and that the results of measurements are never exact.
- Add contextual problems related to triangles that have vertical bases and horizontal height.

Based on the explanation above, the author concluded that the IRME curriculum met the criteria of the content and the construct validity according to the RME experts' point of view.

The Dutch RME experts also evaluated the practicality of the IRME curriculum. The evaluation was performed in the same way as that for the validity. Expert 1 gave the comments on the aspects of the practicality (see Chapter 4, section 4.3.2 and Appendix E) in writing, while the other two preferred to discuss the aspects. In general the experts approved the practicality of the IRME curriculum. However, regarding the potential of the IRME curriculum in developing pupils' understanding, reasoning, activity and creativity and also to improve pupils' motivation, the experts said that it depended very much on the willingness, knowledge and skills of teachers when implementing the curriculum.

Using the same process as that for the first draft, the second draft of the IRME curriculum was also reviewed by four subject matter experts from Indonesia and one primary school teacher. The reviewing process was focused on the appropriateness of the IRME curriculum for the pupils at Grade 4 in Indonesian primary schools. There were some suggestions from the reviewers regarding the language and one expert recommended using pictures of real objects in all contextual problems. The author could not realize the suggestion from the expert because of the time constraints, and also because it did not seem to be necessary. As in the RME theory, the term "realistic" does not always mean "real object". It can be something in the pupils' mind and something that the pupils are already familiar with (see Gravemeijer, 1994). Moreover, a real picture is not always the best choice to present in a contextual problem, because sometimes it can cause distraction.

After improving the language and the wording of some contextual problem, the second draft was called prototype 2 of the IRME curriculum. The following section discusses the implementation of prototype 2 in two Indonesian primary schools.

7.3 THE IMPLEMENTATION OF PROTOTYPE 2

The implementation of prototype 2 of the IRME curriculum was conducted during Fieldwork II in two primary schools namely SD N Percobaan Surabaya and SD Percobaan Padang. The main reasons for choosing the two schools were similar to those when implementing prototype 1 of the IRME curriculum (see Chapter 6, section 6.3). Moreover, the cultures of the two places were different so this would probably enrich the results of the research. The differences in the culture and the local language led to a few changes to the context of the contextual problems. For example, the pupils in Padang did not recognize the context of *Wingko Babat* (see contextual problem 5, lesson 1, in Appendix 1) so that the context was changed to become *Kue Lapis*.

SD N Percobaan Surabaya had two parallel classes: class IVA had 22 pupils and class IV B had 21 pupils. The pupils in each class were heterogeneous in their academic ability. SD N Percobaan Padang divided the pupils into three classes based on their academic ability: one class of upper group (class IV A with 37 pupils) and two classes of lower group (class IV B with 38 pupils and class IV C with 39 pupils). The implementation process in Padang was only conducted in two classes

(IV A and IV B), because class IVB and IVC had the same characteristics. Table 7.2 below summarizes the activities that were conducted during Fieldwork II in Indonesia, from August 2000 until March 2001.

Table 7.2
The activities in Fieldwork II

Activities	**Time**
1. Research preparation	August – September 2000
2. Finding the schools for the implementation	September 2000
3. Administration for the permission of the research in Surabaya	2- 7 October 2000
4. Giving a short training for the observers in Surabaya	7 October 2000
5. Classroom experiments in Surabaya	9 – 28 October 2000
6. Interview with the pupils in Surabaya	26 – 28 October 2000
7. Administration for the permission of the research in Padang	2 – 6 January 2001
8. Giving a short training for the observers in Padang	6 January 2001
9. Classroom experiments in Padang	8- 27 January 2001
10. Interview with the teachers and pupils in Padang	29 – 31 January 2001
11. Data analysis	February – March 2001

One teacher from each school was scheduled to teach in one class and the author would teach in the other class. But after two classroom experiments, both teachers withdrew for different reasons. The teacher in Surabaya was away from the school because of family business, while the teacher in Padang felt that she was not yet capable to teach using the RME approach. The latter teacher said that she needed more time to learn the approach, and preferred the author to teach the two classes while she took the role of observer. This situation meant that the author himself taught the two classes in each school. The author did not conduct training for the teachers before they taught in the class, because only one teacher was involved in each school. Instead of a structured training, discussions were conducted with each of the teachers in order to inform them about the RME approach and ideas that were going to be implemented. For the remainder of this chapter the term *teacher* refers to the author, while the teachers from the schools are called *classroom teachers*.

The classroom experiments in each school took three weeks (10 lessons), and were monitored by several observers. In Surabaya, there were four observers (three Ph.D students and one lecturer from Surabaya State University). Meanwhile, a lecturer from Padang State University and the teacher performed the observations in Padang.

The observers observed the classroom experiments using the observation scheme (see Appendix D). There were two aspects that needed to be observed namely *the general aspect* and *the specific aspect*, and the observers were asked to describe each aspect in as much detail as possible when conducting the classroom observations. The general aspect referred to pupils' activities in solving the contextual problems in general, and teachers' activities in dealing with the pupils. The following examples are points that needed to be observed with regard this aspect:

- Did the pupils understand the contextual problems? If they did not understand, what problems did they have, and what did the teacher do to overcome the problems?
- Did the pupils use their own ideas or strategies in solving the contextual problems? If they did, describe the ideas or strategies the pupils came up with. If they did not, describe what the teacher did in dealing with this situation.
- Did the contexts help the pupils in solving the contextual problems? If they did, explain how the pupils used the contexts. If they did not, explain what the pupils did to solve the contextual problems.
- Describe pupils' motivation and activities during the learning and teaching process

The specific aspects contained the items regarding what happened when the pupils solved each particular contextual problem, such as *how did the pupils solve the contextual problems? What kinds of solutions did they come up with? What kinds of reasons did they use?* Some examples (used for observing lesson 1) of this aspect can be seen below:

- Describe the strategies the pupils used in comparing the rice fields
- How did the pupils deal with the non-standard measurement units in contextual problems 3 and 4?
- Describe pupils' understanding that a shape can also be arranged to form a different shape by cutting and pasting.
- Describe pupils' understanding regarding the irregular shapes

The following section summarizes the outcome of the classroom experiments and evaluation activities during Fieldwork II. The findings of the classroom experiments are not presented in as much detail as those in Chapter 6 because there were many similarities. For the same reason, the discussion about the findings in the two schools is also combined.

7.4 THE OUTCOME OF FIELDWORK II

This section describes the results of Fieldwork II. The validity, practicality and effectiveness of the IRME are discussed consecutively in sections 7.4.1, 7.4.2 and 7.4.3, while section 7.4.4 outlines some notes from the classroom experiments.

7.4.1 The validity

The focus of evaluation regarding the validity of the IRME curriculum was to investigate whether the conjectured learning trajectory for learning and teaching topic Area and Perimeter worked as intended. In this study, the indication of whether the conjectured learning trajectory worked as intended or not was showed in two ways. Firstly, it worked if in general the pupils could learn the topic Area and Perimeter without any significant difficulty. This condition was measured by analyzing the observation scheme with regard to the general aspect as described in the previous section (see also Appendix D), and by asking the observers and the teachers for their general impressions.

After summarizing the observation scheme completed by the observers it was found in general that the conjectured learning trajectory for learning and teaching the topic Area and Perimeter had worked as intended. The observers and the classroom teachers said that in general the pupils could understand the contextual problems presented in each lesson. As being the teacher, the author also observed that no significant problems occurred when the pupils followed the learning and teaching process, and the observers and the teachers agreed with this condition. This showed that in general the pupils could learn the topic Area and Perimeter according to the conjectured learning trajectory that was designed for them.

Secondly, the conjectured learning trajectory worked if the conjectures used in designing the contextual problems were corroborated in practice. Here the term *corroborated* refers to the condition in which most pupils act and reason as expected. This condition was investigated by analyzing the pupils' portfolios, and the observation scheme regarding the specific aspect (see section 7.3 and Appendix D). As described in Chapter 5, each contextual problem was design based on certain conjectures (see also the explanation about each contextual problem in the student book in Appendix A). These conjectures included *the activities the pupils would undertake, the strategy the pupils might use*, and *the solutions the pupils might come up with*, in solving a contextual problem. Moreover, there were also some conjectures used in sequencing the contextual problems in one lesson as well as in sequencing the lessons (see the details in Chapter 5).

There were many conjectures behind designing the contextual problems in the IRME curriculum, the key points of these conjectures can be summarized as follows:

- Broadening the concept of area using irregular shapes.
- Using various strategies in solving the contextual problems.
- The exchange of measurement units as a counting strategy.
- Using the grids as a model.
- The enclosing rectangles.
- The relation between rectangles, parallelograms, and triangles.
- The relation between Area and Perimeter.

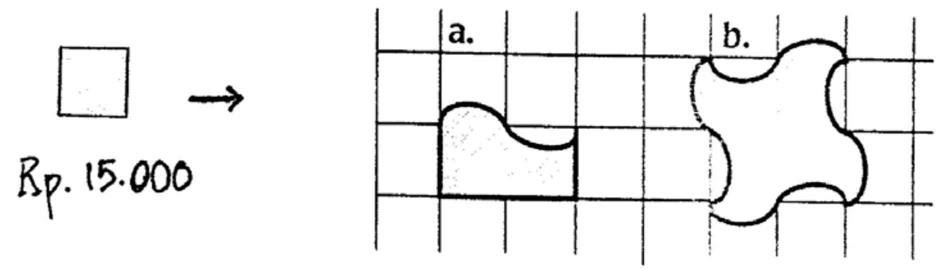
After analyzing the pupils' portfolios and the observation scheme (with regard to the specific aspect) completed by the observers it was found that almost all key points listed above, except *using the grids as a model* and *the enclosing rectangles*, were corroborated in the classroom experiments. With regard to these two points, most pupils only used the grids as a counting method, but not as a model for reasoning, and they rarely used the idea of 'enclosing rectangles' to find the areas of the triangles. The following sections discuss the findings related to the others key points that were found by analyzing the pupils' portfolios and the observation scheme.

Broadening the concept of area using irregular shapes

In the IRME curriculum the concept of area was broadened by relating it to other shapes such as irregular shapes or surface of 3-dimensional objects. It was mentioned in the conjectured learning trajectory (see Chapter 5) that use of the irregular shapes were not only to show the pupils that the concept of area mostly deals with irregular shapes, but also to make them aware of the ideas of approximation (measurement is never exact) and reallotment.

Several contextual problems in the student book deal with the irregular shapes (see for examples contextual problems 1 and 2 (lesson 1), and 7 (lesson 2) in Appendix A). The pupils' portfolios showed that almost all pupils could solve these problems using the ideas of approximation and reallotment, and the observers also found that the pupils neglected the irregularities of the shapes presented in these contextual problems. One example of this condition can be seen when the pupils worked on the following contextual problem. In this case almost all pupils could answer this contextual problem correctly using the idea of reallotment:

*Tessellation **a** and **b** below are made from square tiles. If the price of a square tile is Rp. 15. 000, what is the price of each tessellation?*



Source: Mathematics in Context unit Reallotment, 1997.

Using various strategies in solving the contextual problems

In the conjecture learning trajectory it was mentioned that the pupils would develop various strategies in solving the contextual problems such as cutting and pasting, counting, reallotment, halving, addition, and subtraction. The strategies pupils use are not only important in developing their understanding of area and their ability to determine area, but also to give them a foundation that would help them to better understand how formal area formulas are derived.

After analyzing the pupils' portfolios and the descriptions made by the observers when the pupils worked on each particular contextual problem, it was found that almost all contextual problems in the student book were solved by the pupils using more than one strategy. The pupils also construe almost all of the strategies for solving the contextual problems designed in the teacher guide. For examples the pupils used several strategies such as cutting and pasting, counting, combination of cutting and counting, and reallotment when solving the contextual problem about the rice fields (see contextual problem 2 in lesson 1, Appendix A). In addition, the pupils also used various strategies such as halving, reallotment, addition, and subtraction when solving the contextual problem 16 in lesson 4 (see Appendix A).

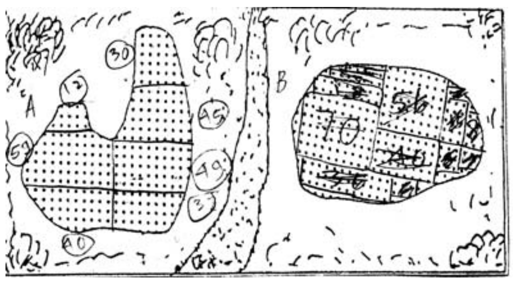
The exchange of measurement units as a counting strategy

As described in Chapter 5, *the exchange of measurement units as a counting strategy* was an important point in the conjecture learning trajectory as it is useful for helping pupils to understand:

- that the measurement units do not have to be the choice of squares as part of standardization;
- the concept of area as the number of measurement units that covers a surface;
- the formulas for the areas of squares and rectangles as length times width;

In the classroom experiments, the pupils worked on the contextual problems that involved various measurements units such as dot, Jati tree, tile, and square. It was found in this part of the study that the exchange of these measurement units as counting strategies (introduced through some of the contextual problems) helped the pupils to find the formulas for the areas of squares and rectangles by themselves. This condition can be explained through the following examples.

Firstly, some pupils used the dot as a measurement unit when they solved contextual problem about the rice fields (*note*: the other pupils used different strategies). One example of the pupils' work is presented below. We can see here that the pupil counted the numbers of dots effectively by dividing the rice fields into some small rectangles.



Secondly, when the pupils worked on contextual problem 1 in assessment 1 (see Appendix A), almost all pupils found the number of the Jati trees in the forests by multiplying the number of the Jati trees in one row by those in one column. These findings showed that the pupils had implicitly used the formulas for the areas of rectangles in solving these contextual problems. Finally, when the pupils worked on the contextual problems 10 -15 (lesson 4) in which they created squares and rectangles using 12 small squares, most pupils could find by themselves the formulas for the areas of squares and rectangles. Based on these findings, it was concluded that the conjectured learning trajectory relating to *the exchange of measurement units as a counting strategy* worked as intended.

The relation between rectangles, parallelograms, and triangles

In the conjecture learning trajectory it was argued that it would be better for the pupils to learn the concepts of areas of rectangles, parallelograms and triangles at the same time because these concepts are related to each other. The activities the pupils performed in learning the topic Area and Perimeter using the IRME curriculum were to change a rectangle into a parallelogram and vice versa. This activity was aimed at developing pupils understanding of the concept that a parallelogram and a rectangle that has the same based and height will have the same area. In addition, the pupils also performed the activities of cutting and pasting to form a rectangle or parallelogram by doubling a triangle and vice versa.

From the observation scheme completed by the observers, it was found that the majority of the pupils could understand the concept that a parallelogram and a rectangle that have the same base and height measurements will also have the same area, and that the area of a triangle is one-half of the area of a rectangle or parallelogram. The results of the post-test also showed that most pupils used the knowledge that they gained from the activities described above to answer correctly the test items number 3 and 4 (see the test items in Appendix C). The understanding of the pupils regarding these concepts can be seen from the note made by the observers on the observation scheme as follows:

After the pupils conducted an activity in which they cut a rectangle along one of its diagonals into two triangles, to create parallelograms (see contextual problems 2-3 in lesson 6) the observer made the following note:

Almost all the pupils found that the area of the rectangle was equal to the areas of the parallelograms. They also understood that the areas of the triangles were one-half of the area of the rectangle or the parallelograms. It was also observed that the pupils understood that the area of the rectangle was equal to the areas of the parallelograms because they were made from two congruent triangles.

The relation between Area and Perimeter

As discussed in Chapter 5, there is a strong belief that Area and Perimeter are directly proportional to each other (Gravemeijer (1992). Moreover, it is frequently found that pupils mix up the concepts of Area and Perimeter. In the IRME curriculum the concepts of Area and Perimeter were taught consecutively, as it was argued that this condition would not only help pupils to understand these concepts better, but also to make them aware of the effect that a systematic change in dimension has on Area and Perimeter. From the pupils' portfolios when they worked on the assessments for unit 5 (see Appendix A), it was found that more than 80 % of the pupils could solve correctly the problems regarding the effect that a systematic change in dimension has on Area and Perimeter (see also Table 7.8).

Based on the above findings, it was concluded that the conjectured learning trajectory design for learning and teaching the topic Area and Perimeter in the IRME curriculum worked as intended. The conjectures used in designing the contextual problems were corroborated in the classroom experiments in which most pupils acted and reasoned as expected.

7.4.2 The practicality

The aspects of the practicality of the IRME curriculum (see Chapter 4, section 4.3.2) was evaluated in Fieldwork II by interviewing four Indonesian subject matter experts, one inspector who had experience of being a teacher as well as a principal in a primary school, one principle, one teacher and 38 pupils. The pupils for interviews were selected from the upper groups and the lower groups in each class in order to gain information from two different viewpoints. The pupils from the middle group were not interviewed because it was assumed that their opinion would be in between that of the upper and lower groups. The interviews with the pupils in each school were done in-groups (small group evaluation), because they were too shy to be interviewed one by one. The interviews with the pupils were recorded using a tape recorder, while the interviews with the others were a noted on the notebook.

According to the subject matter experts, inspector, and principal, the IRME curriculum was usable and useful for teaching the topic Area and Perimeter. They all agreed on the potential of the IRME curriculum for developing pupils' understanding, reasoning, activity, creativity, and motivation, and that the student book was easy to use. One aspect of the practicality that they expressed doubts about was that the pacing provided for each lesson would not be enough. However, the experience from the classroom experiments showed that each lesson could be taught in the time provided.

The supervisor knew about the IRME curriculum because her own child studied in Class IV B SD N Percobaan Padang (one of the classes for the experiments). She voluntarily came to the school to talk with the author regarding the RME approach. She appreciated the approach and said that the content of the IRME curriculum was much better than that in the Indonesian curriculum. The principal also appreciated the RME approach and the IRME curriculum by saying that the teachers in her schools were supposed to teach in the way mentioned in the IRME curriculum. She criticized them for lacking initiative and creativity because most of them only used the textbooks for the teaching of mathematics, and most of the time they preferred the chalk and talk method.

The classroom teacher in Padang thought that the contextual problems in the student book would be difficult for her pupils, and it would need much more time to teach each lesson. From experience, she found it very difficult to make the pupils understand mathematics concepts, especially those in class IVB. She also predicted that it would be difficult to stimulate the pupils in class IVB to be active and creative in the teaching learning process. However, the results from the classroom experiments, especially from the pre-test and post-test, the assessment and the classroom observations, proved that the classroom teacher had underestimated her pupils. These results will be presented in the next section.

From the interviews with the pupils the information was gained that there were no pupils who had experienced significant difficulties when they used the student book. As in Fieldwork I, the pupils were also asked to read contextual problems that were chosen randomly, then they had to explain using their own words what the contextual problems were about. All pupils could perform this task satisfactorily.

7.4.3 The effectiveness

The effectiveness of the IRME curriculum was evaluated through the classroom observations, interviews with 38 pupils from the two schools, assessments, and pre-tests and post-tests. Referring to the levels of effectiveness mentioned by Kirkpatrick (1987), the evaluation of effectiveness of the IRME curriculum during Fieldwork II involved four aspects namely *pupils' reactions, pupils' learning, pupils' use of new knowledge and skills,* and *pupils' learning outcomes*. The results of the evaluation on each aspect are discussed consecutively in the following parts.

Pupils' reactions

The investigation of the pupils' reactions to the IRME curriculum was focused on the following questions:

- Did the pupils like the IRME curriculum?
- Was their time well spent?
- Did they experience the IRME curriculum as useful?

The data to answer these questions was collected by interviewing 38 pupils. They were interviewed in eight groups (two groups in each class). In the interviews all pupils said that they liked the IRME curriculum. They enjoyed working on the contextual problems presented in the student book and also the atmosphere of the teaching learning processes using the RME approach. The pupils valued the RME approach probably because it was very different to the traditional way of teaching. The contextual problems in the student book seemed to give many challenges and were more funs than the routine problems presented in the mathematics textbooks for primary schools in Indonesia.

The pupils also said in the interviews that their time was well spent. Most pupils, especially those from the upper groups, mentioned that they enjoyed a situation in which if they finished working on one contextual problem (in groups or individually), they could move to the next contextual problems or the enrichment section, without waiting for other pupils. This was because they liked competing with each other.
Regarding the usefulness of the IRME curriculum, all pupils said that it was very useful. However, similar to Fieldwork I, only a few pupils could explain why they thought the IRME curriculum was useful for them. Two of the pupils' comments can be seen as follows:

> *The IRME curriculum is very good to develop our reasoning because every time we have to explain our answers.*
> *The teaching learning process using the RME approach gives me more self-confidence. Before I was not so active in raising questions or in answering to the questions, but now I am not afraid anymore.*

Pupil's learning

In this level it was investigated *whether the pupils acquired the intended RME knowledge*. As discussed in section 7.4.1, almost all conjectures that were used to design the contextual problems in the IRME curriculum worked as intended. It meant that most pupils acted and reasoned as expected when they followed the learning and teaching process. This condition indicated that most pupils acquired the intended RME knowledge in learning the topic Area and Perimeter. The pupils' achievements on the assessments, pre-test and post-test that will be discussed later also showed that almost all pupils made a significant progress in the learning and teaching process using the IRME curriculum.

Pupil's use of new knowledge and skills

The effectiveness of the IRME curriculum on this level was related to the question: *did the pupils effectively apply the RME knowledge and skills?* This question was answered through the classroom observations and analysing the pupils' portfolios. From the pupils' portfolios and the observation scheme completed by the observers, it was found that most pupils could use the knowledge that they had acquired from one lesson in the next lessons. The discussion about *the exchange of measurement units as counting strategy* presented in section 4.7.1 showed that most pupils used their experience in counting dots and Jati trees (in lesson 1) to find out the formulas of areas of rectangles by themselves in lesson in lesson 4. It was also found that after the pupils experienced using the grids when determining the area of shapes in lesson 2, most of them continued to use the grids as a counting method in the next lessons.

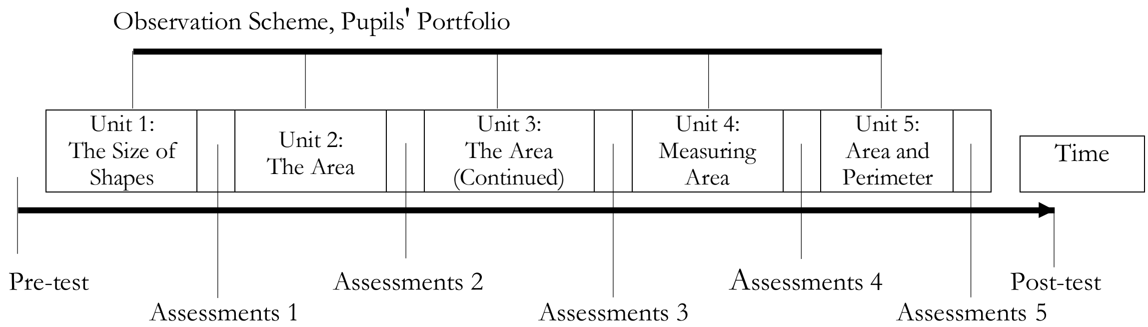
One strategy that the pupils developed in determining the areas of the geometry objects, especially triangles, was *halving*. The pupils' portfolios indicated that some pupils used this strategy from time to time when solving the contextual problems, even in the post-test. These pupils used halving strategy in solving the first item in the post-test (see Appendix C), although this item could be solved using counting strategy or formula. Nevertheless, some other pupils did not want to use this strategy because they had difficulties to divide numbers (especially odd numbers) by two, for example 3, 5, or 9 divided by 2. This group of pupils preferred reallotment strategy when solving most of the contextual problems.

Pupils' learning outcomes

The investigation of the pupils' learning outcomes was to answer the question: *what was the impact of the IRME curriculum on the pupils' performance and achievement?* The term *performance* here refers to pupils' confidence as learners, pupils' reasoning, activity, creativity, and motivation, while the *achievements* involved the results from the pre-tests, post-tests and assessments. The results of the evaluation on each aspect are presented as follows: a) pupils' achievements, b) pupils' confidence as a learner, c) pupils' reasoning, d) pupils activity, e) pupils' creativity, and f) pupils' motivation.

a. Pupils' achievements

The impact of the IRME curriculum on the pupils' achievement was measured by the pre-test and post-test, assessments, observation schemes, and pupils' portfolios. The next schema shows the time when each instrument was used during Fieldwork II.



The results of the evaluation activities using each instrument are presented consecutively as follows.

The findings from the pre-test and post-test

The pre-test was conducted a few days before the teaching learning process started, and the post-test was given after three weeks teaching learning processes. The test items in the pre-tests were the same with those in the post-tests (see Appendix C) because it was assumed that the pupils would not have the opportunity to recognize the item tests during the teaching learning processes. The test contained seven items in which five items were contextual problems (items 1 – 5), while the other two items (items 6 and 7) were the test items that are commonly used in the conventional mathematics tests. The test items were designed by consulting with two Dutch RME-experts.

The same test was also given to the pupils at Grade 5 in SD N Percobaan Padang (Class VA; the class was the upper group of pupils at Grade 5). The aim of this activity was to compare the pupils' achievements and to investigate how the pupils that were taught in the traditional way of teaching solved the contextual problems on the topic Area and Perimeter. The test was not given to the pupils at Grade 4, because there were some units in the IRME curriculum that were not included in the Indonesian curriculum for pupils at this grade.

The results of the pre-tests and post-tests in the experimental classes (the pupils at Grade 4 in Surabya and Padang), and the result of the post-tests in the control class (the pupils at Grade 5 in Padang) are presented in Table 7.3 below. The numbers of the pupils in this table are not the same as those mentioned in section 7.3, because some pupils did not take the pre-test or post-test. After analyzing the data using statistical program MINITAB, it was found that the pupils' achievements in the post-test in the experimental classes were significantly higher than their achievements in the pre-test on the level of significance 99 %. Moreover, the pupils' achievements in class IVA SD N Percobaan Padang and class IV SD N Percobaan Surabaya were significantly higher than the pupils' achievement in class VA SD N Percobaan Padang on the level of significance 95 %. The pupils' achievement in class IVB SD Percobaan was not significantly different than that in class VA SD N Percobaan Padang, even though their average achievement were higher.

Table 7.3
The pupils' achievements on the pre-test and post-test

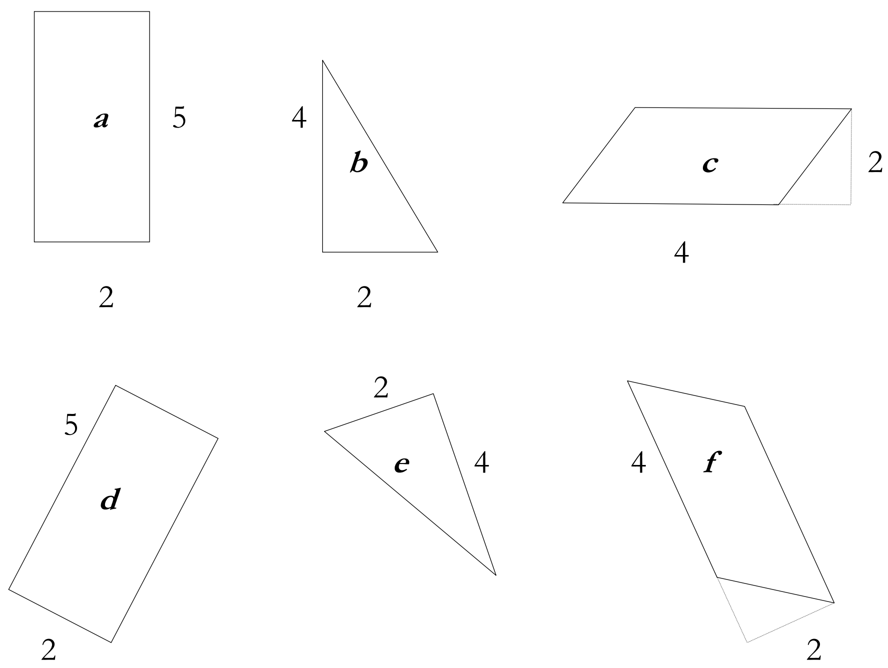
	School/Class	**Pre-test**			**Post-test**		
		N	*(χ)*	*s.d.*	*N*	*(χ)*	*s.d.*
Experimental Classrooms	IV SD N Percobaan Surabaya	39	7.26	4.21	41	12.96	5.89
	IVA SD N Percobaan Padang	36	9.09	2.85	37	16.21	2.97
	IVB SD N Percobaan Padang	37	4.95	2.58	36	12.10	3.37
Control Classroom	VA SD N Percobaan Padang	-	-	-	33	10.76	4.92

Note: the maximum score is 24, **N** = the number of pupils in each class, **(χ)** = the average scores, **s.d.** = standard deviation.

The difference between the pupils' scores for the test items regarding the contextual problems and the conventional problems was not analyzed statistically. However, from the way the pupils at grade 5 solved the test, it was found that they were not used to the contextual problems or solving a problem using an analysis. They also lacked in reasoning and understanding of geometry basic concepts. For example, some pupils compared the perimeter of the triangles when they were asked to compare the areas of those triangles. It seemed that the pupils mixed up the concepts of Area and Perimeter, and also misunderstood about the relation between Area and Perimeter. Another finding showed that five pupils at Grade 5 gave the answers in centimeters instead of "rupiah" for a question about prices (see item test number 2 in Appendix C).

As discussed in Chapter 2 and 5, the focus of the Indonesian curriculum in learning the topic Area and Perimeter was more on the quantitative and verbal aspects (i.e. the pupils could determine the areas and perimeters of various geometry object using the formulas). Therefore, the pupils at Grade 5 were supposed to be good in solving the following test item (test item number 6):

Determine the area of each figure below:



The pupil's answers on the test showed that none of 33 pupils at Grade 5 could determine the areas of the six shapes correctly, while 14 out of 114 pupils in the experiment classrooms answered this test item perfectly. These results indicated that the pupils that were taught using the RME approach were better not only in solving the contextual problems but also in applying the formulas for determining area of the geometry objects.

Further description of the pupils' achievements in the pre-test and post-test can be seen in Table 7.4 below. In this table, the pupils' achievements are categorized into three groups/levels namely upper, middle and lower. The numbers in the table indicate the percentage of the pupils in each level. We can see in this table that around 95 % of the pupils in each class were in the lower and middle group in the pre-test. However, more than 80 % of them were in the middle and upper group in the post-test. Meanwhile, only 67 % of the pupils at Grade 5 that achieved a score in the middle and the upper levels. This result indicated that most pupils made progress in learning the topic Area and Perimeter using the IRME curriculum. Some pupils even made a big improvement in their achievements. For example, pupil M from SD N Percobaan Surabaya only got score 8.3 in the pre-test (he was in the lower group), but then he got score 23.8 (almost perfect) in the post-test.

Table 7.4

The description of pupils' achievements in pre-test and post-test

Group/ Level	**Class IVA SD N Percobaan Padang**		**Class IVB SD N Percobaan Padang**		**Class IV SD N Percobaan Surabya**		**Class VA SD N Percobaan Padang**	
	Pretest	*Posttest*	*Pretest*	*Posttest*	*Pretest*	*Posttest*	*Pretest*	*Posttest*
Lower	44.4 %	2.7 %	94.6 %	11.1 %	69.2 %	19.5 %	–	33.3 %
Middle	55.6 %	48.6 %	5.4 %	80.6 %	25.7 %	51.2 %	–	54.6 %
Upper	–	48.6 %	–	8.3 %	5.1	29.3 %	–	12.1 %

Note: lower group: score 1 – 8, middle group: score 9 – 16, upper group score 17 – 24.

To see the progress of the pupils' achievement between the pre-test and post-test, the data in Table 7.4 are elaborated upon further in Tables 7.5, 7.6, and 7.7 below. In these tables we can see the number of pupils that stayed at the same groups/levels (did not make an improvement) after the post-test, and also the number of pupils that moved from one group/level to the others.

Table 7.5

The movement of the pupils' achievements between the pre-test and post-test in Class IV A SD N Percobaan Padang

	POSTTEST				
		Group/ Level			
	Group/ Level	*N*	*Lower* *N*	*Middle* *N*	*Upper* *N*
Pre test	Lower	16	1	7	8
	Middle	20	–	10	10
	Upper	–	–	–	–
	N	36	1	17	18

Note: **N** = the number of the pupils who took the pre-test and post-test, **n** = the number of pupils in each group/level, **%** = the percentage of the pupils in each group/level.

From Table 7.5 we can see that none of the pupils in Class IV A SD N Percobaan Padang was in the upper group in the pre-test, and 16 of them were in the lower group. However, in the post-test, there were 18 pupils in the upper group and eight of them moved up from the lower group.

Table 7.6

The movement of the pupils' achievements between the pre-test and post-test in Class IV B SD N Percobaan Padang

	POSTTEST				
		Group/ Level			
	Group/ Level	*N*	*Lower* *N*	*Middle* *N*	*Upper* *N*
Pre test	Lower	33	4	27	2
	Middle	2	–	1	1
	Upper	–	–	–	–
	N	35	4	28	3

Note: **N** = the number of the pupils who took the pre-test and post-test, **n** = the number of pupils in each group/level, **%** = the percentage of the pupils in each group/level.

As mentioned in section 7.3, Class IV B SD N Percobaan Padang was the class for the pupils with low academic ability compared to those in Class IV A. The data in Table 7.6 above showed that almost all pupils were in the lower group in the pre-test. Nevertheless, only four pupils that stayed in the lower group in the post-test, while the majority of them moved to the middle group and three pupils moved to the upper group.

Table 7.7
The movement of the pupils' achievements between the pre-test and post-test in Class IV SD N Percobaan Surabaya

	POSTTEST				
		Group/ Level			
	Group/ Level		*Lower*	*Middle*	*Upper*
		N	*N*	*N*	*N*
Pre test	Lower	26	6	16	4
	Middle	9	1	1	7
	Upper	2	-	-	2
	N	37	7	17	13

Note: **N** = the number of the pupils who took the pre-test and post-test, **n** = the number of pupils in each group/level, **%** = the percentage of the pupils in each group/level.

As can be seen from Table 7.7, the majority of the pupils in Surabaya were also in the lower group on the pre-test, nevertheless, only seven of them were in the lower group on the post-test. One of the pupils in this class fell back from the middle group to the lower group, but the reason for this could not identified. Around 19 % of the pupils' in Surabaya was in the lower group on the post-test. This was because some pupils did not have capability that would be expected from the Grade 4 pupils. They had a lack of understanding of basic concepts of the geometry and computation. Although the teacher gave much attention to help those pupils, it did not succeed. More information about these pupils will be discussed at the end of section 7.4.

The findings from the assessments

The assessments were designed to measure whether the pupils achieved the goals in learning the units in the IRME curriculum. There were five assessments (one for each unit) provided for the pupils, these can be found at the end of each unit in the teacher guide (see Appendix A). All the items in the assessments were the contextual problems, and their function was to assess the pupil's ability in achieving the goals of the units. The description of the pupils' achievements in the assessments for each unit is presented in Table 7.8 below. The pupils' achievements in this table are categorized into three groups/levels namely lower, middle and upper group. The maximum score for each assessment was 10.

Table 7.8
The description of pupils' achievements on the assessments

School/ Class	**Group/ Level**	**Unit 1:** *The Size of Shapes*	**Unit 2:** *The Area*	**Unit 3:** *The Area (Continued)*	**Unit 4:** *Measuring Area*	**Unit 5:** *Area and Perimeter*
IV SD N	Lower	-	5.5 %		6.5 %	
Percobaan	Middle		5.5 %	6 %	6.5 %	–
Surabaya	Upper	100 %	89 %	94 %	87 %	
IVA SD N	Lower	-	-	9 %		6 %
Percobaan	Middle	27 %	-	17 %	–	34.5 %
Padang	Upper	73 %	100 %	74 %		59.5 %
IVB SD N	Lower	-	5 %	-		22 %
Percobaan	Middle	26 %	30 %	40 %	–	11 %
Padang	Upper	74 %	65 %	60 %		67 %

Note: lower group: score 1 – 3, middle group: score 4 – 6, upper group score 7-10.

From Table 7.8 we can see that for each assessment more than 90 % of the pupils were in the middle and upper group, except for the assessment unit 5 in which 78 % of the pupils in Class IB B SD N Percoaban Padang were in the middle and upper group. For some assessments even, 100 % of the pupils were in the upper level. This result strengthens the findings described before that the IRME curriculum could promote the pupils' learning.

Some columns on the table are empty because the assessments prepared for those lessons were solved classically (there was no individual score). Those assessments were solved classically because of time constraints. The time for each lesson in the teacher guide was set for the period of 2 x 40 minutes, but the schools arranged some of the mathematics lessons in the timetables for period 3 x 40 minutes. This condition sometimes led to the situation in which the pupils could not finish working on the assessments in the schools, and they continued working at home. From the works of the pupils, it was found that some pupils got help from the parents, brothers or sisters when they worked on those assessments. Although in general the pupils' achievements in the assessments were excellent, nevertheless these few cases would be avoided in the next round of the study in order to get a more accurate conclusion from the assessments.

b. Pupils' confidence as a learner

This aspect was evaluated through the interviews with the pupils and the classroom observations. Most pupils in the interviews said that they had made progress in the learning process, especially in raising questions or giving responses to questions, and that they were no longer afraid to do those activities. The teacher and the observers also observed that it seemed that the pupils had started to realize that asking questions or answering the questions was a part of learning mathematics. It is argued here that there are two reasons for this finding. Firstly, the democratic conditions created by the teacher (see Chapter 6) stimulated the pupils to give their contribution in the teaching and learning process. As discussed in Chapter 2, in the traditional way of teaching pupils are used to the situation where the teacher tells everything, and there is almost no space for discussions, negotiating or sharing ideas in the classrooms. If a pupil gave a wrong answer to a question, then he or she would get negative comments from the teacher, or other pupils would laugh on him/her. But, teaching using the IRME approach provided the pupils with a different atmosphere than that in the traditional way of teaching.

Secondly, by working on the contextual problems in the IRME curriculum the pupils had the opportunity to learn geometry concepts based on their informal knowledge. This condition not only helped the pupil to understand the geometry concepts, but also gave them more confidence as learners because they were able to contribute to building the knowledge that they acquired. By acquiring the knowledge in this way, the pupils would understand the concepts better.

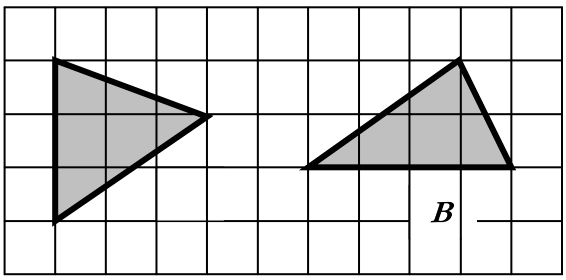
Moreover, it was observed that after a few lessons the dependent attitude of the pupils that was found at the beginning of the classroom experiments, especially in Class IV B SD N Percobaan padang, was changed toward a positive direction. This also indicated that the pupils' confidence as learners had improved, even the classroom teacher in Padang, who had underestimated her pupils before the classroom experiments, admitted that this was the case.

c. Pupils' reasoning

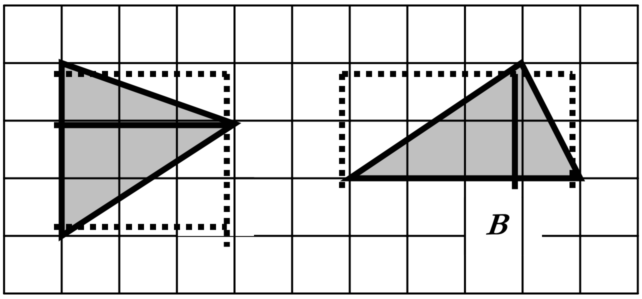
Like in the Fieldwork I, at the beginning it was very difficult to ask the pupils, especially those in Class IV B SD Percobaan Padang, to give a reason for their solutions of the contextual problems, neither orally or in writing. Most of them were only interested in the final results, and did not want to write down the process used in getting the results. It seemed that some pupils considered that writing down the process was only wasting time. Moreover, they were only interested in whether the answers were right or wrong, and did not want to pay much attention or listen to other pupils when they worked on the blackboard or gave an answer orally.

After the teacher doing similar efforts as those in Fieldwork I (see Chapter 6, section 6.2) the pupils started to put the reasons for their answers. At the beginning most reasons given by the pupils in solving the contextual problems were very weak and frequently not relevant to the questions. Nonetheless, in the second week of the classroom experiments, the observers and the teacher observed that most pupils showed a good progress in reasoning. The pupils' portfolios and the pupils' answers on the post-test also showed that some pupils frequently came up with very good reasons for their answers (see also section 7.4.1), as can be seen from one example below. The example is taken from the pupils' answers on the post-test (test item number 1). This test item could be solved using reallotment strategy, or by applying the formula, but some pupils preferred to use *halving strategy* to reason for their answers.

> *Father wants to buy one of the plots of land in the figure below to build a house. If the prices of the two plots are the same, which plot is the better one for Father to buy? Explain your answer!*



The pupils drew the following figure and found the area the area of the triangle A by halving two rectangles with the areas of 3 and 6: ½ (3) + ½ (6) = 4 ½ and the area of the triangle B: ½ (6) + ½ (2) = 4.



Considering that the figures in the test item were presented without *the enclosing rectangles*, it seemed that the pupil used their experience gathered from the lessons to reason for their answers. This finding also strengthens the conclusion made for *the pupils' use of the RME knowledge and skills* as mentioned before.

Pupil's Activity

The pupils' activity was evaluated through the classroom observations and the interviews. At the beginning, it was also difficult to motivate the pupils, especially those in Class IVB SD N Percobaan Padang, to be active in the teaching learning process. They were not used to working in-groups or to sharing ideas among themselves, and did not dare to raise questions about the lessons or to answer the questions from the teacher. Probably influenced by the traditional way of teaching most pupils were very dependent on the teacher. They came up with questions such as *Do we need to rewrite the contextual problems or re-draw the figures in their exercise book or not? Should we make the borderline in their exercise book?* Most of them always reported to the teacher if they finished solving a contextual problem then asked what they should do next, or they just stopped until they got the next instruction.

After the teacher stimulated them, they started to change their attitude, although from time to time the teacher had to remind them that they did not need to worry when they wanted to ask a question, or give a response to a question. The way the teacher stimulated the pupils was by having discussions before and after they solved the contextual problems. Before the pupils solved the contextual problems, the teacher asked some of them to explain using their own words regarding what the contextual problems were about. After that they were asked to share their ideas on how to solve the problems. When the pupils finished solving the contextual problems, the teacher conducted the discussion in order to discuss the solutions given by the pupils. This activity aimed at giving the pupils the opportunity to compare their solutions as well as to find the best solution.

The actions mentioned above succeeded in helping the pupils to develop their confidence and to be more active in the teaching learning process. Most pupils were not afraid to raise their own ideas anymore, and they started to come up with different ideas when solving a contextual problem. They also started realizing that the aims of solving mathematical problems were not only to get the correct or incorrect results or to get the marks, but also to develop their own activity and creativity. The following note (written by an observer in Padang when observing lesson 4) shows the pupils' activity:

> (The teacher showed the pupils a piece of A4 paper in the front of the classroom)…… *the pupils knew that the form of the paper was a rectangle although it was rotated…….the degree of interactivity between the teacher and the pupils was high. Every time the teacher asked questions, most pupils raised their hands willing to answer the questions……the pupils understood the concepts of side, right angle, rectangle and square.*

The findings described above show that the IRME curriculum had the potential to develop pupils' activity, and strengthen the findings regarding *the pupils' learning* and *the pupils' confidence as learners.*

Pupil's Creativity

Like was the case in the previous section, most pupils also lacked creativity at the beginning of the classroom experiments. They stuck to one kind of solution and most of the time did not have any idea on how to solve a contextual problem. However, after the teacher performed the effort as discussed before, it was found that progress was made in the pupils' creativity, except for those with a special case in SD N Percobaan Surabaya. The examples of the pupils' creativity can bee seen in section 7.4.1 in which most pupils used various strategies in solving the contextual problems.

It seemed that the discussions that were conducted by the teacher before and after the pupils solved the contextual problems stimulated the pupils to use their own ideas to solve the problems. Moreover, the opportunity the pupils had to use their informal knowledge and different strategies in solving the contextual problems probably also stimulated them to be more creative.

Pupil's motivation

The data about pupils' motivation were collected trough classroom observations and interviews with the pupils and the classroom teachers. From the observation scheme completed by the observers it was found that in general most pupils were highly motivated in the learning and teaching process, especially after the teacher has made some efforts as discussed in the previous sections. The classroom teachers and the observers agreed with this conclusion. An observer wrote the following notes on the observation scheme when observing the classroom experiments in Padang. The note was made when the pupils had been working in-groups for solving contextual problem number 1 in lesson 3.

> *The pupils get motivated. They perform cutting and pasting. Although some of them are not careful enough in doing these tasks, but in general they enjoy working together The pupils are so active and highly motivated that they dash away to write the answers on the blackboard.*

In addition, based on the interviews with 38 pupils, it was found that all of them enjoyed the learning and teaching processes using the IRME curriculum. In particular cases, some pupils showed the improvement in their motivation, as can be seen as follows:

- According to the classroom teacher in Padang, three of her pupils in class IV B who were already in the second year at Grade 4 (they failed to get promotion to Grade 5 in the year before) were highly motivated in learning mathematics compared to before. Two of them participated in discussions actively, and the other attended the school more frequently (he used to come to school only for a few days in a month).
- In Surabaya, one pupil (pupil W) showed a big improvement in motivation. All his friends in the interviews said that pupil W was the one who made the biggest progress. He used to be a very silent pupil and had a lack of motivation, but now he was highly motivated during the teaching learning process. Pupil W himself agreed with his friends' opinion. He said that he liked the materials and the way the teaching learning processes were conducted.

An interesting fact regarding pupils' motivation was also found. Most pupils had more motivation if the solutions of the contextual problems were discussed classically, so that they had opportunity to express their joy after realizing that they had solved the problems correctly. They also preferred to get the marks directly from the teacher, after they solved a contextual problem, and they would be less happy if this activity was delayed. This situation was probably influenced by the *tradition* in which the parents at home keep asking their children about the mark that the pupils get after they have a mathematics lesson. Nevertheless, sometimes it was difficult to keep the pupils' attention (especially in class IVB SD N Percobaan Padang). Because the was weather, also the mathematics lesson lasted for two consecutive hours and it was at the end of school day, so the pupils were not really focused on the lesson.

Some notes from the classroom experiments

This section describes some other findings from the classroom experiments:

- As mentioned in section 7.3, the pupils in Surabaya were heterogeneous in academic ability. About one third of the pupils could be categorised as the upper group, another one third as the middle group and the remainder as the lower group. The upper group showed very good ability in learning the topic Area and Perimeter. This could be seen from their achievements in the assessments and the post-test in which some of them almost got a maximum score in the post-test. During the teaching learning process they could solve almost all-contextual problems in the pupil's book by themselves, and found almost all the strategies for solving the contextual problems prepared in the teacher guide. They were also highly motivated to work on the contextual problems so that every time they finished solving a contextual problem they moved to the next one without waiting for the instruction from the teacher. The pupils in the middle group needed the instructions from the teacher from time to time when they did an activity, and they also lacked creativity. Meanwhile, the pupils in the lower group could be characterised as follows:
  - They were very weak in basic multiplication, fraction and drawing geometric figures, although they had been taught about these topics. For example, they did not know: 8 x 7 = ….., a half of 6, a half of 9, etc.
  - They could not answer a simple question from the teacher, one of them could not even write properly.
  - They could work on the contextual problems if the teacher stood beside them and then gave them step by step guidance.

The conditions as described above presented a problem to the teacher during the first week of the classroom experiments in SD N Percobaan Surabaya. The teacher paid too much attention to the lower and the middle group so that the pupils from the upper group could not be stimulated maximally. After realizing that the problems with the pupils in the lower group could not be overcome in a short period, the teacher reduced the attention given to helping them.

This situation did not occurr in SD N Percobaan Padang, probably because the pupils in each class were rather homogeneous. Nevertheless, it was also found that some pupils in Class IV B lacked the basic concepts regarding multiplication and fraction so that they made some mistakes in solving the contextual problems.

- The classroom teacher in Padang withdrew after she taught two lessons in the teacher guide. As outlined in section 7.4.2, the classroom teacher thought that the content of the IRME curriculum was difficult for her pupils, and she also underestimated the pupils' capability. When teaching the two lessons, the classroom teacher dominated the whole process, and did not give much of opportunities to the pupils to think and to show their ability. Every time the teacher asked a question, she was not patient and did not wait for the pupils' answers. She also had a tendency to ask the questions only to smart pupils, in order to give the impression (to the author and observer) that the teaching learning process was running smoothly. It seemed that the classroom teacher lacked confidence to be observed when she was teaching. After teaching for two sessions, the classroom teacher said that she was not really capable to teach using the RME approach and preferred to be the observer.
- There were some problems found during the classroom experiments regarding the *neighbourhood* and the *timetables*. The classrooms in the two schools were not built very well so that the pupils could hear the noise from other classes. Moreover, the pupils from other classes who did not have the lessons played around in the schoolyards and made a lot of noise. Then, the two schools arranged the time for mathematics lessons for two hours or at the end of school time. In addition to this, the pupils in Surabaya also had timetables for a mathematics lesson after a sport lesson. It was found that this arrangement was not conducive for the learning and teaching mathematics, because the temperature was high and pupils could not fully concentrate.

- Learning from the experience in Fieldwork I, the author felt much more comfortable in teaching using the RME approach during Fieldwork II. The benefit was not only in how to handle the problems that occurred in the classrooms but also in how to react to the pupils' answers or contributions and how to guide and stimulate the pupils in solving the contextual problems.

7.5 SOME CONCLUSIONS AND THE IMPLICATION TO THE ASSESSMENT STAGE

This section outlines some conclusions from the development and implementation of prototype 2 of the IRME curriculum (section 7.5.1), and the implications of the findings from the development and implementation processes to the next round of the study (section 7.5.2).

7.5.1 The conclusions

Referring to the findings described in the previous sections, the following conclusions could be drawn from the development and implementation of prototype 2 of the IRME curriculum.

1. The results from the experts' validation, involving three Dutch RME-experts, four Indonesian subject matter experts and one classroom teacher, showed that the IRME curriculum material reached the criteria of the content and construct validity (see Chapter 4, section 4.3.2). 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 IRME curriculum developed and implemented for pupils at Grade 4 in Indonesian primary schools met the criteria of *the content and construct validity*. It means that the learning trajectory designed in the IRME curriculum can be used as a local instructional theory for learning and teaching the topic Area and Perimeter. The characteristics of the valid IRME curriculum can be described as follows:
   - The content of the IRME curriculum included the subjects that were supposed to be taught for learning the topic Area and Perimeter based on the RME point of view (see Chapter 5). In this case pupils' understanding of the concepts of Area and Perimeter was built by relating the concepts to other magnitudes such as costs, weight, and to irregular shapes. The reason

for this is that in reality pupils mostly deal with the concepts of Area and Perimeter in regard to these matters.

- The content of the IRME curriculum reflected the RME's key principles. When learning the topic Area and Perimeter using the IRME curriculum, the pupils had the opportunity to find out the concepts involved in the topic by themselves. They learned the topic Area and Perimeter based on the phenomena that they were familiar with, so that they could build an understanding of the topic using their informal knowledge. They also had the opportunity to use their own ideas in solving the contextual problems in the IRME curriculum.
- The IRME curriculum reflected the RME's teaching and learning principle (see Chapter 3)
- The RME curriculum included some important aspects of realistic geometry, especially *measuring and calculating*, and *spatial reasoning* (see Chapter 3).
- The content of the IRME was sequenced properly, in which the learning trajectory for learning the topic Area and Perimeter (see Chapter 5, section 5.3.3) could guide the pupils to learn as intended.
- The goals for each lesson in the IRME curriculum were clearly stated, and the content designed for each lesson was well chosen to meet the goals.
- The relevance and importance of the units in the IRME curriculum were explicit (see Chapter 5, section 5.4).

2. The Dutch RME experts, Indonesian subject matter experts, inspector, and principal agreed that the IRME curriculum had potential to develop pupils' understanding, reasoning, activity, creativity and motivation. They also agreed that the IRME curriculum would be usable and useful for teaching the topic Area and Perimeter. The results from the interviews with the pupils indicated that the student book was easy to use. Based on these results it could be concluded that the IRME curriculum reached the criteria of the practicality (see Chapter 4, section 4.3.2). Considering that the practicality would be evaluated in a broader context in the assessment stage, the characteristics of the practical IRME curriculum will be discussed in Chapter 8.
3. The investigation on four levels of effectiveness: pupils' reactions, pupils' learning, pupils' use of new knowledge and skills, and pupils' learning outcomes led to the following conclusions:

- The pupils liked the IRME curriculum, and admitted that it helped to develop their self-confidence and reasoning
- Most pupils acquired the intended RME knowledge. They found out several geometry concepts by themselves after performing the activities designed in the IRME curriculum and also various strategies in solving the contextual problems.
- Most pupils could use the new knowledge and skills that they had acquired from one lesson in the next lessons. This conclusion is not valid for the few pupils who lacked of knowledge of the basic mathematics concepts.
- The pupils' learning outcomes showed that the IRME curriculum gave a positive impact on the pupils' confidence as learners, and their understanding, reasoning, activity, creativity and motivation. The pupils' achievements in the post-tests were significantly higher than their achievements in the pre-tests.

7.5.2 The implication to the assessment stage

The results of the development and implementation of prototype 2 indicated that there were no further improvements that were needed to be carried out on the IRME curriculum. It meant that the IRME curriculum reached the final version, which could be used for the classroom experiments in the assessment stage. The assessment stage of the study was designed to gain further insights about the practicality and effectiveness of the IRME curriculum. The term *further insights* mean two things: first, the number of schools for the classroom experiments would be increased, and some classroom teachers would be involved in the implementation of the IRME curriculum. The second condition led to the need that the conjectured learning trajectory would be evaluated further when the classroom teachers would implement the IRME curriculum in their classrooms. Moreover, some aspects of the practicality regarding the usefulness of the teacher guide would also be evaluated. Learning from the experience of the classroom teacher in Padang who withdrew because of inadequate preparation, a training would prepare the classroom teachers before they would teach in the classroom experiments.

CHAPTER 8

THE FINAL VERSION OF THE IRME CURRICULUM

After the development and implementation of two prototypes of the IRME curriculum during the prototyping stage, this study moved to the last phase called the assessment stage. In this stage the final version of the IRME curriculum was implemented in five Indonesian primary schools in order to gain more insights about the practicality and effectiveness. This chapter presents the results of the assessment stage. The first part of the chapter (section 8.1) outlines the research question and the evaluation activities. Section 8.2 describes the research activities in the assessment stage that were mainly conducted during Fieldwork III in Indonesia. The outcome of the classroom experiments and the evaluation activities are elaborated upon section 8.3, and section 8.4 presents some conclusions.

8.1 INTRODUCTION

The results from the implementation of prototype 2 of the RME curriculum during Fieldwork II showed that no major changes had to be done, except for some editing of the texts in the teacher guide and the student book. After this editing was completed in prototype 2, the IRME curriculum reached the final version. This final version of the IRME curriculum was implemented in the assessment stage of the study through Fieldwork III in Indonesia. The main focus of the assessment stage was to investigate the practicality and the effectiveness of the IRME curriculum in a broader context than that in the previous stages of the study. The broader context meant that the number of schools in which the classroom experiments took place was increased, and some teachers were involved in implementing the IRME curriculum. The research question in the assessment stage of the study was formulated as follows:

What are the characteristics of a practical and effective IRME curriculum for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian elementary schools?

Considering that four teachers implemented the IRME curriculum, some aspects of the validity and practicality were also re-evaluated during Fieldwork III. The investigation on the validity was focused on whether the conjectured learning trajectory worked as intended, when teachers implemented the IRME curriculum in the classrooms. Meanwhile, the main aspect of the practicality that was evaluated was the usefulness of the teacher guide for teaching the topic Area and Perimeter and for applying the RME approach. The evaluation activities for the assessment stage are summarized in Table 8.1.

Table 8.1
The evaluation activities in the assessment stage

Object Evaluation	Data Collection (Method)	Instruments
1. **The validity of the IRME curriculum:** focused on the conjectured learning trajectory	Classroom observations, analysing pupils' portfolio	Observation scheme
2. **The practicality of the IRME curriculum:** focused on the aspects mentioned in Chapter 4, section 4.3.2)	Interviews with teachers and pupils, classroom observations	Interview guide-lines, observation scheme
3. **The effectiveness of the IRME curriculum:** focused on the aspects mentioned in Chapter 4, section 4.3.3)	Interview with pupils, classroom observation, analysing pupils' portfolios, assessment and pre-test and post-test	Interview guide- lines, observation scheme, assess-ment and test materials.

8.2 THE IMPLEMENTATION OF THE FINAL VERSION

The final version of the IRME curriculum was implemented in two places: Padang (West Sumatera) and Surabaya (East Java). The classroom experiments in Padang were conducted by the author in three primary schools namely SD N Percobaan (Class IV A), SD 16 and SD 28 Polonia, Kecamatan Padang Utara. The author decided to implement the final version of the IRME curriculum himself to justify the results gained from Fieldwork I and II, especially regarding the impact of the IRME curriculum on the pupils' performance and achievement. The implementation of the final version of the IRME curriculum in Surabaya took place in two primary schools: SD Laboratorium in Surabaya State University (Class IV A and IV B) and SD Al-Hikmah (Class IV C and IV D). Two teachers (one teacher from each school) and two Ph.D. students from Surabaya State University (Unesya) conducted the classroom experiments in Surabaya.

The main reason for choosing the schools mentioned above for the classroom experiments was to gain more insights into the practicality and the effectiveness of the IRME curriculum, and because of the willingness of the two teachers in Surabaya to get involved in this research. In general, the academic ability of the pupils in those schools was different (based on the pupils' achievement from the last year), as can be seen from Table 8.2 below.

Table 8.2
The characteristics of the pupils from the classroom experiments

Schools	**Pupils' ability**
SD N Percobaan Padang	Average to High
SD N 16 Polonia Padang	Low to Average
SD N 28 Polonia Padang	Low to Average
SD Laboratorium Surabaya	Low to High
SD Al-Hikmah Surabaya	Low to High

The pupils in SD N Percobaan Padang were homogeneous in their academic ability, while those in the other schools were heterogeneous. Based on the information gathered from the teacher in each school in Surabaya, it was already known that the pupils in Class IV A SD Laboratorium were much better in mathematical ability than those in Class IV B, while the pupils in Class IV C SD Al-Hikmah were always very noisy during the teaching learning process. SD Al-Hikmah was a full-day school (the pupils were in the school for about eight and a half hours/day), while the other schools were half-day schools (the pupils were in the school for about five and a half hours/day). The intention behind of these particular schools was not to make comparison among them, but to gain information as to whether the IRME curriculum worked as intended in the different school conditions.

Two teachers and four student teachers from Padang State University (UNP) observed the classroom experiments in Padang, while the classroom experiments in Surabaya were observed by nine observers (four Ph.D students, one master student, and two lectures all were from Surabaya State University, and two teachers). The observers, except the teachers, had all majored in mathematics education. In every lesson, at least two observers observed the classroom activities. One observer focused on the teacher's activities and the other focused on the pupils' activities. The teachers also observed the pupils' activities when they were teaching in the classrooms. Table 8.3 below presents the activities for the classroom experiments during Fieldwork III in Indonesia.

Table 8.3
The activities for the classroom experiments in Fieldwork III

Activities	**Place**	**Date**	**Time**
Training for observers	Padang	28- 29 September 2001	4 hours/day
Classroom Experiments	SD 16 Polonia Padang SD Percobaan Padang SD 28 Polonia Padang	8-27 October 2001 8-27 October 2001 22 October – 10 November 2001	
Reflection	Padang	15 October 2001	
Training for teachers	Surabaya	27 – 29 Dec. 2001, and 2 January 2002	4 hours/day
Training for Observers	Surabaya	27 – 28 Dec. 2001	4 hours/day
Classroom Experiments	IVA SD Lab. Surabaya IVB SD Lab. Surabaya IVC SD Al-Hikmah IVD SD Al-Hikmah	4 – 25 January 2002 4 – 25 January 2002 7 – 27 January 2002 7 – 27 January 2002	
Reflection 1	Surabaya	10 January 2002	
Reflection 2	Surabaya	20 January 2002	

The teachers and observers underwent training before they were involved in the classroom experiments. The training for teachers was conducted over four days (four hours per day). The training consisted of two main activities:

- The lecture, working groups, and discussion about the RME theory (four hours)
- Discussing the content of the teacher guide and each contextual problem in the student book (twelve hours). During the discussion the author also shared his experiences gained from Fieldwork I and II. The discussion about the contextual problems involved various solutions of the contextual problems, the possibility of the pupils' answers, the mistake that the pupils would probably make, and how to overcome them.

The training for the observers was conducted in two days (four hours per day). On the first day the observers joined the activities conducted for the teachers, while on the second day the training was focused on the list of aspects to be observed in the observation scheme.

There were two observation schemes used during this fieldwork. The first observation scheme (type 1) was to observe the pupils' activities, the second one was to observe the teacher's activities (see Appendix D). The observation scheme regarding the pupils' activities contained the following aspects to observe. In filling in the observation scheme the observers were asked to describe each aspect in as much detail as possible.

- Pupils' understanding of the contextual problems.
- Pupils' ability in using their own ideas or their own strategies in solving the contextual problems.
- Pupils' ability in finding various solutions.
- The role of contexts when the pupils were solving the contextual problems.
- Pupils' interaction during the learning and teaching processes.
- Pupils' activity, motivation, and reasoning.
- The role of the classroom discussions in helping the pupils' understanding.
- Pupils' attention to the process in finding the solutions.

The second observation scheme (type 2) contained the items regarding teacher's activities in stimulating or facilitating the pupils in relation to the aspects mentioned above. For example, *what did the teacher do to help the pupils to understand the contextual problems? What did the teacher do to stimulate pupils' reasoning?*

Some of the aspects described above, for both types of the observation scheme, were also provided in the form of a checklist. The observers were asked to fill this part of the observation scheme by crossing the options on the checklist. These options were presented in the form of numbers that referred to the Likker- Scale in which 1 means *very poor*, 2 means *poor*, 3 means *fair*, 4 means *good*, and 5 means *very good*. Moreover, in both observations scheme there were some items namely *the specific aspects*, in which the observers were asked to describe what happened when the pupils solved each contextual problem such as (see Appendix D):

- How did the pupils solve the contextual problem?
- What kinds of solutions did they come up with?
- What kinds of reasons did they use?
- Describe their understanding, for example about the situation in which two different shapes may have the same area.

8.3 THE OUTCOME OF FIELDWORK III

In general, the outcome of Fieldwork III was similar to that of Fieldwork II. The classroom experiments in Padang resulted in positive findings, especially regarding the effects of the IRME curriculum on the pupils. Meanwhile, despite some teachers' weaknesses found in the classroom experiments in Surabaya, the pupils also made significant improvement in learning the topic Area and Perimeter. Considering this, the discussion on the outcome of the classroom experiments in each school is combined in this section. The validity of the IRME curriculum is discussed in section 8.3.1 and section 8.3.2 outlines the practicality of the IRME curriculum. The latter also discusses some findings regarding the teachers' performance when they implemented the IRME curriculum. Section 8.3.3 presents the effects of the IRME curriculum on the pupils in learning the topic Area and Perimeter.

8.3.1 The validity

The focus of evaluation regarding the validity of the IRME curriculum was to investigate whether the conjectured learning trajectory for learning and teaching topic Area and Perimeter worked as intended when teachers implemented the IRME curriculum in the classrooms. As discussed in Chapter 7, the indication as to whether the conjectured learning trajectory worked as intended or not was shown in two ways. Firstly, it worked if in general the pupils could learn the topic Area and Perimeter without a significant difficulty. This condition was measured by analyzing the observation scheme type 1, and by asking the general impression of the observers and the teachers.

After analyzing the observation scheme type 1 filled in by the observers it was found that in general the conjectured learning trajectory for learning and teaching the topic Area and Perimeter worked as intended. The observers mentioned that in general pupils' understanding of the contextual problems in each lesson was good.

The results from the checklist (see Table 8.9 in section 8.3.3) made by the observers also showed the same finding. This indicated that pupils could learn the topic Area and Perimeter without any significant difficulty. The teachers also agreed with this finding, and one of them even gave a comment in writing as follows:

> "*According to me as an educator, the learning and teaching process using the RME approach in SD Laboratorium was running well*".

Secondly, the conjectured learning trajectory worked if the conjectures used in designing the contextual problems were corroborated (in which most pupils act and reason as expected) in practice. This was investigated by analyzing the pupils' portfolios and the observation scheme type 1 and 2, which focused on the specific aspects.

As mentioned in Chapter 7, there were several key points in the conjectured learning trajectory for learning and teaching the topic Area and Perimeter namely:

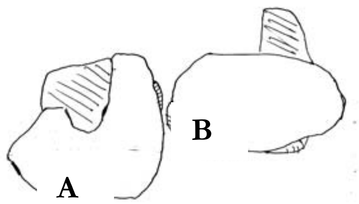
- Broadening the concept of area using irregular shapes.
- Using various strategies in solving the contextual problems.
- The exchange of measurement units as a counting strategy.
- Using the grids as a model, the enclosing rectangles.
- The relation between rectangles, parallelograms, and triangles.
- The relation between Area and Perimeter.

After analyzing the pupils' portfolios and the observation scheme it was found that the key points were corroborated in the classroom experiments. The following parts discuss the findings with regard to each of these key points.

Broadening the concept of area using irregular shapes

In the IRME curriculum the concept of area was broadened by relating it to other shapes such as irregular shapes or surface of 3-dimensional objects. The reasons for choosing the irregular shapes were not only to show the pupils that the concept of area mostly deals with irregular shapes, but also to make them aware of the idea of approximation (measurement is never exact) and reallotment.

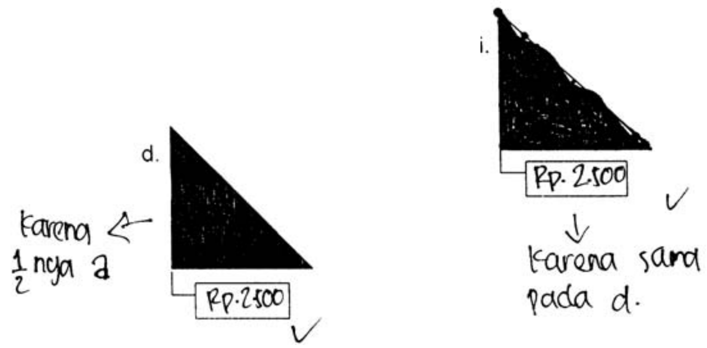
Several contextual problems in the student book deal with the irregular shapes such as contextual problems 1, 2 in lesson 1 (see Appendix A). From the pupils' portfolios, it was found that most pupils solved these two contextual problems using cutting and pasting or by cutting one figure then putting it on top of another figure. An example of the pupils' works on contextual problem 2 can be seen as follows:



The pupils (*note*: they were working in-groups) drew rice field A on top of rice field B, then did it in vice versa. By comparing the shaded parts the pupil came to the conclusion that rice field B produces more rice than rice field B. We can see here that the pupils used the idea of approximation and neglected the irregularities in comparing the two shapes. We can also observe from the pupil's answer that they showed a critical thinking because after putting one shape on top of the other they had to argue about the shape that had more area by observing carefully the parts that were not overlapped.

The same findings were found when analyzing the pupils' portfolios on contextual problem 4, in assessment 1 (see Appendix A). Here almost all pupils could determine the price of the cake that had an irregular shape (item 4i). The following two examples show that the pupils were not confused by the irregular shape. A pupil found that the price of the cake represented by the figure on the right hand side was a half of the price of the cake shown by the figure on the left hand side, although he realized that *the figure on the right had curves*.

Another pupil answered this problem by drawing a straight line to connect the two corners of the shape and found that the area of figure on the right hand side below was the same as the area of the figure on the left. Before that, the pupil had found that the price for the cake represented by the figure on the left hand side below was one-half of the price of the cake shown by the figure on the left side above.



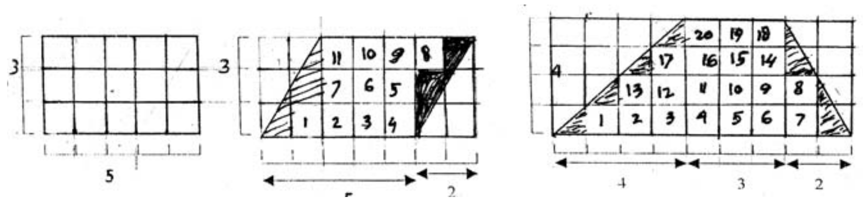
Considering that most pupils could reason in similar ways as proved by the examples above, it is concluded that the intention to broaden the concept of area to the irregular shapes in the IRME curriculum worked as intended.

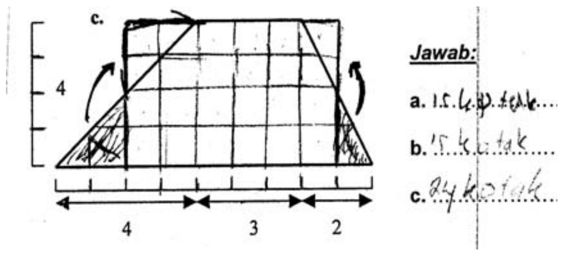
Using various strategies in solving the contextual problems

In the conjectured learning trajectory it was mentioned that the pupils would develop various strategies in solving the contextual problems such as cutting and pasting, counting, reallotment, addition and subtraction. The strategies pupils use are not only important in developing their understanding of area and their ability to determine area, but also to give them a foundation that will help them to better understand how formal area formulas are derived.

Like in Fieldwork II, it was found in this fieldwork that almost all-contextual problems in the student book were solved by the pupils using more than one strategy. The pupils also found out almost all of the strategies for solving the contextual problems designed in the teacher guide. In addition, the results of the classroom observation (see Table 8.9) also indicated that the pupils' creativity to find various solutions in solving the contextual problems was good. Some examples below show the various strategies that the pupils used when determining the areas of a rectangle, a parallelogram and a trapezoid (see contextual problem 22 in lesson 5, Appendix A)

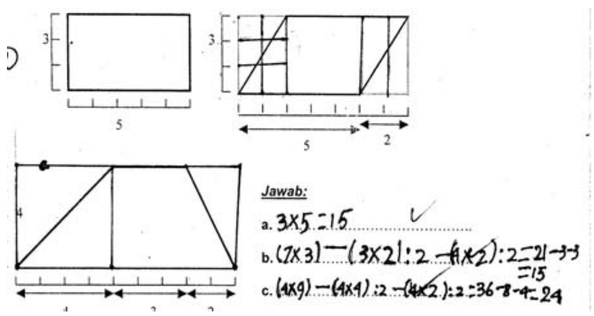
Most pupils solved this problem by drawing the grids on each figure then used *counting* or *reallotment strategy* to find that the areas of the rectangle and the parallelogram were 15, while the area of the trapezoid was 24. An example of the pupils' work using this type of strategy can be seen as follows:





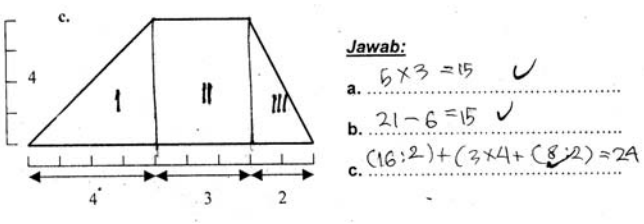
Another pupil used *global reallotment* to find that the area of the trapezoid is 24.

Some pupils combined several strategies in solving this problem as can be seen as follows:



For the first figure it seemed that the pupil drew the grids his mind then found the area of the rectangle as 3 x 5 = 15. In the second figure, the pupil drew a rectangle to enclose the parallelogram, and then he also drew the grids on one part of the figure. By using *halving strategy* the pupil found that the area of one triangular part outside the parallelogram was (3 x 2): 2 = 3. Meanwhile, to find the area of the parallelogram the pupil subtracted the area of the enclosing rectangle from the areas of the triangular parts outside the parallelogram. The pupil found the area of the trapezoid using the same strategies, but as we can see the pupil did not draw the grids anymore. This was an indication that the conjectured learning trajectory in the IRME curriculum guided the pupils to use their experiences gained from one lesson in the next lessons.

This combination of strategies also can be seen from the pupil's work below. The pupil divided the trapezoid into three parts then used halving strategy to find the areas of part I and III. At the end the pupil added the areas of part I, II and III to find that the area of the trapezoid was 24.



Based on the explanation above, we can see that the contextual problems presented in the IRME curriculum could stimulate the pupils to develop various strategies that are useful for them to understand the concept of area and how formal area formulas are derived.

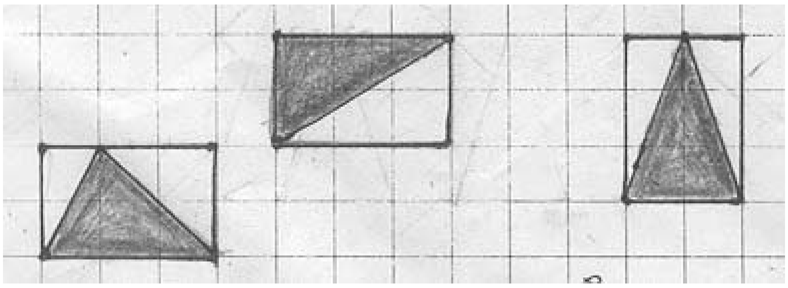
With regard to this key point, the finding in Fieldwork III was similar to that in Fieldwork II. It was found from the pupils' portfolios and the observation scheme completed by the observers that the pupils could use their experience in counting the areas using various measurement units to gain understanding of how the formal formulas to determine the areas of squares, rectangles, parallelograms and triangles were derived. An example of this condition can be seen from the note written by an observer below, when she observed the pupils when they were working on contextual problem 10 –15 in lesson 4, (see Appendix A). Here the pupils were asked to create squares and rectangles using twelve small squares.
At the beginning some pupils had doubts about what they should do, but then the teacher came closer to those pupils and had a discussion with them. At the end all pupils could create the rectangles. Most pupils could find that the area of a rectangle is length times width, although a few of them determined the areas of the rectangles by counting the number of small squares.

Using the grids as a model

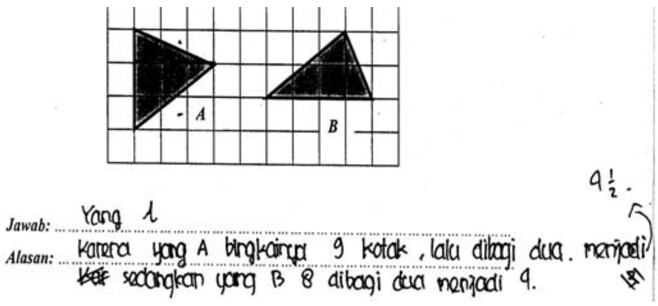
From the pupils' works described in the previous section we can see that they were already using the formula *length times width* to determine the are of the rectangle, although at that time they had not learnt about the formula yet. Considering that the original figures on the contextual problems were without grids, the pupils' answers showed that they used grids, although some of them did not actually draw the grids, as the *model* to find the areas of the figures. Most pupils continued to use the grids as the model to solve the contextual problem in the next lessons, even in the post-test. These findings indicated that one of the key principles of RME namely *the emergent model* (see Gravemeijer, 1999) that was used as a basis in designing the IRME curriculum appeared to be functioned in this study.

The enclosing rectangles

One concept that was developed through the conjectured learning trajectory in the IRME curriculum was that the area of a triangle is one-half of the area of the enclosing rectangle if one of the triangle's sides is the same as one side of the enclosing rectangle. The pupils' frequently used this concept in determining the areas of triangles. One example for this is shown by the pupil's work below in which the pupil was asked to draw three different triangles that were the same in the area.



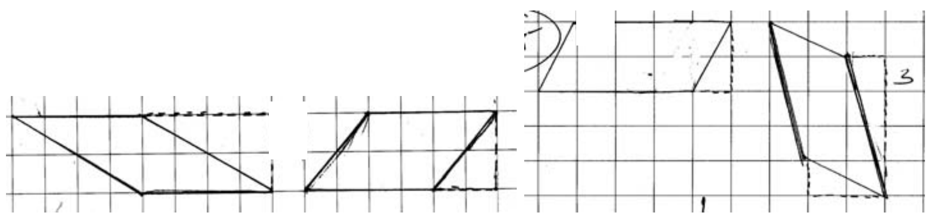
Another example, taken from the pupil's answer on the first test item in the post-test (see Appendix C), can be seen as below. The pupil found that the are of triangle A was 4 ½ unit and the area of triangle B was 4 units.



According to the pupil: the area of the enclosing rectangle for triangle A was 9 units, then divided by 2, it becomes 4 ½, while for triangle B was 8, divided by 2 it becomes 4.

The relation between rectangles, parallelogram and triangles

One activity the pupils performed in learning the topic Area and Perimeter was to change a rectangle into a parallelogram or vice versa. This activity was aimed at developing pupils understanding of the concept that a parallelogram and a rectangle that have the same base and height will have the same area. Through one item in the post-test the pupils. Most pupils used this knowledge to answer a question in the post-test where they were asked to draw two different parallelograms that had the same are as a given rectangle with an area of 8 square units Two examples of the pupils' answers can be seen as follows:



From the pupils' answers we also can see that they have understanding that the geometry objects that have the same area might be different in shape. The answer of the right hand side also indicated that the pupil was also good in *spatial orientation* (see De Moor, 1991).

The relation between Area and Perimeter

The pupils' portfolios and the observation schemed completed by the observers showed that the pupils could understand the relationship between Area and Perimeter after they had worked on some contextual problems (see lesson 10 in the student book, Appendix A) in which they created geometry objects that had the same area but were different in perimeter and vice versa. The results of the assessment 5 (see assessment 5 at the end of unit 5 in the student book, Appendix A) presented in Table 8.8 also indicated that the pupils had a good understanding regarding this key point. Here the average score of the pupils was 8.1 on a scale of 1 to 10.

Based on the findings described above, it was concluded that in general the conjectured learning trajectory for learning and teaching the topic Area and Perimeter as designed in the IRME curriculum worked as intended.

8.3.2 The practicality

The investigation of the practicality of the final version was aimed at answering the following questions:

- Is the student book easy to use?
- Do pupils learn as intended?
- Is the teacher guide useful for teachers?
- Is the teacher guide easy to use?
- Is the time mentioned in each lesson enough?
- Do teachers use the teacher guide as intended?

These questions were answered by conducting the interviews with 48 pupils and four teachers, who implemented the IRME curriculum in Surabaya, and the classroom observations. The pupils interviewed were selected from the upper groups and the lower groups in each class in order to gain information from two different viewpoints. The interviews with the pupils were done in small groups (two groups in each class).

As mentioned in section 8.2, the classroom experiments in Surabaya were conducted by two classroom teachers and two Ph.D students from Surabaya State University (Unesya). All of them volunteered to be involved in this study. For the remainder of this chapter, they are called 'teachers'. Table 8.4 below presents a brief profile of these teachers.

Table 8.4
A brief profile of the teachers in Surabaya

	Teaching in:	**Education**	**Experience**
Teacher 1	Class IV A SD Laboratorium	Graduated from Institute of Teacher Training Surabaya, majored in Biology	Has been teaching for three years
Teacher 2	Class IV A SD Laboratorium	Ph.D student, and holding master degree in Mathematics Education	Has been lecturing in university for more than 15 years
Teacher 3	Class IV A SD Al-Hikmah	Graduated from Institute of Teacher Training Surabaya, majored in Chemistry	Has been teaching for more than 10 years
Teacher 4	Class IV A SD Lab. Surabya	Ph.D. student and, holding master degree in Mathematics Education	Has been lecturing in university for more than 20 years

The first question mentioned above was answered by conducting the interviews with 48 pupils and the classroom observations. Similar to Fieldwork II, all pupils that were interviewed in this fieldwork said that the student book was easy to use. The observers also mentioned that in general they found that the pupils did not have any significant difficulties when they used the student book.

With regard to the second question, it was found that the pupils could learn the topic Area and Perimeter as intended. The discussion presented in section 8.3.1 shows that the pupils could learn according to the conjectured learning trajectory designed in the IRME curriculum. The results of the classroom observations presented in Table 8.8 strengthen this finding, as in general the pupils' performance during the classroom experiments was good.

The aspects of the practicality concerning teacher guide were evaluated by conducting the interviews with the four teachers who implemented the IRME curriculum and the classroom observations. In the interviews all teachers said that the teacher guide was useful for them in teaching the topic Area and Perimeter. Three teachers said that the teacher guide was easy to use, while one teacher suggested that the teacher guide should be enhanced further in order to make it easier to use.

With regard to the use of the teacher guide by the teachers, the observation scheme completed by the observers showed that in general the teacher could use the teacher guide as intended. The results of the classroom observation using the checklist also indicated that the teachers' performance in implementing the IRME curriculum was rather good, as can be seen from Table 8.5 below.

Table 8.5
Teachers' performance in implementing the IRME curriculum

	Teacher 1	**Teacher 2**	**Teacher 3**	**Teacher 4**
1. Introduce the contextual problems	3.5	4.0	4.1	4.2
2. Guide the pupils to solve the problems	3.5	4.1	3.9	4.0
3. Stimulate the pupils to:				
– Use their own ideas	3.3	3.8	4.1	3.5
– Find different strategies	3.4	3.6	3.8	3.9
– Raise and answers questions	3.0	4.2	3.9	3.3
– Give reasoning	3.7	4.1	3.7	3.5
– Write out the process of solving the problems	3.2	3.9	3.7	3.4
– Explain their answers	3.7	4.4	3.4	3.5
4. Conducting the classroom discussions	3.2	4.5	3.4	3.3
5. Motivate the pupils	3.5	4.2	4.1	3.9
6. Maximise the interactions among pupils	3.1	4.0	4.3	4.3
7. Interact with the pupils	4.1	4.5	5	4.9
Mean	**3.4**	**4.1**	**4.0**	**3.8**

Note: The score for each item range from 1 (very poor), 2 (poor), 3 (fair), 4 (good), 5 (very good).

However, the observers and the author found that sometimes the teachers, especially Teacher 1, still practiced the traditional way of teaching. This condition can be described as follows:

- The teacher tended to give the impression to the observers that the learning and teaching learning process was running smoothly, by dominating the activities in the classrooms.
- When asking questions, the teachers expected the correct answers from the pupils and did not pay much attention to the pupils who gave the wrong answers. They also tended to direct their questions to the smart pupils.
- It seemed that Teacher 1 and 3 were worried their pupils would achieve bad results in this research and so, because of this, they tended to give the answers without giving sufficient time to the pupils for them to think or to find the answers by themselves. They were also anxious that this research should be successful in their schools.

After having the reflection session at the end of the first week of the classroom experiments, in which the observers, the author and the teachers discussed what had happened in the classroom, some of the teachers' tendencies as described above were reduced. Nevertheless, the notes made by the observers after the reflection showed that sometimes the teachers forgot their new role in teaching using the RME approach (see Chapter 6). Some of the notes written by the observers can be seen below:

- In lesson 6, Teacher 2 still acted as the source of information in the classroom discussion.
- In lesson 8, Teacher 3 dominated the classroom.
- In lesson 9, Teacher 1 frequently gave the answers directly to the pupils who had difficulty in solving the contextual problems.

These situations probably still occurred because the teachers were not used to the RME approach yet. Reflecting on the experience of the author in implementing the IRME curriculum in Fieldwork I and II, time was needed to grasp the whole idea of how to teach in this new teaching style. By providing the teachers with more experience to teach using the RME approach, it is assumed that their performance would be better.

8.3.3 The effectiveness

The investigation of the effectiveness of the final version of the IRME curriculum was focused on the levels of effectiveness of: *pupils' and teachers' reactions, pupils'* *learning, pupils' use of new knowledge and skills,* and *pupils' learning outcomes* (see Kirkpatrick, 1987; Guskey, 1999, 2000).

As discussed in section 8.3.1, most pupils found out by themselves various strategies such as cutting and pasting, reallotment, halving, addition and subtraction in determining the areas of the geometry objects. This is an indication that the pupils acquired the intended RME knowledge. The tendency of most pupils in using the grids as a model to reason about area, and their continuity of using different strategies in solving the contextual problems, were also an indication that the pupils' could apply the RME knowledge and skills that they had acquired from one lesson in the next lessons. It means that the IRME curriculum met the criteria regarding pupils' learning and pupils' use of new knowledge and skills (see Chapter 4). The remainder of this section presents the results of the evaluation of *pupils' and teacher's reaction and pupils' learning outcomes.*

Pupils' and teachers' reaction

The pupils' and the teachers' reactions were investigated by conducting interviews with 48 pupils and four teachers. All pupils in the experimental classes and the four teachers were also asked to write down their comments and impressions about the IRME curriculum.

Based on the interviews with the pupils, the findings were the same as those found in Fieldwork II (see section 7.4.3). The pupils liked the IRME curriculum, and they also said that that their time was well spent during the learning and teaching processes and the IRME curriculum was useful for them. The comments and impressions given by the pupils in writing indicated that almost all pupils liked the IRME curriculum and only a few came up with negative comments. Some of the positive comments and impressions from the pupils can be seen as follows:

> *"I like the lessons very much because as long as I have studied here I have never had a lesson like this. Automatically my knowledge is increased. I am also more motivated to study."*
> *"Learning RME for three weeks was enjoyable. Although at the beginning it was difficult, but then became easier. So I really like these lessons. It was difficult before because I did not understand, but now I understand, that is why it was enjoyable."*

"The lessons are difficult sometimes. The way the teacher teaches is excellent, we can understand easily. Activity of the pupils during the teaching learning process was very good. These lessons are useful for the future."

"I am very pleased because the lessons were more enjoyable than the usual mathematics lessons."

"The lessons are not so easy but are very interesting because sometimes it is just like playing games."

"My impression on these lessons: sometimes I liked it because we worked in groups, sometimes I felt a little bit bored."

Two negative comments and impressions of the pupils:

"My impression on these lessons: sometimes boring because I have to work continuously."

"Since the beginning these lessons just like that, boring! The contextual problems are difficult for me"

The pupil who gave the last comment mentioned in the interview that he did not like to study any of the subjects that are taught in the school except the sport lesson, and that he wanted to be a soccer player.

Based on the interviews with the teachers it was evident that they liked the RME approach, and they said that the IRME curriculum was useful for learning and teaching the topic Area and Perimeter. The comments below were given by *Teacher 4,* and these are followed by the comments from *Teacher 1* regarding the RME approach.

"It is better to teach mathematics in primary schools using the RME approach, because RME encourages the pupils to find the concepts by themselves. The pupils are also stimulated to answer the questions and to reason and mention their own ideas either orally or in writing. This means that the pupils' knowledge will stay longer. It is important to ask pupils to give the reasons for their answers in writing so that they get used to this situation, considering that most students, even those in university, have great difficulties in writing a paper."

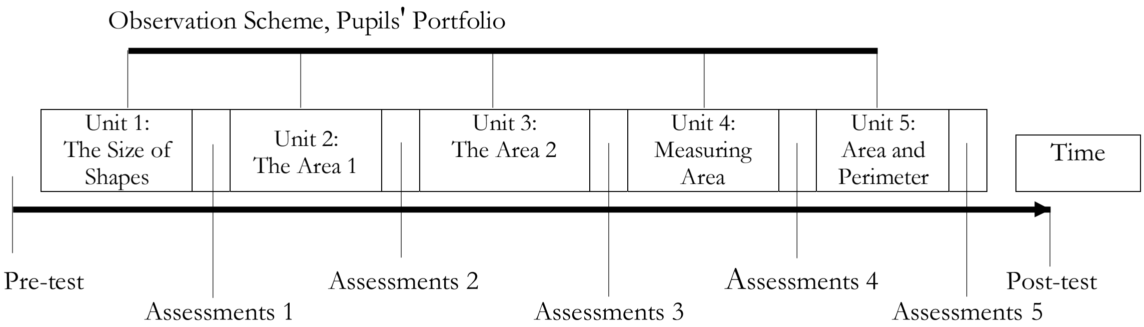
"The implementation of the RME approach in my school was going well. In my opinion the RME approach is good because the pupils are expected to find mathematical concepts by themselves. The RME approach is also good to stimulate the pupils to have critical thinking and to be creative. For pupils who pay serious attention to the learning and teaching process it will be easy to understand, but pupils who do not like mathematics will have difficulties in remembering and understanding the lesson."

Pupils' Learning Outcomes:

The investigation on *the pupils' learning outcomes* was focused on the impact of the IRME curriculum on *the pupils' understanding and performance.* The pupils' understanding mainly referred to the pupil's achievements in the pre-tests, post-tests, and assessments, while the pupils' performance included pupils' confidence as learners, and pupils' reasoning, activity, creativity, and motivation. The following sections discuss each of these aspects.

Pupils' understanding

The impact of the IRME curriculum on the pupils' understanding was measured by pre-test, post-test, assessments, observation scheme, and pupils' portfolios. The evaluation processes of the pupils' understanding followed the scheme below:



The results of the pre-test and posttest

The pre-test was given a few days before the classroom experiments, while the post-test was given soon after the last day of the classroom experiments. The test items on the pre-test were slightly different to those on the post-test, but they were parallel (see Appendix B). The pre-test consisted of six test items regarding the contextual problems, and in the post-test two test items were added that are normally used in conventional mathematics tests. The test items for the pre-test and post-test were designed based on the vision and goals of the IRME curriculum, and they were consulted on with two Dutch RME-experts. The results of the pre-test and post-test are presented in Table 8.6 below.

Table 8.6
Pupils' achievements in the pre-test and post-test in the experimental classes

	Pretest			Posttest				
School/Class	*N*	χ	*s.d.*	*N*	*X*	*s.d.*	**t**	**P**
IV SD N Percobaan Padang	32	4.79	1.61	33	6.62	1.66	4.52	.0000
IV SD N 16 Polonia Padang	20	2.96	2.10	20	5.74	2.04	4.24	.0000
IV SD N 28 Polonia Padang	15	2.51	1.16	17	5.01	2.35	3.74	.0001
IVA SD Lab. Surabaya	23	3.80	1.31	21	6.28	1.96	4.97	.0004
IVB SD Lab. Surabaya	23	3.90	1.64	24	8.23	1.34	9.90	.0000
IVC SD Al-Hikmah Surabaya	28	3.40	1.37	28	6.51	1.83	7.21	.0000
IVD SD Al-Hikmah Surabaya	30	3.42	0.82	30	7.24	1.55	11.99	.0000

Note: the ideal score is 10, **N** = the number of students in each class, χ = the average scores, **s.d.** = standard deviation, **t** = t-value, **P**= probability of **t** with the level of significance 99%.

We can see from the table that the pupils' achievements in the post-test were significantly higher than their achievements in the pre-test. This conclusion was valid in each classroom experiment. The pupils who were taught by the four teachers in Surabaya also showed a good improvement in their achievements.

The test material used in the post-test was also given to the pupils at Grade 4 (24 pupils) and 6 (20 pupils) in a primary school with a good quality (based on the school achievements in the national examination in the last few years), and to the pupils at Grade 5 (38 pupils) and 6 (20 pupils) in a primary school with an average quality. These two schools were called *the control classes*. The main intention for giving the test to pupils in the control classes was to know whether they could solve the contextual problems. Therefore, the difference in the pupils' scores between the experimental classes and the control classes for the test items regarding the contextual and the conventional problems was not analyzed statistically.

The comparison between the pupil's achievements in the experimental classes and the control classes can be seen in Table 8.7.

Table 8.7
Pupils' achievements in the experimental and control classes

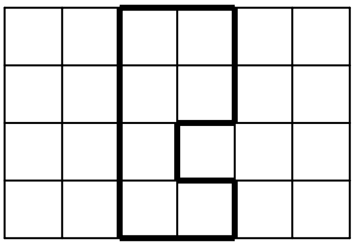
Control Classes	Experimental Classes: N=173, χ = 6.63, s.d.=1.97				
	N	*X*	*s.d.*	**t**	**P**
Class IV	24	3.94	1.35	6.47	0.0000
Class V	38	5.06	1.54	4.62	0.0000
Class VI	40	6.08	1.69	1.64	0.052

Note: the ideal score is 10, **N** = the number of students in each class; χ = the average scores, **s.d.** = standard deviation, **t** = t-value; **P**= probability of **t** with the level of significance 95%.

The data presented in Table 8.7 show that the pupils' achievements in the experimental classes were significantly higher than the achievements of the pupils at Grade 4 and 5. Meanwhile, there was no significant difference between the pupils' achievements in the experimental classes and those at Grade 6, although the achievements of the pupils in the experimental classes were higher than the achievements of the pupils at Grade 6. Based on further analysis of the pupils' answers in the test the following points were found. The cases mentioned here, are a general description of how the pupils who were taught by the traditional method solved the contextual problems

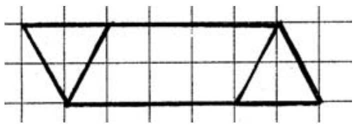
- 30 out of 40 pupils at Grade 6 solved the first test item (see Appendix B) using the formula, while most pupils at grade 4 and 5 in the control classes solved this item by guessing or using their impression. In the contrary, very few pupils in the experimental classes solved this test item by using the formula as most of them used reallotment strategy, and the rest used the strategies such as halving, subtracting and enclosing the triangles in the rectangles.
- When the pupils were asked to draw a figure with a perimeter of 14 units (item test number 6), 44 out of 102 pupils in the control classes gave the correct answers by drawing a rectangle with a size of 3 x 4 (42 pupils), and a size of 2 x 5 (two pupils). Only 11 out of 44 pupils could enlarge the figures that they drew to get the new figures, which were double in perimeter, and none of them could answer the question about the effect on the area compared to the area of the original figure, after they doubled the perimeter. Most pupils in the experimental classes answered this test item correctly, and their answers were not only in the form of rectangles with the sizes mentioned before, but also in the form of rectangles with a size.

- 1 x 6 and other irregular shapes such as:

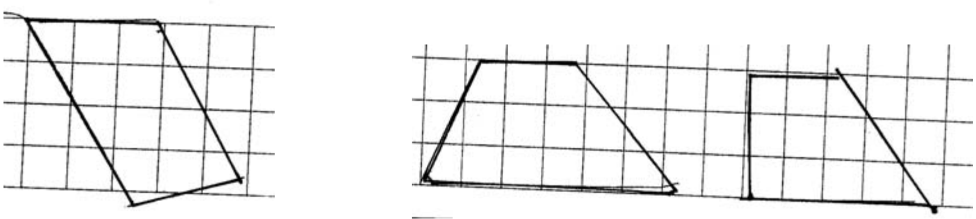


- As indicated in section 8.3.1, most pupils in the experimental classes showed a good understanding of the concept that a parallelogram and a rectangle that have the same base and height will have the same area. They used this knowledge to answer the third test item, and most of them came up with the correct answers. In this test item the pupils were asked to draw two different parallelograms that had the same area as a given rectangle with the area 8 square units. They were also asked to draw two different triangles in which each of them had an area one-half of the areas of the parallelograms. The majority of the pupils in the experimental classes could solve this test item correctly, while most of the pupils in the control classes could not solve this test item because they lacked knowledge of the basic concepts, as can be seen from some examples below.

  A pupil at Grade 6 drew a parallelogram with an area of 12 square units, and then drew the two triangles as follows:



  The figure on the left hand side below was the answer of a pupil at Grade 5, while the figure on the right hand side was the answer of a pupil at Grade 4.



  The answers showed that these pupils did not understand the concepts of *parallelogram* or *one-half*.

The results of the assessments

The assessments were aimed at measuring the pupils' achievement on the goals set for each unit in the IRME curriculum. As described in the scheme presented earlier in this section, there were five units in the IRME curriculum, namely *the size of shapes, the area, the area (continued), measuring area,* and *Area and Perimeter*. The assessment for each unit was designed based on the goals of the unit (see the goals of, and the assessments for each unit in the teacher guide in Appendix A). The pupils' achievements in the assessment for each unit are presented in Table 8.8 below.

Table 8.8
Pupils' achievements in the assessments

School/Class	Unit 1 The Size of Shapes	Unit 2 Area 1	Unit 3 Area 2	Unit 4 Mea-suring Area	Unit 5 Area and Peri-meter	Mean
IV SD N Percobaan Padang	8.7	8.3	7.7	7.3	8.2	8.0
IV SD N 16 Polonia Padang	8.2	7.2	7.9	8.2	7.4	7.9
IV SD N 28 Polonia Padang	8.2	7.8	7.5	7.1	8.0	7.5
IVA SD Lab. Surabaya	9.4	8.2	8.9	8.4	8.6	8.7
VB SD Lab. Surabaya	7.3	7.6	7.6	7.3	7.9	7.5
IVC SD Al-Hikmah Surabaya	8.7	8.4	8.7	7.5	8.0	8.3
IVD SD Al-Hikmah Surabaya	8.5	8.2	8.5	8.0	8.3	8.3
Mean	8.4	8.0	8.1	7.7	8.1	**8.1**

Note: Maximum score for each assessment was 10.

In general the pupils produced good achievements in the assessment in which the average score of the pupils was 8.1 on a scale of 1 to 10. The pupils' achievements in each assessment, except in unit 4, were also more than 8. This result indicated that the goals of the IRME curriculum were successfully achieved. With regard to the pupils' achievements in the assessment, the teachers and observers found that the following conditions might help the pupils when they were working on the assessment:

- the opportunity the pupils had to work in groups and to raise questions to the teachers and sometimes to the observers;
- the hints or the challenging questions given by the teachers; and
- the questions from observers asking for further explanations from the pupils,

Based on the results of the post-test and the assessment it could be concluded that the IRME curriculum gave a positive impact on the pupils' understanding in learning the topic Area and Perimeter. The findings described in this section also indicated that the traditional way of teaching caused the pupils' lack understandings of basic geometry concepts.

Pupils' performance

The pupils' performance in this study referred to pupils' confidence as learners, pupils' reasoning, activity, creativity, and motivation. These aspects were investigated by, conducting the interviews with the pupils and the teachers, the classroom observations, analyzing the pupil's portfolios, and giving the questionnaire to the pupils.

As mentioned in section 8.2, the observation scheme regarding pupils' activities was divided into two parts (see Appendix C). In the first part the observers were asked to describe the pupils' activities during the classroom experiments in as much detail as possible, while in the second part they were asked to evaluate several aspects of the pupils' performance by crossing the options on the checklist. The results of the classroom observations regarding the second part in the observation scheme are presented in Table 8.9 below. The numbers in the table are the average score of each aspect that was evaluated during the classroom experiments. The score for each aspect range from 1 (very poor), 2 (poor), 3 (fair), 4 (good), 5 (very good).

Table 8.9
Pupils performance in the classrooms

Aspects of Evaluation	Schools							Mean
	1	*2*	*3*	*4*	*5*	*6*	*7*	
1. Pupils' understanding on the contextual problems	4.5	4.2	4.0	4.5	3.6	4.0	4.2	4.1
2. Pupils' activity	4.3	4.1	4.2	4.4	4.2	4.1	4.4	4.2
3. Pupils' motivation	4.1	4.0	4.0	3.7	4.0	3.5	4.1	3.9
4. Interaction among the pupils	4.3	3.8	3.9	3.8	3.7	3.6	4.3	3.9
5. Pupils' reasoning	4.2	3.5	3.2	3.5	3.3	3.7	3.9	3.6
6. Pupils' creativity in solving the contextual problems	4.2	3.6	3.7	4.5	3.5	3.8	4.2	3.9
MEAN	4.3	3.9	3.8	4.1	3.7	3.8	4.2	3.9

Note: **1** = SD N Percobaan Padang; **2** = SD N 16 Polonia; **3** = SD N 28 Polonia; **4** = IV A SD Lab. Surabaya; **5** = IV B SD Lab. Surabaya; **6** = IV C SD Al-Hikmah; **7** = IV D SD Al-Hikmah.

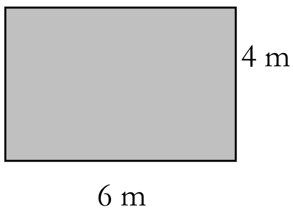
From Table 8.9 we can see that in general the pupils' performance in learning the topic Area and Perimeter using the IRME curriculum was good (the average score was 3.9). *Pupils' activity* appeared to be the most positive aspect influenced by the IRME curriculum, while the average score for *pupils' reasoning* was rather low in each school. Probably the latter was because the pupils still needed more time to practice how to reason, as they had almost never been asked to give their reasons in answering mathematical problems when they were taught using the traditional way of teaching.

Pupils' reasoning

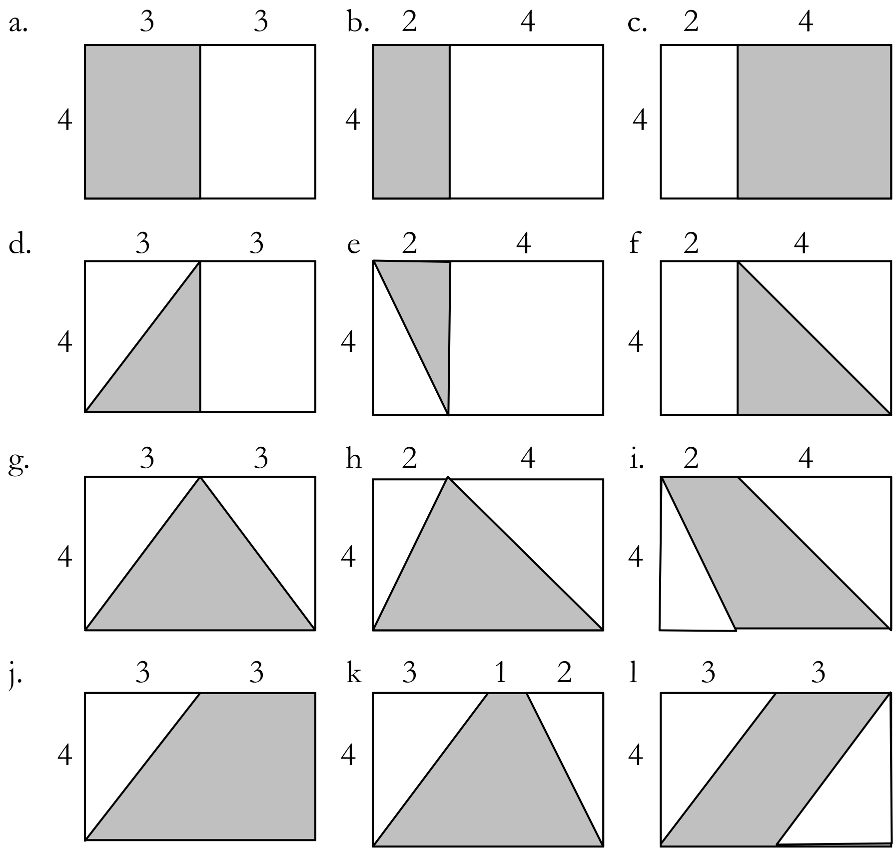
The data presented in Table 8.9 showed that the performance of the pupils in reasoning was not as good as their performance for other aspects. Nevertheless, the pupil's portfolios indicated that some pupils used very good reasoning in solving the contextual problems. They could reason mathematically as was expected. This condition can be seen when the pupils solved the following contextual problem:

Plywood

The price of a piece of plywood sized 4m × 6m is Rp. 48. 000.



Determine the prices of the pieces of plywood the size (in meters) of the shaded part in each figure below



From the reasoning given by the pupil below, we can see that he could understand the relationship between one figure and the others. Based on this understanding he used *the concept of proportion and division*, and *addition strategy* to reason for his answers mathematically.

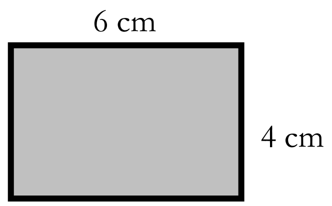
The reasons given by the pupil


a. Karena yang A ½ nya sebuah tripleks, jika sebuah tripleks 48000, jadi 48 : 2 = 24, jadi harganya Rp 24000.
b. Karena yang B ⅓ nya sebuah tripleks, jika sebuah tripleks 48000, jadi 48 : 3 = 16, jadi harganya Rp 16000,00
c. Karena jika yg B dikali 2, jadilah C, jadi 16 x2 = 32, jadi harganya Rp 32000,00.
d. Karena jika yg A dibagi 2, jadi yg D, jadi 24 : 2 = 16, jadi harganya Rp 16000,00
e. B : 2 = E
F. C : 2 = F
G. Sebuah tripleks : 2 =
H. E + F = H
I. E + F = I
J. A + D = J
K. ½ B + E + D = K
L. D + D = L

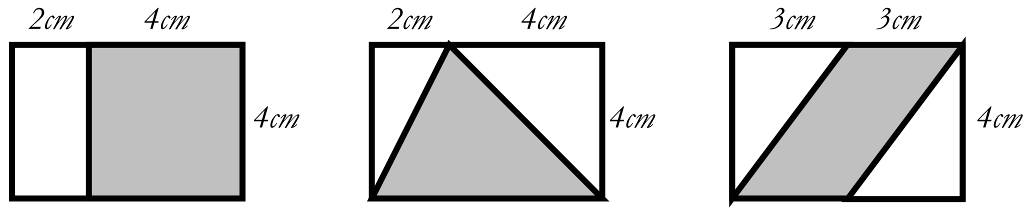
a. *Because A is ½ of the plywood, and the price of the plywood is 48.000, so 48:2 =24, so the price for A is Rp. 24.000*
b. *Because B is 1/3 of the plywood, and the price of the plywood is 48.000, so 48:3 =16, so the price for A is Rp. 16.000*
c. *Because, if B is multiplied by 2, it becomes C, so 16 x 2 = 32, so the price is Rp. 32.000*
d. *Because, if A is divided by 2, it becomes D, so 24 : 2 = 16* (the pupil made a mistake in division), *so the price is Rp. 16.000*
e. B : 2 = E
f. C : 2 = F
g. *The original plywood : 2*
h. E + F = H *i.* E + F = I
j. A + D = J *k.* ½ B + E + D = K
l. D + D = L

The analysis of the pupils' answers in the test was also showed that the pupils in the experimental classrooms were much better in reasoning than those in the control classes. This condition can be seen from the pupils' answers on test item number 2 below:

The price of a piece of chocolate with the size as it is shown in the following figure is Rp. 12,000.



Determine the price of a piece of chocolate the size of the shaded part in each figure below and explain your answers!



a. *b.* *c.*

Less than one half of the pupils at Grade 6 answered this contextual problem correctly. Almost all of these pupils answered it by calculating the area of the given piece chocolate: 6 x 4 = 24, then they divided 12.000 by 24 to get 500 as the price for one unit of chocolate. To find the prices of the chocolates in item *a, b*, and *c*, the pupils calculated the area of each shaded part using the formula, then multiplied it by 500.

Only 9 out of 38 pupils at grade 5 gave the answer about prices, while the rest of the pupils at Grade 5 and all of the pupils at Grade 4 in the control classes did not know how to answer this contextual problem. It seemed that the pupils at Grade 4 and 5 in the control classes had difficulties in understanding contextual problems. The number of pupils in the experimental classes who answered this contextual problem correctly was also less than one-half, but all of them gave their answers about price.

Pupils' activity and creativity

Similar to Fieldwork II, in this stage of the study evidence of progress was also found in the pupils' activity and creativity. The observation scheme completed by the observers indicated that most pupils, who were passive and lacked creativity at the beginning, showed progress after a few lessons. From the data presented in Table 8.9 we can see that the observers gave the highest score for the pupils' activity, while the score for the pupils' creativity was good. Some examples presented in section 8.3.1 also indicated that the pupils were very creative in finding the various solutions in solving the contextual problems.

Pupils' motivation

The pupil's motivation in this stage of the study was evaluated through the classroom observation and questionnaire. The questionnaire used in this study was adapted from the instrument developed by Blote (1993), and it includes three aspects of motivation namely *affect towards the IRME curriculum, self-concept of mathematical ability*, and *intended effort in doing mathematics*. The questionnaire was given to the pupils before and after the classroom experiments. Table 8.10 below presents the mean and standard deviation for these three motivational aspects. The score for the three sub-scales was a range from 1 (low) to 4 (high).

Table 8.10
Pupils' motivation

	Affect		**Self-Concept**		**Effort**	
	Mean	*s.d.*	*Mean*	*s.d.*	*Mean*	*s.d.*
Before Classroom Experiments (n =171)	3.2	.55	2.7	.46	3.1	.41
After Classroom Experiments (n=152)	3.2	.52	2.8	.46	3.2	.40

MANOVA with repeated measures revealed a significant differences between motivation of the pupils before and after classroom experiments, with F (1, 317) = 6.69, $p < 0.05$. In this case, the motivatian of the pupils was higher after they were taught using the IRME curriculumlearn than those learning traditional mathematics. Separate measure for the different subscales showed a significant diference for *self-concept* $t = 2.06$, $p < 0.05$, but no significant differences were found for aspects *affect* and *effort*.

The results of the classroom observation presented in Table 8.9 also indicated that the pupils' motivation during the learning and teaching process using the IRME currculum was good. Based on these findings, it was concluded that the IRME crriculum had the potential to stimulate pupil's motivation.

8.4 THE CONCLUSIONS

Based on the findings presented in the previous sections, some conclusions of the assessment stage of the study can be drawn as follows:

1. In general the conjectured learning trajectory for learning and teaching the topic Area and Perimeter worked as intended for most pupils, when the teachers implemented the IRME curriculum in the classrooms.
2. 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 IRME curriculum. 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. From these findings it can be concluded that the IRME curriculum met the criteria of the practicality. The practical IRME curriculum can be characterized as follows:
   - The IRME had the potential to develop pupils' understanding, reasoning, activity, creativity and motivation in learning the topic Area and Perimeter.
   - The teaching learning process using the IRME curriculum created pupils' 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 time set for each lesson in the teacher guide was adequate.
3. The IRME curriculum met the criteria of *the effectiveness* as it resulted in some positive impacts on the pupils at Grade 4 in Indonesian primary schools in learning the topic Area and Perimeter. The positive impacts of the IRME curriculum on the pupils are characterised as follows:
   - The pupils liked the IRME curriculum. They said that the IRME curriculum 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 involved in the IRME curriculum. 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 engaged actively in the learning and teaching processes. They also became more motivated and were stimulated to find different strategies in solving the contextual problems. Their reasoning was 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 themselves in the learning teaching process using the IRME curriculum, 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. The pupils' achievements in the assessments were also satisfactory.
- A significant difference was found between the motivation of the pupils before and after they had been taught the IRME curriculum, especially on the aspect *self-concept of mathematical ability*.

4. The teachers liked the IRME curriculum, and in general they could implement the IRME curriculum as intended, although sometimes they still used the traditional way of teaching. It was also observed that on 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.

CHAPTER 9

CONCLUSIONS

This chapter presents the conclusions of a four-year study of the development and implementation of the IRME curriculum at Grade 4 in Indonesian primary schools. The chapter begins with the summary of the study (section 9.1). This section summarises the motive to conduct the study, the aim of the study, research question and methods, and the results of the study. Section 9.2 discusses some important points that can be learned from this study. Finally, section 9.3 presents some recommendations for policy and practice, further research and further development work.

9.1 SUMMARY

Similar to other countries (see for example Niss, 1996; NCTM, 2000), the mathematics curriculum for primary schools in Indonesia pays much attention to several important aspects such as developing pupils' reasoning, activity, creativity and attitude, and providing pupils with mathematics skills so that they can handle real-world problems mathematically. These aspects are crystallised in the goals of the mathematics curriculum for Indonesian primary schools as follows:

- Preparing the pupils to be able to deal with the dynamic world situation effectively and efficiently through practical works based on 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.

Despite its lofty goals, the curriculum appears to have fallen short of its aims, giving rise to the following questions: Why is the quality of mathematics education in Indonesian primary schools still poor? Why do most pupils hate to learn mathematics? (see Marpaung, 1995, 2001), and Why pupils' achievements in mathematics are poor from year to year? (see www.depdiknas.co.id). These questions indicate that there are some problems in mathematics education in Indonesia, especially regarding the curriculum and the learning and teaching process in primary school.

In the last three decades, the curriculum in Indonesia has been changed four times (Curriculum 1975, 1984, 1994 and 2002). Each curriculum was based on a different approach (see Chapter 2) and each one was presented as an ideal curriculum (see Goodlad, 1984). However the changes from one curriculum to another did not result in a significant improvement for several reasons. Firstly, the changes of the curriculum always followed a Top-Down model (see Noor, 2000), while the need for changes, especially at the school level, was never thoroughly investigated.

Secondly, each curriculum that has been implemented has lacked an implementation strategy. The in-service training provided to support teachers in implementing each revised curriculum seems not to have been effective (see Somerset, 1997; Hadi, 2002). Most teachers who went through the training frequently 'got lost' when they tried to put the new ideas into practice in their schools. Because there was no adequate supervision and evaluation after the training (Somerset, 1997), the teachers preferred to teach in the ways they had used before.

Thirdly, the implementation of the curriculum was never carefully evaluated. The only criteria used by the government to measure the success of the curriculum implementation was pupils' achievements. Meanwhile, data about the process of curriculum implementation such as how the learning and teaching process was conducted in classrooms, how the pupils learned, or the difficulties that teachers faced in implementing the curriculum, remain unknown.

There are also some weaknesses regarding the content of the mathematics curriculum in the primary school. Firstly, the content of the curriculum is burdensome because there are too many topics that have to be taught (see Soedjadi, 2000). Teachers complain about the numbers of topics that they have to teach in a limited amount of time. Pupils complain about having too many exercises and too much homework to complete, while parents frequently become confused when they are helping their children with their homework.

The second weakness is the lack of connection between the topics in the curriculum. As a result, teachers perceive the curriculum as a set of disconnected topics that they have to teach (see Vignette 2 in Chapter 1), while pupils experience the curriculum as a number of separate topics that they have to learn.

Thirdly, the curriculum lacks examples of practical applications. Referring to the goals mentioned earlier in this section, the content of the curriculum is supposed to be very rich with practical work and meaningful applications. In fact, the content is dominated by an approach that focuses on introducing and memorising abstract concepts, applying formulas and practising computational skills (see some examples in Chapter 2).

The learning and teaching process in Indonesian primary schools is mostly organized in the traditional way. Teachers become the center of almost all activities in the classrooms (see example in Chapter 1; Fauzan, 1999; Fauzan, Slettenhaar & Plomp, 2002, 2002a; Marsigit, 1999) in which the pupils are treated as an 'empty box' that needs to be filled. In general, the climate in Indonesian classrooms (see Fauzan, 2001; Sommerset, 1997) is similar to that in several African countries, summarized by de Feiter & Akker (1995) and Ottevanger (2001) as follows:

- pupils are passive throughout the lesson;
- 'chalk and talk' is the preferred teaching style;
- the emphasis is on factual knowledge;
- questions require only single words, often provided in chorus;
- 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 these classroom characteristics is that most pupils are not learning the mathematics they need. They also do not have the opportunity to learn significant mathematics. For most pupils, learning mathematics is an endless sequence of memorising and forgetting facts and procedures that make little sense to them, while for most teachers, teaching mathematics has become a routine task in which the same topics are taught or re-taught year after year (see also Battista 1999).

A number of attempts were made by the Indonesian government to overcome the problems (see some innovative projects in Chapter 2). However, most of these attempts were relatively ineffective. Until recently mathematics curriculum and textbooks still did not give the pupils adequate opportunity to *learn* mathematics, but only the opportunity to *memorizing* mathematics. Meanwhile, teachers proved reluctant to depart from their traditional methods, and a significant proportion of pupils tended to develop distaste for learning mathematics.

Based on the explanation above, we can summarise some fundamental problems in mathematics education in Indonesia:

1. The content of the mathematics curriculum is burdensome. This leads to situations in which the learning and teaching process concentrates only on learning objectives and learning outcomes, while the process that leads to these learning outcomes remains a black box. In addition, most of the learning objectives only focus on memorising facts and concepts, and computational procedures (i.e. applying formulas).
2. The approach to teaching mathematics is very mechanistic and conventional.
3. The changes and innovations in mathematics education have never addressed the previous two problems because those changes and innovations lacked an implementation strategy.

The rationale for this study emerged from a general dissatisfaction with mathematics education in Indonesia, especially at the primary level, and aimed to contribute to solving the fundamental problems outlined above. This idea was developed by developing and implementing a piece of curriculum material namely *Indonesian Realistic Mathematics Education (IRME) curriculum* for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools. The term *curriculum* referred to an operational plan for instruction including what mathematics pupils need to know, how pupils are to achieve the identified goals, what teachers are to do to stimulate pupils to develop their mathematical knowledge, and the context in which learning and teaching occur (see NCTM, 1989). In this study the operational plan was crystallized in the form of a teacher guide and a student book.

The IRME curriculum was developed and implemented based on Realistic Mathematics Education (RME) approach through a development research. The results of the literature study (see Chapter 3) suggested that RME was a very promising approach to overcome the fundamental problems. In RME pupils learn mathematics based on activities they experience in their daily life; and they are provided with ample opportunity to reinvent mathematical concepts and to construct their knowledge by themselves (see Gravemeijer, 1994, 1997). Instruction in RME calls for work to be done in-groups, where investigation, experimentation, discussion and reflection form the core of the teaching learning process (de Moor, 1991). The development research was applied in this study because it provided sufficient and useful support for the development and implementation of the IRME curriculum. (*Note:* the term *implementation* is used here to indicate the process of the classroom experimentation using the IRME curriculum to teach the pupils in Indonesian primary schools). The study followed two "schools of thought" in development research. The first one is mentioned by van den Akker (1999), van den Akker & Plomp (1993), and Richey & Nelson (1996) and the second one proposed by Freudenthal (1991) and Gravemeijer (1994, 1994a, 1999) (see Chapter 4).

The aim of the study was to develop and implement a *valid*, *practical* and *effective* IRME curriculum for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools. The terms valid, practical and effective refer to the classifications created by Nieveen (1997, 1999), Kirkpatrick (1999) and Guskey (2000) (see Chapter 4). This aim of the study was elaborated further as follows:

- The development of a valid RME-based curriculum refers to the development of '*local instructional theory*' (see Gravemeijer, 1999) and to methodological guidelines for further development of RME materials in Indonesia.
- A practical RME-based curriculum refers to the question of whether the RME approach could be utilised in Indonesian primary schools or not.
- An effective RME-based curriculum refers to the extent to which the RME-approach could address some of the problems in mathematics education in Indonesian primary schools, more specifically in the geometry instruction.

In line with the aim of the study the main research question was formulated as follows:

> *What are the characteristics of a valid, practical and effective IRME curriculum for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools?*

This research question was broken down into sub-research questions (see Chapter 6, 7 and 8), and these were investigated in the three stages of the study. The first stage was *the front-end analysis*, in which the current situation of Indonesian education was analyzed (see Chapter 2), and literature on RME and research trends in mathematics education was reviewed (see Chapter 3). The literature review on RME theory resulted in the first draft of the IRME curriculum and of the conjecture learning trajectory for learning the topic Area and Perimeter (see Chapter 5).

The second stage of the study was called *the prototyping stage*. This stage consisted of the development and implementation of Prototype 1 (see Chapter 6) and Prototype 2 (see Chapter 7) of the IRME curriculum and formative evaluation of each prototype. While evaluation activities in the prototyping stage were focused primarily on the validity and practicality of the IRME curriculum, some aspects of the effectiveness were also evaluated in this stage. The last stage of the study was *the assessment stage*. In this stage the final version of RME-based curriculum was developed and implemented, followed by a summative evaluation activity (see Chapter 8). The assessment stage of the study was designed to gain further insights about the practicality and effectiveness of the IRME curriculum.

The evaluation activities that were conducted in this study included interviews and discussions with the Dutch RME-experts, Indonesian subject matter experts, an inspector, principals of two Indonesian primary schools, teachers and pupils, as well as classroom observations, analysing pupils' portfolios, assessments, pre-tests and post-tests. The instruments used for the evaluation were the interview guidelines, observation scheme, questionnaire, and the assessment and test materials (see the detail in Chapter 4). The schools for the classroom experiments in this study were chosen with the main consideration being the willingness of the schools, especially the teachers, to collaborate or to participate in the study.

Prototype 1 of the IRME curriculum was implemented by the author in two primary schools in Surabaya, Indonesia, during Fieldwork I (September 1999 - February 2001). Two teachers and one Dutch RME expert observed the classroom experiments. The formative evaluation in this fieldwork was conducted in a rather informal way. The results of the evaluation on the development and implementation of Prototype 1 can be summarised as follows (see also Chapter 6):

- There were several problems found at the beginning of the classroom experiments such as:
  - Dependent attitude of the pupils;
  - Pupils were not used to working on the contextual problems;
  - Pupils' tendency to get the result without paying attention to the process;
  - Pupils were not used to working in-groups;
  - Pupils' lack of motivation, activity, creativity and reasoning.

  After some efforts by the author (as the teacher) in overcoming the problems (see Chapter 6) and after the pupils became familiarised with the RME approach, some improvement was noted in pupils' attitudes, motivation, activity, creativity, and reasoning. The teachers from the two schools also observed the changes. The contextual problems in the student book and the teaching method as applied by the author played very important roles in these changes.
- The content and construct of Prototype 1 of the IRME curriculum were considered to be valid after the prototype was evaluated by two Dutch RME experts and reviewed by four Indonesian subject matter experts and two primary school teachers. The findings from the classroom experiments also showed that in general the learning trajectory for learning and teaching the topic Area and Perimeter worked as intended. However, problems regarding the pupils' attitudes found at the beginning of the classroom experiments and also the findings from the pupils' portfolios lead to some changes being made to the contextual problems in the student book.
- In terms of the practicality, the results from the interviews with the teachers and pupils and the classroom observations showed that the student book was easy to use. The pupils were able to learn as intended according to the RME perspective, after the problems mentioned before were solved. Nevertheless, it was found that the pace planned for some lessons was insufficient because most pupils needed more time to solve the contextual problems than was expected, and also because of the above mentioned problems regarding the pupils' attitudes.
- It took some time for the pupils as well as the author to adapt to the RME approach. The presence of the RME Dutch expert and the observers during the classroom experiments helped the author to get used to the new teaching style and also to overcome the problems that occurred in the classrooms.

The implementation of Prototype 2 of the IRME curriculum was performed by the author in two primary schools: one school (2 classes) in Surabaya, East Java, and another school (2 classes) in Padang, West Sumatera, during Fieldwork II in Indonesia that took place from August 2000 until March 2001. One teacher from each school was scheduled to teach the IRME curriculum in one class, but after two classroom experiments, both teachers withdrew. The teacher in Surabaya was away from the school because of family business, while the teacher in Padang felt that she was not yet capable of teaching using the RME approach because of inadequate preparation. In the assessment stage of the study it was considered to be important that proper training should be provided for the teachers before they conducted the classroom experiments.

The following summarizes the results from the evaluation of the development and implementation of Prototype 2 of the IRME curriculum:

- The same problems as those experienced in Fieldwork I were also faced at the beginning of the classroom experiments during Fieldwork II. Learning from the experience of the previous fieldwork, the author (as the teacher) could overcome the problems more effectively. The experience gained from Fieldwork I also meant that the author felt more comfortable using the RME approach to teach during Fieldwork II. The benefit was not only in how to handle the problems that occurred in the classrooms, but also in how to react to the pupils' answers or contributions and how to guide and stimulate the pupils in solving the contextual problems.
- The results of the experts' validation, which involved three Dutch RME-experts, four Indonesian subject matter experts, and one teacher, showed that the IRME curriculum material reached the criteria of the content and construct validity (see Chapter 4, section 4.3.2). It was also found that the pupils could learn the topic Area and Perimeter according to the conjecture learning trajectory designed in the IRME curriculum.
- The experts, an inspector and the principal, all agreed that the IRME curriculum has the potential to develop pupils' understanding, reasoning, activity, creativity and motivation. They also agreed that the IRME curriculum would be usable and useful for learning and teaching the topic Area and Perimeter. The results from the interviews with the pupils and the classroom observations indicated that the student book was easy to use, and the pupils could learn as intended

according to the RME point of view. Based on these data it was concluded that the IRME curriculum fulfilled the criteria of practicality. One teacher in Padang, who initially doubted the practicality of the IRME curriculum, also appreciated it as she herself observed some progress in her pupils by the end of the classroom experiments.

- The investigation on four levels of the effectiveness: *pupils' reactions, pupils' learning, pupils' use of new knowledge and skills,* and *pupils' learning outcomes* (see Chapter 4) lead to the following conclusions:
  - The pupils liked the IRME curriculum and believed that it had helped them to develop self-confidence and reasoning skills.
  - Most pupils had acquired the intended RME knowledge. They construe several geometry concepts by themselves after performing the activities designed in the IRME curriculum and also found various strategies for solving the contextual problems.
  - Most pupils demonstrated that they were able to use the new knowledge and skills that they had gained from an earlier lesson in subsequent lessons. This was not so for a few pupils who lacked knowledge of fundamental mathematics concepts (see Chapter 7).
  - The pupils' learning outcomes showed that the IRME curriculum had a positive impact on the pupils' confidence as learners and also their understanding, reasoning, activity, creativity and motivation.
  - The pupils' achievements on the post-tests were significantly higher than their achievements in the pre-test, and their average achievement on the assessments was more than 8 on a scale of 1 to 10.

The final version of the IRME curriculum was implemented through Fieldwork III (August 2001 –February 20002) in Padang, West Sumatera and Surabaya, East Java. The classroom experiments in Padang were conducted by the author in three primary schools. Three teachers and four student teachers took the role of observers. The author decided to implement the final version of the IRME curriculum himself in order to validate the results gained from Fieldwork I and II, especially regarding the impact of the IRME curriculum on the pupils' learning outcomes.

The implementation of the final version of the IRME curriculum in Surabaya took place in two primary schools (four classes). Two teachers (one teacher from each school) and two Ph.D. students conducted the classroom experiments. Nine observers (four Ph.D. students, one master student, two lectures, and two teachers) took the role of observers during the classroom experiments. In every lesson, at least two observers viewed the classroom activities. One observer focused on the teacher's activities and the other focused on the pupils' activities. The observers and the teachers were trained before the classroom experiments. The results from the assessment stage of the study are summarized as follows (see also Chapter 8):

- In general it was concluded that the learning trajectory for learning and teaching the topic Area and Perimeter could work as intended for most pupils.
- The pupils could use the student book without any difficulties and they could learn the topic Area and Perimeter as intended according the RME approach.
- The teacher guide was useful for the teachers in implementing the IRME curriculum. Three teachers said that the teacher guide was easy to use, while one teacher suggested that the teacher guide should provide more detail.
- The evaluation on the aspects of the effectiveness: *pupils' reactions, pupils' learning, pupils' use of new knowledge and skills,* and *pupils' learning outcomes (performance and achievement)* resulted in the same findings as those in Fieldwork II (see Chapter 7)
- The results of the evaluation indicated that the teachers felt positive about the IRME curriculum. In general the teacher could implement the IRME curriculum as intended, although sometimes they still used traditional ways of teaching. The author also observed that on some occasions the teachers could not fully apply the RME knowledge and skills that they gained from the training probably because they were not yet used to the RME approach.
- The pupils' achievements on the post-tests were significantly higher than those in the pre-tests. The pupils' achievements in the experimental classrooms were also significantly higher than the achievements of the pupils in Grade 4 and 5 who had been taught the topic Area and Perimeter using traditional methods.
- A significant difference was found between the motivation of the pupils before and after they had been taught the IRME curriculum, especially in terms of *self-concept* (see Chapter 4).

Based on the results from the two stages of this part of the study, it has been concluded that:

1. The IRME curriculum developed and implemented for pupils at Grade 4 in Indonesian primary schools met the criteria of *the content and construct validity*. It suggests that the learning trajectory designed in the IRME curriculum can be used as a local instructional theory for learning and teaching the topic Area and Perimeter. The way the IRME curriculum was designed (see Chapter 5) can also be used as a reference to design other RME materials. The characteristics of the valid IRME curriculum can be described as follows:
   - The content of the IRME curriculum included the subjects that were supposed to be taught for learning the topic Area and Perimeter based on the RME point of view (see Chapter 5). In this case pupils' understanding of the concepts of Area and Perimeter was built by relating the concepts to other magnitudes such as costs, weight, and to irregular shapes. The reason for this is that in reality pupils mostly deal with the concepts of Area and Perimeter in regard to these contexts.
   - The content of the IRME curriculum reflected the RME's key principles. When learning the topic Area and Perimeter using the IRME curriculum, the pupils had the opportunity to find out the concepts involved in the topic by themselves. They learned the topic Area and Perimeter based on the phenomena that they were familiar with, so that they could build an understanding of the topic using their informal knowledge. They also had the opportunity to use their own ideas in solving the contextual problems in the IRME curriculum.
   - The IRME curriculum reflected the RME's teaching and learning principle (see Chapter 3, section 3.4)
   - The RME curriculum included some important aspects of realistic geometry, especially *measuring and calculating*, and *spatial reasoning* (see Chapter 3, section 3.5).
   - The content of the IRME was sequenced properly, so that the learning trajectory for learning the topic Area and Perimeter (see Chapter 5, section 5.3.3) could guide the pupils to learn as intended.
   - The goals for each lesson in the IRME curriculum were clearly stated, and the content designed for each lesson was well chosen to meet the goals.
   - The relevance and the importance of the units in the IRME curriculum were explicit (see Chapter 5, section 5.4).

2. The IRME curriculum met the criteria of *practicality*. This condition is characterised as follows:
   - The IRME curriculum could stimulate pupils' understanding, reasoning, activity, creativity and motivation in learning the topic Area and Perimeter.
   - The teaching learning process using the IRME curriculum created pupils 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 and easy to use by the teachers. The time set for each lesson in the teacher guide was adequate.
3. The IRME curriculum met the criteria of *the effectiveness* as it resulted in some positive impacts on the pupils at Grade 4 in Indonesian primary schools. The positive impacts of the IRME curriculum on the pupils are characterised as follows:
   - The pupils reported that they liked the IRME curriculum. They said that the IRME curriculum was useful and gave them more confidence as learners.
   - Most pupils acquired the intended RME knowledge in which they found out several concepts involved in the IRME curriculum by themselves. They also developed various strategies in solving the contextual problems. Moreover, they could use the new knowledge and skills that they had acquired in one lesson in the following lessons.
   - The pupils developed more positive attitudes towards learning mathematics. They became more independent and engaged actively in the learning process. They also became more motivated and were stimulated to find different strategies in solving the contextual problems. Although their mathematical reasoning had been very weak initially, the pupils demonstrated that by the end of the classroom experiments they were able to reason mathematically.
   - The pupils' achievements on the post-test were improved significantly compared to their achievements in the pre-test. The achievement of the pupils in the classroom experiments was significantly higher than the achievement of the pupils who had been taught using traditional methods. The pupils' achievements on the assessments were also satisfactory.

4. The results outlined above indicate that the RME approach could be utilised 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.

9.2 DISCUSSION

This section discusses some lessons that can be learned from this study, resulting from a reflection on the research methodology, the substantive part of the research and the contribution of the research to "the scientific body of knowledge".

Methodological reflection

As discussed in Chapter 4, this study followed two "schools of thought" of development 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, 2002; Richey & Nelson, 1996) and the other developed within the area of mathematics education (see Freudenthal, 1991; Gravemeijer, 1994, 1999). It appears that the combination of the two schools of thought played a very important role in achieving the positive results of the study as described in the previous section. The first approach of the development research, developed at the University of Twente, The Netherlands, gave useful support for the development and implementation of Prototype 1 of the IRME curriculum until it reached the final version. The cyclical processes, consisting of *design*, *evaluation* and *reflection*, suggested by this approach gave the opportunity to design a valid, practical and effective IRME curriculum. In relation to this development research approach, the study was divided into three stages namely *front-end analysis, prototyping stage* and *assessment stage*. Dividing the study in this way assisted in maintaining the focus of the research and providing time for reflection in each stage of the study.

The second development research approach, developed at the Freudenthal Institute, The Netherlands, played a very important role in developing the content of the IRME curriculum, especially in giving a direction towards developing the local instructional theory for learning and teaching the topic Area and Perimeter. This type of development research is characterized by a cyclic process of thought experiments and instruction experiments to develop instructional sequences in learning mathematics. In this study the cyclical process consisted of *consideration* and *classroom experiments*.

The cyclical process of thought and instruction experiments in this approach is applied on a daily basis (see the detail in Chapter 4, section 4.2.2) until the local instructional theory for learning and teaching a mathematics topic is developed. However, this process could not be fully applied in Indonesia for two reasons. Firstly, the schools in Indonesia have to finish the curriculum on time because the pupils are required to sit local and/or national examinations, and secondly, it is not possible for a school to withdraw from the local and/or national examination system. Consequently, the cyclical process of considerations and classroom experiments in this study was confined within an annual time-table, because the topic Area and Perimeter can only be taught once a year for the pupils at Grade 4 in Indonesian primary schools.

The results of the study indicated that the learning trajectory for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools could still be developed under these circumstances. Nevertheless, it would have been better if the conjecture learning trajectory designed in the IRME curriculum could have been investigated by applying the cyclical process on a daily basis. It would mean that the processes of considerations and classroom experiments could be done intensively, in which the findings from one class experiment could be applied directly in the next classroom experiments after a consideration. Moreover, the cyclical process of considerations and classroom experiments could be performed more than just three times (*Note*: The cyclical process in this study was performed for three times because the time to conduct the study was limited).

In this study the author took the roles of developer, researcher and teacher. This situation could lead to a bias in forming the conclusions of the study, but this problem was overcome by using triangulation. Three types of triangulation were applied in this study. The first was *data triangulation* in which the data of the same phenomenon, for example the effect of the IRME curriculum on the pupils, was studied in different time*s*, places and from different subjects. The second type of triangulation, namely *investigator triangulation*, used multiple sources to evaluate the same phenomenon. For example, the practicality of the IRME curriculum was investigated by interviewing the Dutch RME experts, Indonesian subject matter experts, the inspector, principals and teachers and the classroom experiments were also observed by multiple observers. Finally, *methodological triangulation* was used in this study by combining some methods in investigating the same phenomena. For example, pupils' reaction to the IRME curriculum was evaluated by conducting the interviews with the pupils in combination with the classroom observations.

Substantive reflection

The results of this study showed that the IRME curriculum worked for learning and teaching the topic Area and Perimeter at Grade 4 in Indonesian primary schools. As discussed in Chapter 4, the IRME curriculum developed and implemented in this study was inspired by the project Wiskobas in the Netherlands (summarized by Gravemeijer (1992) in the paper entitle *Reallotment*) and the project MiC in the USA. To some extent the results of this study were similar to those in the two projects. The local instructional theory for learning and teaching the topic Area and Perimeter developed in those projects appeared to be valid for the pupils at Grade 4 in Indonesian primary schools.

Further results indicated that the teachers and the pupils liked the IRME curriculum, as it was very different to the Indonesian curriculum both in the content and the approach. The content that was designed based on *the RME's key principles* (see Chapter 3, section 3.3), allowed the pupils to build their understanding using their informal knowledge. The approach to teaching the IRME curriculum that was based on *the RME's teaching and learning principles* (see Chapter 3, section 3.4) was also conducive to a stimulating learning and teaching process. As mentioned in section 9.1, the classroom climate in Indonesian schools is not conducive to effective learning and teaching of mathematics. However, learning and teaching the IRME curriculum produced a very different classroom environtment. The pupils became more active and creative, there was not just 'chalk and talk' method, and the role of the teachers was changed from being the center of the learning and teaching process to become that of guide and resource person.

At the beginning of the classroom experiments in each block of fieldwork there were some problems regarding the negative attitude of the pupils towards learning mathematics (see Chapter 6 and 8). These problems were largely the product of the traditional ways of teaching. Nevertheless, efforts made by the author (as the teacher) were successful in overcoming these problems. Considering that the conditions of the schools in Indonesia are rather similar in general, the following aspects might be important for further development and implementation of the RME approach in Indonesia, especially for teachers:

- It is important to tell pupils from the very beginning about the change of their and the teacher's roles in the teaching learning process as compared to those in the traditional way of teaching.
- Teachers need to explain clearly to pupils the expectations of the IRME curriculum regarding what activities the pupils need to perform, and what kind of answers they are expected to give in solving the contextual problems.
- Regarding the negative attitudes of the pupils that were found at the beginning of the classroom experiments, the following activities may help in changing these attitudes:
  - Creating a challenging introduction (see Chapter 6) before the pupils begin to solve the contextual problems so that the pupils feel a sense of excitement and responsibility in solving them.
  - Creating a democratic atmosphere in the classrooms so that the pupils are not afraid to be actively engaged in the teaching learning process. The democratic condition means that the pupils feel free to be active in the learning teaching process without feeling afraid to make mistakes, if they want to ask questions or to answer questions. There were two conditions that probably resulted from the traditional way of teaching that prevented the pupils from being active. Firstly, only the correct answers were expected. If a pupil came up with an incorrect answer, there was no response or follow up from the teacher. Secondly, most of the time other pupils laughed at pupils who came up with the incorrect answer. Telling the pupils that we can learn from the incorrect answers or by giving a positive response to the pupils who gave an incorrect answer might solve these problems.
  - Applying some rules on how to ask questions (i.e. raising hands instead of shouting) and how to respond to the questions may contribute to creating an atmosphere of learning and task orientation. Informing the pupils of the consequence if they do not behave or act according to the expectations (i.e. they will get better marks if they give the reasons for their answers) may also help to reduce the negative attitude of the pupils.

- As some parents help pupils with their homework, it is important to inform the parents about the changes from a traditional mathematics approach to learning and teaching mathematics based on the RME approach.
- It took some time for the pupils and the author (when being the teacher) to adapt to the RME approach. The author felt more comfortable in conducting the classroom experiments during Fieldwork II after learning from the experience in Fieldwork I. It was realised also that the presence of the RME Dutch expert and observers helped the author to get used to the new teaching style. It was observed that the teachers could not fully apply the knowledge and skills that they acquired from the training because they were not fully used to the RME approach yet. They probably needed more time to grasp the whole idea of the new teaching style.

Scientific reflection

RME is a theory concerning mathematics education that deals with three main aspects (see Chapter 3):

- What mathematics has to be taught together with a rationale of why it is important that certain mathematics be taught?
- How pupils learn mathematics and how mathematics should be taught? These imply the methods by which teachers should teach mathematics).
- How to assess students' learning capacity?

So far, researchers in the field of mathematics education have paid more attention to the last two aspects, while the investigation of '*what the content of mathematics have to be taught?*' is seen as being the responsibility of curriculum designers/developers. It was argued in this study that some of the negative effects of the traditional way of teaching (see Chapter 1 and 2) resulted from teachers' lack of knowledge of the importance of the mathematics topics that they were teaching. The same was true for the pupils who became unmotivated in the learning of mathematics, and even hated to learn mathematics, because the mathematics topics that they learnt were not useful or relevant for them in their everyday lives.

This study tried to cover all the aspects, as it was considered that a good understanding of the first aspect would lead to a better way to realise the second and the third aspects. Because the time to conduct the study was limited, priority was given to developing a high quality IRME curriculum and studying its effect on the pupils, while the investigation regarding the teachers and the assessments was not investigated thoroughly. However, as described in section 9.1, this study proved that the RME approach has good potential in overcoming some fundamental problems (see Chapter 1 and 2) regarding mathematics education in Indonesian primary schools.

To conclude the discussion in this section, this study together with three other studies (see Armanto, 2002; Hadi, 2002; Zulkardi, 2002) were the first pilot studies of RME in Indonesia. All these RME studies had different focuses but were similar in vision, in that they explored the extent to which RME approach could be utilized in Indonesia, and could stimulate a reform in Indonesian education. The results of these studies indicated that if the RME materials are properly prepared and also properly taught then the RME approach works in Indonesia. This study and the study by Armanto (2002) showed that the RME materials had a positive influence on the pupils, while the other two studies concluded that the teachers could implement the RME materials after they were properly trained. These findings strengthen the results from the previous studies. Firstly, some studies showed that RME worked in the Netherlands, as the origin of this approach (see De Lange, 1987; Gravemeijer, 1994; Klein,1998; Streefland, 1991). Then, the adaptations of the RME approach in several countries such as in the USA (see NSF, 1997), Malaysia, England, Brazil, South Africa (see De Lange, 1987, 1996), and Korea (see Kwon, 2002) lead to a conclusion that the RME approach had a positive impact on the learning and teaching mathematics in those countries.

9.3 RECOMMENDATIONS

Based on the results of the study, this section presents some recommendations that can be used for policy and practice, further research and further development work.

Recommendations for policy and practice

RME is an approach to mathematics education developed in the Netherlands, but the study reported here, and also the results of the other RME studies in Indonesia (see Armanto, 2002; Hadi, 2002; Zulkardi, 2002) show that this approach has the potential to address some fundamental problems in Indonesian primary schools.

The study has also indicated that the RME approach is not something that would be impossible to utilize in Indonesia. However, to realize this, a big effort is needed in the areas of curriculum development, assessment practices, and teacher (in-service) training, all supported by focused development research and formative evaluation to assure that 'local' relevancy will be obtained. The efforts needed should not be underestimated as the changes touch on the roots of mathematics education in Indonesia: it is necessary that all stakeholders understand that not only a new curriculum and a new pedagogy is needed, but above all that the notion of what is effective mathematics education has to change (see Fullan, 2001). Therefore, a process to change the mathematics curriculum and culture towards introducing RME in Indonesia is only possible with the support of the government. The government has to play a key role, in the first place is to take the policy decision and to provide the budget to facilitate the research and development in all three areas mentioned above. The government must also develop a policy on mathematics education that provides the formal and 'administrative' support that such a change to the national curriculum and assessment approach needs. Moreover, the teacher training institutes may become the first "targets' for change, as they have to play a central role in preparing the teachers to be capable of teaching and disseminating RME.

Recommendation for further research

Many aspects of mathematics teaching and learning can be explored using the RME approach, for example: How pupils learn and teachers teach mathematics using the RME approach? What is the impact of the RME approach on teachers and pupils? One aspect that was investigated in this study was the impact of the IRME curriculum on the pupils' understanding, reasoning, activity, creativity, and motivation. However, as discussed in section 9.2, some conclusions regarding these aspects, especially pupils' reasoning, activity and creativity were rather impressionistic. Therefore a better operationalization and research design is needed to investigate these aspects, by developing more specific criteria, for example to determine whether pupils are active and creative or not.

Referring to the level of effectiveness mentioned by Kirkpatrick (1987), the investigation of the effect of the IRME curriculum on the teachers was more focused on the level of participants' reaction, participants' learning and participants' use of knowledge and skills. It is recommended, therefore, that the effect of the IRME curriculum on the teachers, on the level of participants' learning outcomes (i.e. the teachers' achievement on the training), should be investigated more thoroughly.

Recommendation for further development work

One important result of this study was the local instructional theory for learning and teaching topic Area and Perimeter at Grade 4 in Indonesian primary schools. The research from Armanto (2002) resulted in the local instructional theory for learning and teaching addition and multiplication of two digit numbers for pupils at the same grade. The two studies showed that it was possible to develop for the Indonesian context the conjecture learning trajectory (as an embryo of the local instructional theory) for learning and teaching a mathematics topic. Positive findings of the two studies showed that the pupils could learn as intended according to the learning trajectories that were designed for them. These results suggest that learning trajectories for learning and teaching other mathematics topics in the primary schools need to be developed. As it is assumed that the problems regarding pupils' attitude found in this study resulted from the traditional method that the pupils had experienced since they were in Grade 1, it is recommended that the development of *the local instructional theory* should begin with the learning and teaching of mathematics topics in Grade 1, and then gradually move to the higher grades. For this purpose, it is also recommended that some schools be selected for pilot studies, in which the local instructional theory can be developed by performing the cyclical process of thought experiments and instruction experiments on a daily basis.

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Dutch summary
Het toepassen van Realistisch Wiskunde-Onderwijs in meetkundeonderwijs op Indonesische basisscholen

Evenals in andere landen (zie bijvoorbeeld Niss, 1996; NCTM, 2000), wordt in het wiskundecurriculum van de basisscholen in Indonesië veel aandacht besteed aan belangrijke aspecten, zoals de ontwikkeling van het logisch denkvermogen van leerlingen, inzet, creativiteit en houding. Ook het aanleren van wiskundige vaardigheden is een belangrijk aspect, omdat dit leerlingen in staat stelt praktische en realistische problemen wiskundig aan te pakken. Deze aspecten zijn als volgt uitgekristalliseerd in de doelen van het wiskundecurriculum voor de Indonesische basisschool:

- De leerlingen zijn in staat om effectief en efficiënt om te gaan met de dynamische wereld door praktisch bezig te zijn met logisch redeneren, rationeel en kritisch denken, gebaseerd op zorgvuldigheid en eerlijkheid.
- De leerlingen zijn in staat wiskunde en wiskundig redeneren te hanteren in het dagelijks leven en bij het bestuderen van andere vakken.

Het huidige wiskundeonderwijs blijkt deze doelen echter niet te realiseren, waardoor de volgende vragen rijzen: waarom is de kwaliteit van het wiskundeonderwijs op Indonesische basisscholen nog steeds zo laag? Waarom hebben de meeste leerlingen een aversie tegen het vak wiskunde ontwikkeld (zie Marpaung, 1995, 2001), en waarom behalen de leerlingen jaar in jaar uit slechte resultaten? (zie www.depdiknas.co.id). Deze vragen tonen aan dat er een aantal problemen speelt in het wiskundeonderwijs op Indonesische basisscholen, vooral wat betreft het curriculum en het leer- en onderwijsproces.

In de afgelopen drie decennia, is het curriculum viermaal aangepast (Curriculum 1975, 1984, 1994 en 2002). Elk van deze curricula was gebaseerd op een andere onderwijsbenadering (zie hoofdstuk 2) en werd gepresenteerd in de vorm van wat Goodlad, (1984) een ideaal curriculum noemt. De overstap van het ene naar het andere curriculum heeft echter geen significante verbeteringen opgeleverd. Daar is een aantal oorzaken voor aan te wijzen. Ten eerste is bij het invoeren van de nieuwe curricula steeds gebruik gemaakt van een top-downbenadering (zie Noor, 2000), zonder daarbij grondig onderzoek te doen naar de werkelijke behoefte aan verandering, in het bijzonder op schoolniveau.

Ten tweede is er bij de implementatie van de curricula geen duidelijke strategie gevolgd. De nascholing, die gegeven is om de leerkrachten te ondersteunen bij de implementatie van de herziene curricula, lijkt niet effectief te zijn geweest (zie Somerset, 1997; Hadi, 2002). De meeste leerkrachten die aan de nascholing hebben deelgenomen, zijn het spoor bijster geraakt zodra ze de nieuwe ideeën op hun school in praktijk probeerden te brengen. Aangezien de nascholing niet werd gevold door adequate supervisie en evaluatie (Somerset, 1997), gaven de leerkrachten de voorkeur aan de methode van lesgeven waaraan ze gewend waren.

Ten derde is de implementatie van het curriculum niet zorgvuldig geëvalueerd. Het enige criterium dat door de overheid is gebruikt om te beoordelen in welke mate de implementatie succesvol was, is het prestatieniveau van de leerlingen. De gegevens over de andere belangrijke aspecten van het implementatieproces blijven daardoor onbekend, zoals over hoe het leer- en onderwijsproces in de praktijk is ingevuld, hoe het leerproces bij leerlingen is verlopen, of de moeilijkheden waar leerkrachten mee te maken hebben gekregen tijdens de implementatie van het curriculum.

Ook is er een aantal zwakke punten aan te wijzen aangaande de inhoud van het wiskundecurriculum voor de basisschool. Ten eerste is het curriculum overladen, aangezien er te veel onderwerpen moeten worden behandeld (zie Soejadi, 2000). Leerkrachten klagen over het grote aantal onderwerpen dat in een betrekkelijk korte tijd behandeld moet worden. Leerlingen klagen over de grote hoeveelheid oefeningen die ze moeten uitvoeren en over een overmaat aan huiswerk. Ouders, tot slot, raken verward als zij hun kinderen proberen te helpen met hun huiswerk.

Een tweede punt van zwakte is dat de verschillende onderwerpen van het curriculum te weinig met elkaar samenhangen. Dit heeft ertoe geleid, dat leerkrachten het curriculum beschouwen als een verzameling onafhankelijke onderwerpen (zie vignet 2 in hoofdstuk 1), terwijl leerlingen het curriculum ervaren als een reeks afzonderlijke onderwerpen die zij moeten leren.

In de derde plaats ontbreken in het curriculum voorbeelden van praktische toepassingen van wiskunde. Gezien de doelen, die eerder in deze paragraaf staan vermeld, zou de inhoud van het curriculum rijk aan praktische oefeningen en betekenisvolle toepassingen moeten te zijn. Feitelijk overheerst echter een benadering die gericht is op de introductie en memorisatie van abstracte concepten, het toepassen van formules en het oefenen van rekenvaardigheden (zie enige voorbeelden in hoofdstuk 2).

Het leer- en onderwijsproces op Indonesische basisscholen is veelal op traditionele wijze georganiseerd. De leerkracht staat centraal bij vrijwel alle lesactiviteiten (zie voorbeeld in hoofdstuk 1; Fauzan, 1999; Fauzan, Slettenhaar & Plomp, 2002, 2002a; Marsigit, 1999), waarbij de leerling wordt gezien als een 'leeg vat' dat gevuld dient te worden. Het lesklimaat in Indonesische basisschoolklassen komt in grote lijnen overeen met dat in verschillende Afrikaanse landen, als volgt samengevat door De Feiter & Van Den Akker (1995) en Ottevanger (2001):

- leerlingen zijn gedurende de les passief;
- 'chalk and talk' is de voorkeursstijl van de leerkracht;
- veel nadruk op feitenkennis;
- vragen kunnen met één woord worden beantwoord, dat veelal in koor wordt opgedreund;
- het ontbreken van vragen die zijn gericht op het bevorderen van leren;
- alleen correcte antwoorden worden geaccepteerd, terwijl foute respons wordt genegeerd;
- geoefend wordt met de hele klas tegelijk, en praktische vaardigheden worden niet toegepast.

Een onderwijsvorm met bovengenoemde kenmerken zorgt ervoor dat de meeste leerlingen niet de wiskundige scholing krijgen die ze nodig hebben. Ze worden niet in de gelegenheid gesteld betekenisvolle wiskunde te leren. Voor de meeste leerlingen is wiskunde een eindeloze reeks van feiten en procedures die ze uit het hoofd moeten leren, die ze daarna snel weer vergeten en waarvan ze weinig begrijpen. Voor de meeste leerkrachten is het lesgeven in de wiskunde een routineklus, waarbij jaar na jaar dezelfde onderwerpen worden behandeld (zie ook Battista, 1999).

De Indonesische overheid heeft een aantal pogingen ondernomen om deze problemen aan te pakken (zie enkele innovatieprojecten in hoofdstuk 2). De meeste van deze activiteiten waren echter relatief ineffectief. Tot voor kort gaven zowel het wiskundecurriculum als de tekstboeken de leerlingen nog steeds niet de mogelijkheid om actief met wiskunde bezig te zijn, maar alleen om wiskunde te memoriseren. Leerkrachten blijken er weinig voor te voelen af te wijken van de traditionele onderwijsmethode voor wiskunde, en een significant deel van de leerlingen heeft een aversie tegen het vak ontwikkeld.

Gebaseerd op heb bovenstaande kan een aantal fundamentele problemen van het wiskundeonderwijs in Indonesië worden samengevat:

1. Het wiskundecurriculum is overladen. Dit leidt tot situaties waarbij het leren uitsluitend is gericht op het bereiken van de leerdoelen, terwijl het proces dat moet leiden tot die leerdoelen wordt veronachtzaamd. Daarbij zijn de meeste leerdoelen alleen gericht op het memoriseren van feiten en concepten en rekenkundige procedures (bijv. het toepassen van formules).
2. De onderwijsbenadering voor het lesgeven in het vak wiskunde is erg mechanistisch en traditioneel.

Bij het veranderen en vernieuwen van het wiskundeonderwijs is nooit aandacht besteed aan de twee hiervoor genoemde problemen, omdat er nooit een bewuste implementatiestrategie is gevolgd.

De aanleiding tot dit onderzoek komt voort uit een algemeen gevoel van ontevredenheid over het wiskundeonderwijs in Indonesië, vooral in het basisonderwijs. Het onderzoek beoogt bij te dragen aan het vinden van oplossingen voor de fundamentele problemen die hierboven zijn beschreven. De resultaten van de literatuurstudie (zie hoofdstuk 3) wijzen erop dat realistisch wiskundeonderwijs [In het vervolg zal de Engelse afkorting 'RME' worden gehanteerd; Realistic Mathematics Education] een goede methode zou zijn om de geschetste problemen te overwinnen. In de RME-benadering wordt het vak wiskunde onderwezen aan de hand van problemen die de leerlingen kunnen kennen uit het dagelijks leven. Ze krijgen de gelegenheid om wiskundige concepten zelf te ontdekken en om hun kennis zelfstandig op te bouwen (zie Gravemeijer, 1994, 1997). Instructie volgens de RME-benadering vereist werken in kleine groepjes, waar onderzoek, experimenteren, discussie en reflectie de kern van het onderwijs- en leerproces vormen (De Moor, 1991).

In het kader van dit onderzoek wordt voor het leren en onderwijzen van het onderwerp 'oppervlakte en omtrek' in grade 4 [vergelijkbaar met groep 6 in Nederland] van de Indonesische basisschool volgens de RME-benadering een curriculum ontwikkeld en geïmplementeerd, namelijk het *curriculum voor Indonesisch Realistisch wiskundeonderwijs* [IRME- Indonesian Realistic Mathematics Education, Indonesisch realistisch wiskundeonderwijs]. Met de term curriculum wordt in dit verband bedoeld een plan van uitvoering voor de instructie, waarin onder meer staat wat de leerlingen moeten weten, hoe zij de vastgestelde doelen moeten bereiken, wat leerkrachten zouden moeten doen om de leerlingen te stimuleren in het ontwikkelen van hun wiskundekennis en een beschrijving van de context waarin het leren plaatsvindt (zie NCTM, 1989). In dit onderzoek, waarin een ontwerpgerichte onderzoeksbenadering is gevolgd, is het plan van aanpak vormgegeven in een docentenhandleiding en een leerlingenboek.
Voor een ontwerpgerichte onderzoeksbenadering is gekozen, omdat het toereikende en nuttige ondersteuning biedt bij de ontwikkeling en implementatie van het IRME curriculum (noot: de term *implementatie* verwijst naar praktijkexperimenten met het IRME-curriculum op de Indonesische basisscholen). Het onderzoek volgt twee 'schools of thought' binnen de ontwerpgerichte onderzoeksbenadering. De eerste wordt beschreven door Van Den Akker (1999), Van Den Akker & Plomp (1993) en Richey & Nelson (1996) en de tweede door Freudenthal (1991) en Gravemeijer (1994, 1994a, 1999) (zie hoofdstuk 4)

Het onderzoek heeft tot doel een valide, bruikbaar en effectief IRME-curriculum voor het leren en onderwijzen van het onderwerp 'oppervlakte en omtrek' in grade 4 van de Indonesische basisscholen te ontwikkelen en implementeren. De termen valide, bruikbaar en effectief refereren aan de classificaties zoals gehanteerd door Nieveen (1997, 1999), Kirkpatrick (1999) en Guskey (2000) (zie hoofdstuk 4). Het doel van het onderzoek is als volgt uitgewerkt:

- De ontwikkeling van een *valide* curriculum houdt in dat er een 'lokale instructie theorie' (zie Gravemeijer, 1999) ontwikkeld dient te worden, alsmede ontwerprichtlijnen voor de verdere ontwikkeling van RME-lesmateriaal in Indonesië.
- Het criterium *bruikbaar* verwijst naar de vraag of het wel mogelijk is de RME-benadering in het Indonesisch primair onderwijs te introduceren.
- Een *effectief* curriculum refereert aan de mate waarin de RME-benadering een aantal van de problemen van het wiskundeonderwijs op de Indonesische basisscholen kan oplossen, met name in het meetkundeonderwijs.

In het verlengde van deze onderzoeksdoelstelling is de volgende onderzoeksvraag geformuleerd:

> *Wat zijn de kenmerken van een valide, bruikbaar en effectief IRME-curriculum voor het leren en onderwijzen van het onderdeel 'oppervlakte en omtrek' in grade 4 van de Indonesische basisschool (vergelijkbaar met groep 6 in Nederland)?*

Deze onderzoeksvraag is onderverdeeld in een aantal sub-vragen (zie hoofdstuk 6, 7 en 8), die zijn onderzocht in drie onderzoeksfasen. De eerste fase was een vooronderzoek (front-end analysis), waarin de huidige situatie van het Indonesische onderwijs is geanalyseerd (zie hoofdstuk 2). Ook is literatuur over RME en andere nieuwe ontwikkelingen in het wiskundeonderwijs bestudeerd (zie hoofdstuk 3), resulterend in een eerste opzet van het IRME-curriculum en een *voorlopig* leertraject voor het leren van het onderwerp 'oppervlakte en omtrek' (zie hoofdstuk 5).

De tweede onderzoeksfase wordt de prototypefase genoemd. Deze bestond uit de ontwikkeling, implementatie en formatieve evaluatie van prototype 1 (zie hoofdstuk 6) respectievelijk prototype 2 (zie hoofdstuk 7) van het IRME-curriculum. Hoewel evaluatieactiviteiten in de prototypefase in de eerste plaats gericht waren op het beoordelen van de validiteit en toepasbaarheid van het IRME-curriculum, werden in deze fase ook al enkele aspecten van de effectiviteit geëvalueerd. Het laatste stadium van het onderzoek was de evaluatiefase. In dit stadium werd de definitieve versie van het curriculum ontwikkeld en geïmplementeerd, gevolgd door een summatieve evaluatie (zie hoofdstuk 8). Het doel van de laatste evaluatie was om meer inzicht te krijgen in de bruikbaarheid en vooral de effectiviteit van het IRME-curriculum.

De evaluatieactiviteiten die in dit onderzoek zijn uitgevoerd behelzen interviews en discussies met Nederlandse RME-experts en Indonesische inhoudsdeskundigen, een inspecteur, en de directeuren, leerkrachten en leerlingen van twee Indonesische basisscholen. Ook is gebruik gemaakt van praktijkobservaties, analyse van de portfolio's van leerlingen, en voor- en natoetsen. De instrumenten die zijn gebruikt bij de summatieve evaluatie zijn interview- en observatieschema's, vragenlijsten en toetsen (zie in detail in hoofdstuk 4). De scholen waar de praktijkexperimenten zijn uitgevoerd, zijn hoofdzakelijk geselecteerd op basis van bereidheid van de school, en met name van de leerkrachten, om deel te nemen aan het onderzoek.

Prototype 1 is door de onderzoeker geïmplementeerd op twee basisscholen in Surabaya, Indonesië, gedurende de eerste periode van veldwerk (september 1999 – februari 2001). Twee leerkrachten en een Nederlandse RME-deskundige hebben de praktijkexperimenten, die in de klassensituatie plaatsvonden, geobserveerd. De formatieve evaluatie van dit veldexperiment was enigszins informeel. De resultaten van de evaluatie van de ontwikkeling en de implementatie van prototype 1 kunnen als volgt worden samengevat:

- Bij aanvang van de praktijkexperimenten, kwamen enige problemen aan het licht, zoals:
  - De afhankelijke houding van de leerlingen.
  - De leerlingen waren niet gewend om aan contextopgaven te werken.
  - De leerlingen waren resultaatgericht, niet procesgericht.
  - De leerlingen waren niet gewend aan werken in groepjes.
  - De leerlingen vertoonden gebrek aan motivatie, inzet, creativiteit en logisch denken.

  Nadat de onderzoeker (als leerkracht) zich had ingezet om deze problemen te verhelpen (zie hoofdstuk 6) en nadat de leerlingen gewend waren geraakt aan de RME-benadering, was er een lichte verbetering te zien in de motivatie, inzet, creativiteit en het logisch redeneren van de leerlingen. De leerkrachten van de twee scholen signaleerden deze verandering ook. De contextopgaven die waren opgenomen in het leerlingenboek en de docentenhandleiding, hebben een belangrijke rol gespeeld bij deze verandering.
- Na de evaluatie door twee Nederlandse RME-experts en de beoordeling door vier Indonesische inhoudsdeskundigen en twee basisschoolleerkrachten, werd aangenomen dat de inhoud en structuur van prototype 1 valide is. De resultaten van de praktijkexperimenten gaven aan dat de leerlijn voor het leren en onderwijzen van het onderwerp 'oppervlakte en omtrek' ook naar behoren functioneert. De problemen met de houding van de leerlingen aan het begin van de praktijkexperimenten en de bevindingen uit de portfolio's van de leerlingen, gaven aanleiding tot het aanpassen van de contextuele problemen in het leerlingenboek.
- Wat betreft de toepasbaarheid van het prototype, tonen de resultaten van de interviews met leerkrachten en leerlingen aan dat het leerlingenboek gemakkelijk is te gebruiken. De leerlingen waren goed in staat te leren volgens de RME-principes, nadat de hiervoor genoemde problemen waren verholpen. Niettemin

bleek dat de tijd die gereserveerd stond voor de behandeling van bepaalde onderwerpen te kort was, aangezien de meeste leerlingen meer tijd nodig hadden voor het oplossen van de contextuele problemen dan vooraf werd aangenomen. Ook het bovengenoemde houdingsprobleem speelde daarbij een rol.

- Zowel de leerlingen als de leerkracht hadden tijd nodig om te wennen aan de RME-benadering. De aanwezigheid van een Nederlandse RME-expert en de observatoren tijdens de praktijkexperimenten, hebben de onderzoeker geholpen vertrouwd te raken met deze nieuwe onderwijsstijl en problemen die in de klassenpraktijk ontstonden te verhelpen.

Prototype 2 van het IRME-curriculum is gedurende de tweede periode van veldwerk van augustus 2000 tot maart 2001 geïmplementeerd op twee basisscholen: een school (twee klassen) in Surabaya, Oost-Java, en een andere school (twee klassen) in Padang, West-Sumatra. Het was de bedoeling dat van elke school één leerkracht het IRME-curriculum zou uitvoeren. Maar na twee lessen trokken beide leerkrachten zich terug. De leerkracht van de school in Surabaya was wegens familieomstandigheden niet op school aanwezig, terwijl de leerkracht van de school in Pedang het gevoel had dat ze onvoldoende voorbereid was om les te geven volgens de RME-principes. In de evaluatiefase van het onderzoek werd dan ook geconcludeerd dat het van belang is dat leerkrachten voordat ze deelnemen aan de praktijkexperimenten een passende training krijgen.

De evaluatie van de ontwikkeling en implementatie van prototype 2 van het IRME-curriculum leidden tot de volgende conclusies:

- Gedurende het tweede veldexperiment werden dezelfde problemen ondervonden, als bij het begin van het eerste veldexperiment. Lerend van de ervaringen van het vorige experiment, was de onderzoeker (als leerkracht) in staat de problemen op een meer effectieve manier aan te pakken. Dankzij de ervaring die is opgedaan bij het voorgaande experiment, was het tijdens de tweede veldwerkperiode gemakkelijker de RME-benadering te hanteren. De ervaringen zorgden er niet alleen voor dat de leerkracht beter in staat was de praktijkproblemen op te lossen, maar ze verbeterden ook de manier waarop hij reageerde op de antwoorden van de leerlingen en waarop hij ze begeleidde en stimuleerde bij het oplossen van de contextuele problemen.
- De resultaten van de expertbeoordeling, waaraan drie Nederlandse RME-deskundigen, vier Indonesische inhoudsdeskundigen en één Indonesische

leerkracht hebben meegewerkt, toonden aan dat het IRME-curriculummateriaal voldoet aan de criteria voor inhoud- en constructievaliditeit (zie hoofdstuk 4, paragraaf 4.3.2). Ook bleek dat leerlingen in staat zijn het onderwerp 'oppervlakte en omtrek' te leren, via het voorlopige leertraject dat is ontworpen in het IRME-curriculum.

- Indonesische deskundigen, een inspecteur en een directeur, waren het erover eens dat het IRME-curriculum de potentie heeft het begrip, het logisch denken, de inzet, de creativiteit en de motivatie van de leerlingen te ontwikkelen. Ook waren ze van mening dat het curriculum bruikbaar en zinvol is voor het leren en onderwijzen van het onderwerp 'oppervlakte en omtrek'. De resultaten van de interviews met leerlingen en de praktijkobservaties wijzen erop dat het leerlingenboek gemakkelijk is te gebruiken en dat de leerlingen in staat zijn te leren zoals dat wordt aangegeven vanuit de RME-principes. Gebaseerd op deze gegevens, kon worden geconcludeerd dat het IRME-curriculum voldoet aan de criteria voor bruikbaarheid. Eén van de leerkrachten, die aanvankelijk twijfelde aan de praktische haalbaarheid van het curriculum, beoordeelde het curriculum ook positief, nadat ze vooruitgang geconstateerd had bij de leerlingen.

De effectiviteit van het curriculum werd op vier niveaus onderzocht, namelijk: de *reactie* van de leerlingen, het *leren*, het *gebruik van de kennis en de vaardigheden* en het *leereffect* (zie hoofdstuk 4). De resultaten van dit onderzoek leiden tot de volgende conclusies:

- Het curriculum bevalt de leerlingen goed, ze geloven dat het bijdraagt aan hun zelfvertrouwen en hun vaardigheden in logisch denken ontwikkelt.
- De meeste leerlingen hebben binnen de RME naar behoren kennis verworven. Ze ontleden zelfstandig verscheidene geometrische concepten, nadat ze de activiteiten van het IRME-curriculum uitgevoerd hebben. Ook ontwikkelen ze verschillende strategieën voor het oplossen van contextuele problemen.
- De meeste leerlingen hebben aangetoond dat ze in staat zijn om de nieuwe kennis en vaardigheden die ze hebben verworven in voorgaande lessen toe te passen in daaropvolgende lessen. Dit bleek echter niet het geval te zijn voor de leerlingen die de kennis van bepaalde basisvaardigheden missen (zie hoofdstuk 7).
- Uit de leerresultaten bleek dat het IRME-curriculum een positief effect heeft op het vertrouwen dat de leerlingen hebben in hun leren, begrip, logisch denken, inzet, creativiteit en motivatie.

- De leerlingen presteerden gemiddeld significant hoger op de natoets dan op de voortoets, en hun gemiddelde score op een schaal van 1 tot 10 was hoger dan een 8.

De definitieve versie van het IRME-curriculum is geïmplementeerd tijdens veldexperiment III (augustus 2001- februari 2002) in Pedang, West-Sumatra, en in Surabaya, Oost-Java. De praktijkexperimenten in Pedang zijn door de onderzoeker op drie basisscholen uitgevoerd. Drie leerkrachten en vier docenten in opleiding namen de rol van observator op zich. Besloten was de laatste versie van het IRME-curriculum zelf te implementeren om de resultaten die zijn verkregen bij veldexperiment I en II te valideren, met name wat betreft het effect van het IRME-curriculum op de leerresultaten van de leerlingen.

De implementatie van de definitieve versie van het IRME-curriculum in Surabaya heeft plaatsgevonden op twee basisscholen (vier klassen). Twee leerkrachten (één leerkracht op iedere school) en twee Ph.D.-studenten hebben de praktijkexperimenten uitgevoerd. Negen observatoren (vier Ph.D.-studenten, één masterstudent, twee docenten van de pedagogische universiteit en twee basisschooldocenten namen de rol van observator op zich tijdens de praktijkexperimenten. Bij elke les waren minimaal twee observatoren aanwezig. Eén van de observatoren richtte zich op de activiteiten van de leerkracht en de ander op de activiteiten van de leerlingen. De leerkrachten en de observatoren hebben vooraf een training ondergaan. De resultaten uit deze summatieve evaluatie kunnen als volgt worden samengevat (zie ook hoofdstuk 8):

- De algehele conclusie is dat het leertraject voor het leren en onderwijzen van het onderwerp 'oppervlakte en omtrek' voor de meeste leerlingen het gewenste resultaat kan opleveren.
- De leerlingen kunnen het leerboek zonder problemen hanteren en ze zijn in staat het onderwerp 'oppervlakte en omtrek' te leren volgens de RME-benadering.
- De docentenhandleiding is nuttig gebleken bij het implementeren van het IRME-curriculum. Drie leerkrachten gaven aan dat de handleiding makkelijk in het gebruik is, terwijl één leerkracht vindt dat er meer gedetailleerde informatie aangereikt zou moeten worden.
- De evaluatie van de effectiviteitaspecten van het curriculum (*de reactie van de leerlingen*, *het leren*, *het gebruik van de kennis en de vaardigheden* en *het leereffect)* heeft geresulteerd in dezelfde bevindingen als in veldexperiment II (zie hoofdstuk 7).

- De resultaten van de evaluatie tonen aan dat de leerkrachten het IRME-curriculum als positief ervaren. Over het algemeen zijn leerkrachten in staat het IRME-curriculum naar behoren te implementeren, alhoewel ze soms terugvallen op de traditionele manier van lesgeven. In de evaluatie werd ook geconstateerd dat de leerkrachten de RME-kennis en -vaardigheden die ze hebben verworven gedurende de training, soms niet volledig konden toepassen, waarschijnlijk doordat ze nog niet helemaal gewend waren te werken met de RME-benadering.
- De leerlingen scoorden op de natest significant hoger dan op de voortest. De prestaties van de leerlingen uit de klassen waar de praktijkexperimenten zijn uitgevoerd, zijn tevens significant hoger dan die van de leerlingen van groep 4 en 5 die les hebben gehad in het onderwerp 'oppervlakte en omtrek' met gebruik van de traditionele lesmethodes.
- Een significant verschil werd gevonden tussen de motivatie van de leerlingen voor en nadat ze les hebben gekregen met het IRME-curriculum; dit gold vooral voor het zelfconcept (zie hoofdstuk 4).

Gebaseerd op de resultaten van beide fasen van dit onderzoek, kan worden geconcludeerd dat:

1. Het IRME-curriculum, dat is ontwikkeld en geïmplementeerd voor leerlingen van grade 4 van Indonesische basisscholen, voldoet aan de criteria voor *inhouds- en constructievaliditeit*. Het leertraject dat is ontworpen, kan gebruikt worden als een lokale instructie theorie voor het leren en onderwijzen van het onderwerp 'oppervlakte en omtrek'. De manier waarop het IRME-curriculum is vormgegeven (zie hoofdstuk 5), kan tevens worden gebruikt als richtlijn bij de ontwikkeling van ander RME-materiaal. De kenmerken van het valide IRME-curriculum kunnen als volgt worden beschreven:
   - De inhoud van het IRME-curriculum behelst alle onderwerpen, waarvan wordt aangenomen dat ze moeten worden onderwezen om het onderwerp 'oppervlakte en omtrek' te beheersen, gebaseerd op de principes van RME (zie hoofdstuk 5). In dit geval wordt het begrip van de leerlingen wat betreft de concepten 'oppervlakte en omtrek' ontwikkeld door deze concepten te relateren aan andere grootheden zoals kosten, gewicht, en aan bijzondere / onregelmatige vormen. Voor deze benadering is gekozen aangezien leerlingen in de realiteit meestal met deze concepten te maken krijgen in de genoemde contexten.

- De inhoud van het IRME-curriculum weerspiegelt de belangrijkste principes van RME. Bij het leren van het onderwerp 'oppervlakte en omtrek' volgens deze benadering, krijgen de leerlingen de mogelijkheid om de concepten die betrekking hebben op het onderwerp zelf te ontdekken. Reeds bekende fenomenen vormen het uitgangspunt voor het leren van het onderwerp 'oppervlakte en omtrek', waardoor de leerlingen begrip kunnen ontwikkelen voor het onbekende onderwerp door gebruik te maken van hun informele kennis. De leerlingen werden tevens in de mogelijkheid gesteld hun eigen ideeën te gebruiken bij het oplossen van de rijke problemen.
- Het IRME-curriculum weerspiegelt het onderwijs- en leerprincipe van RME (zie hoofdstuk 3, paragraaf 3.4)
- Het IRME-curriculum behelst een aantal belangrijke aspecten van realistische meetkunde, met name meten, berekenen en ruimtelijk inzicht (zie hoofdstuk 3, paragraaf 3.5).
- De inhoud van het IRME-curriculum is zorgvuldig opgebouwd, zodat het leertraject voor het leren van het onderwerp 'oppervlakte en omtrek' (zie hoofdstuk 5, paragraaf 5.3.3) de leerlingen ondersteunt, waardoor ze naar behoren leren.
- De leerdoelen zijn duidelijk omschreven voor elke les en de inhoud is vormgegeven en samengesteld met het oog op het bereiken van de doelen.
- De relevantie en het belang van de onderdelen van het IRME-curriculum zijn geëxpliciteerd (zie hoofdstuk 5, sectie 5.4).

2. Het IRME-curriculum voldoet aan de criteria voor de bruikbaarheid. Deze voorwaarde wordt gekenmerkt door de volgende punten:
   - Het IRME-curriculum kan het begrip, het inzicht, de inzet, de creativiteit en de motivatie bij het leren van het onderwerp 'oppervlakte en omtrek' van leerlingen stimuleren.
   - Het onderwijs- en leerproces wordt, bij toepassing van het IRME-curriculum, omgebogen naar studentgecentreerd leren.
   - De leerlingen zijn in staat zonder problemen het leerlingenboek te gebruiken en kunnen daarmee tevens het onderwerp 'oppervlakte en omtrek' leren zoals bedoeld binnen RME.
   - De docentenhandleiding blijkt nuttig te zijn en gemakkelijk te gebruiken door de leerkrachten. De in de docentenhandleiding geschatte lestijd is adequaat.

3. Het IRME-curriculum voldoet aan de criteria voor effectiviteit, aangezien het enig positief resultaat heeft opgeleverd bij de leerlingen van groep 4. De positieve effecten van het IRME-curriculum worden als volgt gekarakteriseerd:
   - De leerlingen hebben te kennen gegeven dat ze het IRME-curriculum als positief hebben ervaren. Ze gaven aan dat het curriculum nuttig was en dat het hen meer vertrouwen in hun capaciteiten als lerenden heeft gegeven.
   - De meeste leerlingen hebben de beoogde (RME-)kennis verworven, waarbij ze verscheidene concepten die in het curriculum aan de orde komen zelfstandig hebben ontdekt. Ook hebben ze uiteenlopende strategieën ontwikkeld bij het oplossen van rijke problemen. Bovendien kunnen ze de nieuwe kennis en vaardigheden die ze in een bepaalde les hebben verworven toepassen in de daaropvolgende lessen.
   - De leerlingen hebben een positievere houding richting het vak wiskunde ontwikkeld. Ze zijn onafhankelijker geworden en meer betrokken bij hun eigen leerproces. Ook is hun motivatie toegenomen en zijn ze gestimuleerd in het vinden van strategieën bij het oplossen van rijke problemen. Alhoewel de leerlingen aanvankelijk weinig wiskundig inzicht hadden, hebben ze aan het eind van de praktijkexperimenten laten zien dat ze in staat zijn wiskundig te redeneren.
   - De prestaties van de leerlingen op de natoets zijn duidelijk verbeterd, vergeleken met de prestaties op de voortoets. De prestaties van de leerlingen die hebben deelgenomen aan de praktijkexperimenten, zijn significant beter dan die van de leerlingen die les hebben gehad volgens de traditionele methode.

4. De resultaten die hierboven staan beschreven, geven aan dat de RME-benadering bruikbaar kan zijn voor Indonesische basisscholen. Verder kan de RME-benadering bijdragen aan het oplossen van een aantal van de problemen, die eerder dit hoofdstuk genoemd zijn, met name aan het veranderen van de klassen-omstandigheden. Het kan richtlijnen bieden met betrekking tot de ontwikkeling en implementatie van kwalitatief goed curriculummateriaal voor het onderwijs in wiskunde.

APPENDIX A
THE TEACHER GUIDE

This appendix contains the student book and the assessments for each unit.

Buku Petunjuk Guru

Luas dan Keliling

Digunakan untuk Topik Geometri di Kelas IV SD Cawu II

Surat untuk Guru

Ibu/Bapak Guru yth.

Selamat bertemu dalam pelajaran matematika topik "Luas dan Keliling". Topik ini disusun berdasarkan pendekatan Realistic Mathematics Education (RME), suatu pendekatan dalam pengajaran matematika yang pertama kali dikembangkan di Belanda. Dengan menggunakan pendekatan ini, siswa akan belajar konsep-konsep matematika berdasarkan konteks-konteks nyata di sekitar mereka.

Ada lima unit (pelajaran) yang disajikan dalam buku ini, yaitu: Ukuran Bangun-bangun, Luas, Luas (Lanjutan), Mengukur Luas, dan Keliling dan Luas.

Dalam setiap unit (pelajaran) Ibu/Bapak akan menemui komponen-komponen seperti berikut:

- ***Tujuan;*** *menerangkan tujuan pelajaran yang ingin dicapai dalam tiap unit.*
- ***Aktivitas Siswa;*** *menerangkan kegiatan-kegiatan yang akan dilakukan siswa dalam mengikuti pelajaran.*
- ***Waktu****; menerangkan perkiraan waktu yang dibutuhkan untuk melaksanakan proses belajar mengajar.*
- ***Tentang Matematika;*** *menerangkan konsep-konsep matematika yang dibicarakan dalam tiap unit (pelajaran).*
- ***Material;*** *berisi rincian alat/bahan serta peraga yang dibutuhkan untuk pelaksanaan proses belajar mengajar.*
- ***Pekerjaan Rumah****; berisikan masalah-masalah kontekstual yang harus dikerjakan siswa di rumah..*
- ***Rencana Penilaian Kemampuan Siswa****; menerangkan tujuan pelajaran serta item-item yang akan digunakan untuk mengevaluasi ketercapaian tiap tujuan pelajaran..*
- ***Ringkasan;*** *menerangkan inti sari pelajaran, serta menggarisbawahi bagian terpenting dari apa yang dibahas dalam tiap unit (pelajaran).*
- ***Perencanaan;*** *berisikan saran, petunjuk serta keterangan tentang bagaimana sebaiknya proses belajar mengajar berlangsung di kelas.*
- ***Halaman Buku Siswa;*** *berisikan soal-soal kontekstual.*
- ***Komentar Tentang Soal-soal dan Penyelesaian;*** *menerangkan kemungkinan jawaban dari tiap soal, contoh jawaban siswa, serta penyelesaian soal-soal.*

Ibu/Bapak guru, terima kasih atas kerjasama yang diberikan dalam mengimplementasikan buku ini. Semoga Ibu/Bapak terinspirasi dengan ide-ide yang dikembangkan di sini, dan semoga sukses dalam menjalankan tugas-tugas.

Hormat Saya,

Ahmad Fauzan

Topik 1: Ukuran Bangun-bangun

1. *Tujuan*

Siswa akan:

- Membandingkan luas daerah dari berbagai bangun dengan menggunakan berbagai cara dan satuan-satuan pengukuran.
- Menaksir dan menghitung luas bangun-bangun geometri.
- Menaksir dan menghitung harga sesuatu menggunakan perbandingan luas

2. *Aktivitas Siswa*

- Siswa mengembangkan dan menggunakan berbagai cara untuk membandingkan luas daerah bangun-bangun yang mempunyai berbagai bentuk dan ukuran. Misalnya, siswa meletakkan suatu bangun di atas bangun yang lain dan mengamati bagian-bagian yang berimpit.
- Siswa menggunakan satuan-satuan pengukuran yang tidak baku, contohnya titik-titik atau gambar-gambar, untuk membandingkan luas daerah dari berbagai bangun (siswa menaksir atau menghitung jumlah titik-titik atau gambar-gambar yang ada pada kedua bangun).
- Siswa mengembangkan pengertian tentang konsep "***reallotment***", yaitu konsep tentang merubah bentuk suatu bangun geometri menjadi bentuk baru dimana luasnya tidak mengalami perubahan. Biasanya hal ini dilakukan dengan cara menggunting dan menempel. Perubahan bentuk bangun ini dilakukan agar diperoleh bangun baru yang lebih mudah ditentukan luasnya.
- Siswa menaksir harga sepotong kue dengan cara membandingkan luas permukaan kue tersebut dengan suatu kue yang harganya diketahui.
- Siswa menggunakan sebuah ubin persegi yang harganya ditentukan sebagai satuan pengukuran, untuk menentukan ukuran dan harga ubin-ubin dari bangun-bangun yang lain.
- Siswa memecahkan soal-soal kontekstual yang berkaitan dengan pengubinan, untuk mengembangkan pengertian lebih jauh tentang konsep reallotment

3. Waktu: lebih kurang dua kali 80 menit (2 kali pertemuan)

4. Tentang Matematika

Konsep luas daerah- Jumlah satuan-satuan pengukuran yang diperlukan untuk menutupi suatu bangun- secara implisit diperkenalkan. Siswa menggunakan taksiran dan secara informal menggunakan konsep rasio dan proporsi untuk membandingkan luas daerah berbagai bangun dari berbagai ukuran. Istilah "luas" tidak diperkenalkan sampai siswa mempunyai pengalaman mengisi daerah dari bangun-bangun dua dimensi menggunakan satuan-satuan pengukuran. Satuan pengukuran "persegi" diperkenalkan sebagai suatu konvensi dalam matematika dan berhubungan dengan harga-harga ubin-ubin dari berbagai bentuk dan ukuran.

Cara-cara yang digunakan siswa untuk membandingkan luas dari beberapa bangun tidak hanya penting untuk mengembangkan pengertian mereka tentang luas daerah dan kemampuan mereka untuk menentukan luas, tetapi juga memberi fondasi yang membantu mereka untuk memahami dengan lebih baik bagaimana rumus untuk menghitung luas daerah diturunkan. Cara-cara ini secara umum berkenaan dengan pembentukkan kembali suatu bangun. Luas suatu bangun dapat dipandang sebagai jumlah dari bangun-bangun yang lain atau bagian dari bangun yang lain. Suatu bangun juga dapat diubah ke bangun yang lain dengan cara menggunting dan menempel (*reshape*).

5. Material

Lembaran kerja siswa, gunting, kertas tipis untuk menjiplak, karton, lem, mistar, kertas untuk menggambar. transparansi dan OHP.

6. Pekerjaan Rumah

Pertemuan 1: soal nomor 4 - 5, Pertemuan 2: soal nomor 8 - 10

7. Rencana Penilaian Kemampuan Siswa

- Membandingkan luas daerah dari berbagai bangun menggunakan berbagai cara dan satuan-satuan pengukuran, melalui Latihan 1 nomor 1
- Menaksir dan menghitung luas bangun-bangun geometri, melalui Latihan 1 nomor 2 dan 4.
- Menaksir dan menghitung harga sesuatu menggunakan perbandingan luas, melalui Latihan 1 nomor 3 dan 4.

Pertemuan 1: Ukuran Bangun-bangun

Material: lembaran kerja siswa, gunting, kertas tipis untuk menjiplak, lem, kertas gambar, transparansi dan OHP.

Ringkasan: Siswa secara informal mengeksplorasi konsep luas dengan mengembangkan metode/cara mereka sendiri untuk membandingkan ukuran berbagai bangun. Kata "luas " belum diperkenalkan pada bagian ini. Siswa juga membandingkan luas tiga buah hutan jati nggunakan beberapa cara untuk menentukan hutan mana yang mempunyai lebih banyak pohon jati.

Tentang Matematika: Topik dalam pertemuan ini difokuskan pada konsep luas suatu bangun. Beberapa cara untuk membandingkan luas beberapa bangun dapat digunakan, misalnya: meletakkan suatu bangun di atas bangun yang lain kemudian mengamati bagian yang berimpit; menggunting dan menempel (meletakkan) suatu bangun di atas bangun yang lain untuk melihat apakah bangun itu dapat menutupi bangun yang lain; menghitung jumlah titik-titik/gambar-gambar yang terdapat pada tiap bangun.

Soal nomor 2 dan Latihan 1 nomor 1 memperlihatkan bahwa persegi, persegipanjang, titik-titik, atau gambar pohon dapat digunakan untuk membandingkan ukuran bangun-bangun. Cara ini secara informal memperkenalkan konsep luas sebagai jumlah satuan-satuan pengukuran yang dibutuhkan untuk menutupi suatu bangun.

Dalam membadingkan luas hutan jati, siswa mungkin menggunting satu gambar kemudian menyusun/menempelkannya pada gambar yang lain. Cara ini berdasarkan pada sifat: jika suatu bangun di bagi, dipotong dan/atau ditata kembali maka luasnya tidak berubah. Siswa yang lain mungkin saja menyelesaikan soal ini dengan cara menghitung pohon jati satu persatu, atau dengan mengalikan banyaknya pohon jati dalam satu baris dan satu kolom. Cara yang terakhir ini akan memudahkan siswa memahami rumus menghitung luas $L = p \times l$, yang akan dibicarakan pada pertemuan ke 8.

Perencanaan Pengajaran:

- Sebelum siswa mengerjakan soal-soal, sebaiknya guru mencek pemahaman siswa tentang konteks yang terdapat pada setiap soal. Misalnya, guru dapat meminta beberapa orang siswa untuk mengemukakan pendapat mereka tentang: apa cerita yang terdapat pada soal, apa ide mereka untuk memecahkan soal tersebut, dan lain-lain.
- Dengan menggunakan material seperti tersebut di atas beri siswa motivasi dan dorongan untuk mengembangkan cara-cara mereka sendiri dalam membandingkan luas bangun-bangun.
- Diskusikan beberapa cara yang digunakan siswa secara klasikal, terutama untuk saol nomor 2 dan 3, serta Latihan 1 nomor 1.
- Siswa dapat bekerja secara kelompok atau berpasangan dalam pertemuan ini.
- Latihan 1 nomor 1 diberikan setelah siswa mengerjakan soal nomor 3.

Halaman depan buku siswa

Surat untuk Keluarga di Rumah

YTH. IBU/BAPAK DI RUMAH

Melalui buku ini anak kita akan mempelajari suatu topik dalam pelajaran Matematika yaitu "Luas dan Keliling". Pada halaman berikut Ibu/Bapak dapat melihat gambaran dan tujuan dari pelajaran ini. Topik ini akan diajarkan menggunakan pendekatan Pendidikan Matematika Realistik (Realistic Mathematics Education (RME)), suatu pendekatan yang dikembangkan di Belanda dan telah mencapai keberhasilan. Pendekatan ini juga telah diadaptasi di beberapa negara lain seperti, Afrika Selatan, Amerika Serika, Brazil, dan lain-lain.

Ibu/Bapak dapat membantu anak kita untuk mengaitkan pelajaran di sekolah dengan kegiatan sehari-hari di rumah. Misalnya Ibu/Bapak dapat meminta anak kita: menemukan cara untuk membandingkan mana yang lebih luas antara kamar tidur dengan ruang tamu, mengukur benda-benda yang terdapat di rumah kemudian memperkirakan luasnya, dan lain-lain. Ibu/Bapak dapat juga meminta anak kita untuk memperkirakan harga pemasangan pagar di halaman atau karpet di ruang tamu, seandainya akan diganti dengan yang baru.

Pada pelajaran ini anak kita juga diperkenalkan pada topik "pengubinan". Ibu/Bapak dapat memotivasi anak kita untuk menemukan pola-pola pengubinan yang ada di rumah atau sekitarnya, kemudian minta mereka untuk membuat pola karya mereka sendiri. Arahkan juga mereka untuk dapat memperkirakan harga keseluruhan keramik/ubin yang terdapat pada suatu pola pengubinan, seandainya harga sebuah keramik/ubin diketahui.

Semoga kegiatan ini menyenangkan dan dapat menjembatani Matematika dengan dunia nyata.

Salam hormat,
Ahmad Fauzan

Halaman depan buku siswa

Surat untuk Siswa

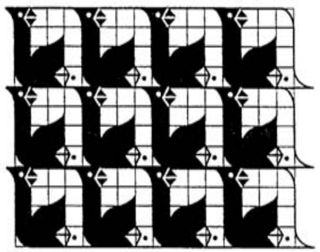
Siswa sekalian,

Selamat bertemu dalam pelajaran "Luas dan Keliling". Pada pelajaran ini kamu akan mempelajari luas dan keliling berbagai bangun geometri yang sering kamu temui dalam kehidupan sehari-hari.

Pertama kamu akan membandingkan luas permukaan berbagai benda, misalnya daun, sawah, hutan dll. Kemudian kamu akan menentukan harga berbagai benda seperti tanah, triplek, wingko babat dan lain-lain, dengan menggunakan perbandingan luas permukaan benda-benda tersebut.

Kamu juga akan membandingkan dan menaksir luas beberapa provinsi di Jawa, dan Madura, serta beberapa danau. Semua kegiatan ini diharapkan dapat membawamu untuk menemukan rumus untuk menentukan luas dan keliling bangun-bangun geometri, seperti persegi, persegipanjang, jajargenjang, dan segitiga.

Kegiatan lain yang akan kamu temui dalam pelajaran ini berkaitan dengan pola pengubinan. Salah satu contoh pengubinan terlihat seperti gambar berikut ini.



Selamat mengerjakan semua kegiatan-kegiatan yang terdapat dalam buku ini, dan jangan lupa membuat pekerjaan rumah yang akan kamu temukan diakhir tiap pelajaran. Semoga kamu semua senang dan makin mencintai pelajaran matematika.

S a l a m,
Pak Fauzan

Halaman 1 Buku Siswa

Pertemuan 1

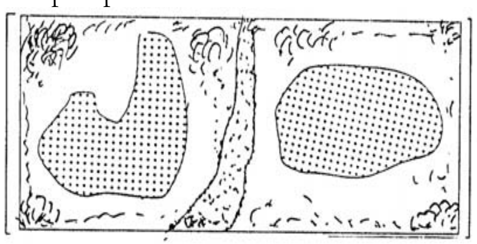
Pelajaran 1: Ukuran Bangun-bangun

Kue Coklat

1. Berikut ini adalah gambar dari dua potong kue coklat yang dipotong secara tidak beraturan. Jika kamu diminta memilih, kue manakah yang akan kamu pilih. Gunakan Lembar Kerja 1 untuk menjelaskan alasanmu.

Sawah

2. Gambar di bawah ini menunjukkan dua petak sawah yang dipisahkan oleh sebuah jalan. Kedua sawah ditanami padi yang sama dan diberi pupuk yang sama. Titik-titik pada gambar menunjukkan rumpun padi.

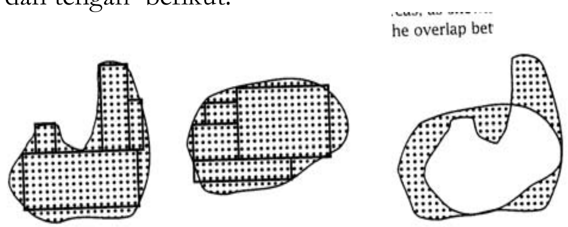


Gunakan Lembar Kerja 2 untuk memperkirakan sawah mana yang akan menghasilkan padi lebih banyak.

Komentar tentang Soal-soal dan Penyelesaian

1. Soal ini mengacu pada satu cara/cara dalam membandingkan luas yaitu dengan meletakkan satu bangun di atas bangun yang lain (setelah menggunting atau menjiplak salah satu bangun), kemudian dicermati bagian yang berimpit. Guru diharapkan dapat memotivasi siswa sehingga mereka menemukan sendiri cara-cara ini. Kemudian minta beberapa siswa untuk mengemukakan pendapat mereka tentang kue mana yang lebih besar beserta dengan alasannya.
   Penyelesaian: Kue yang lebih besar adalah kue B. Alasan yang dikemukan siswa akan bervariasi. Misalnya, setelah kedua gambar kue dibuat berimpit, siswa mungkin akan melihat bagian yang berlebih pada kue B lebih banyak dibandingkan pada kue A.

2. Sawah di sebelah kanan akan menghasilkan padi lebih banyak, meskipun secara sepintas kedua sawah seperti sama besar. Beberapa siswa mungkin akan menggunakan cara seperti soal nomor 1. Siswa yang lain mungkin membandingkan kedua sawah dengan cara menghitung banyaknya rumpun padi pada tiap sawah. Jika siswa menghitung tiap titik satu persatu, motivasi mereka untuk menggunakan cara menghitung yang lebih efektif, misalnya dengan membagi tiap sawah menjadi beberapa persegipanjang/persegi, kemudian menghitung rumpun padi di dalam tiap persegipanjang/persegi, seperti ditunjukkan pada gambar bagian kiri dan tengah berikut.

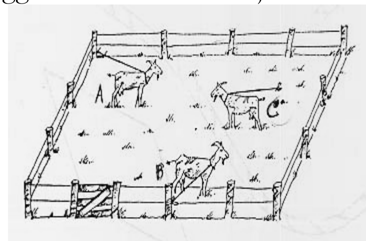


Cara lain adalah dengan mengkombinasikan menjiplak dan menghitung. Pertama siswa akan menjiplak satu gambar kemudian menempatkannya di atas gambar yang lain. Selanjutnya mereka hanya membandingkan jumlah rumpun padi yang ada pada bagian yang tidak berimpit, seperti terlihat pada gambar paling kanan di atas.

Halaman 2 Buku Siswa

Kambing dan Rumput

3. Tiga ekor kambing diikatkan dengan tali yang sama panjang di sebuah padang rumput yang diberi pagar dikelilingnya. Jika rumput tumbuh merata di semua tempat, menurutmu kambing manakah yang akan mendapat rumput paling banyak? Jelaskan alasanmu dengan menggunakan Lembar Kerja 3.



Pekerjaan Rumah

4. Jiplaklah telapak tangan dan telapak kakimu masing-masing pada selembar kertas. Kemudian bandingkan manakah yang lebih besar telapak kaki ataukah telapak tanganmu? Berikan alasan untuk jawabanmu!
5. Tentukanlah banyaknya ubin-ubin yang terdapat pada gambar di bawah ini! Jangan lupa memgemukakan cara yang kamu gunakan dalam menemukan jawaban!

Komentar tentang Soal-soal dan Penyelesaian

3. Jika siswa mengalami kesulitan, atau memberikan alasan yang kurang akurat dalam mengerjakan soal ini, guru dapat memotivasi mereka untuk menggambar garis batas daerah di mana kambing dapat memakan rumput seperti terlihat pada gambar di bawah ini. Kemudian minta siswa untuk mengenali bentuk dari tiap bangun geometri yang mereka gambar. Diskusikan juga bentuk sebenarnya dari padang rumput sehingga siswa dapat mengenali bahwa bangun-bangun geometri yang mereka gambar masing-masing berbentuk seperempat lingkaran (kambing A), setengah lingkaran (kambing B) dan satu lingkaran (kambing C)
   Kambing C akan memperoleh lebih banyak rumput. Siswa dapat menggunakan alasan berdasarkan bentuk daerah di mana tiap kambing dapat memakan rumput. Beberapa siswa lain mungkin juga akan menjiplak satu gambar kemudian meletakkannya di atas gambar-gambar yang lain, atau melanjutkan pekerjaannya dengan menggunting tiap daerah, kemudian menempuh cara seperti pada soal nomor 1.
4. Gambar telapak kaki akan lebih luas dari pada telapak tangan. Siswa mungkin akan menjiplak gambar telapak kaki, kemudian meletakkannya di atas gambar telapak tangan atau sebaliknya, lalu mengamati bagian yang berimpit. Pekerjaan yang sama mungkin juga dilakukan siswa dengan cara menggunting salah satu gambar. Telapak kaki akan lebih panjang, tetapi telapak tangan lebih lebar. Untuk mendapatkan hasil yang lebih akurat mungkin siswa akan menggunting bagian yang berlebih pada telapak kaki, kemudian menempelkannya pada gambar telapak tangan atau sebaliknya. Siswa mungkin juga menggambar telapak kaki dan tangan pada kertas berpetak, kemudian menghitung jumlah persegi yang terdapat pada tiap gambar.
5. Beberapa siswa mungkin akan menggunkan penjumlahan berulang untuk menghitung banyaknya ubin yang ada. Siswa yang lain mungkin akan menggunkan perkalian antara banyaknya ubin dalam satu baris dengan banyaknya ubin dalam satu kolom.
   Penyelesaian: Gambar yang dimaksud berbentuk persegi, dimana terdapat 13 ubin masing-masing dalam satu baris dan kolom. Sehingga banyaknya ubin yang terdapat pada gambar adalah 13 x 13 = 169.

Pertemuan 2: Ukuran Bangun-bangun

Material: lembar kerja siswa, gunting, kertas tipis untuk menjiplak, kertas berpetak, lem, kertas gambar.

Ringkasan: Siswa menaksir harga beberapa potong kue yang bentuknya berbeda-beda, dengan cara membandingkan luas permukaan setiap kue dengan sepotong kue berbentuk persegi yang harganya Rp. 5.000. Proses yang sama juga dilakukan siswa untuk menaksir harga ubin-ubin yang bentuknya berbeda-beda. Di samping itu siswa juga akan menggunakan beberapa cara berbeda untuk membagi empat buah persegi menjadi delapan bagian yang sama besar. Tiap bagian yang sama besar tidak mesti sama bentuknya.

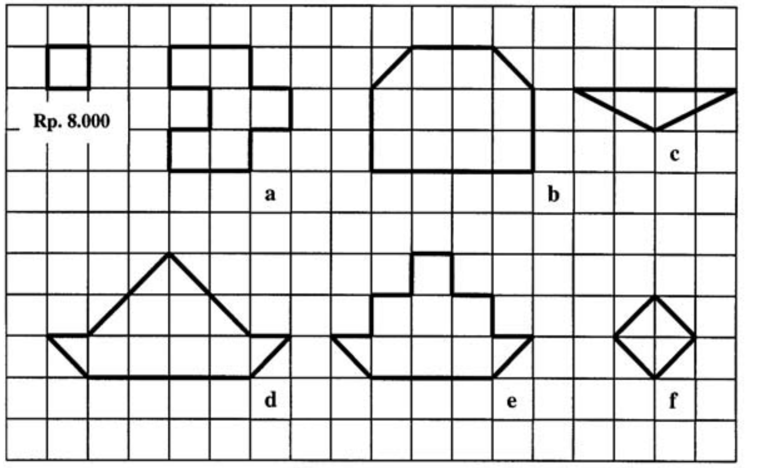
Tentang Matematika: Konsep membandingkan luas bangun-bangun yang berbeda diperluas ke konsep membandingkan harga kue/ubin berdasarkan luas permukaan masing-masing kue/ubin. Siswa dapat menaksir harga sebuah kue/ubin berbentuk segitiga tanpa menggunakan rumus, yaitu dengan cara membandingkan luasnya dengan sebuah kue/ubin berbentuk persegipanjang/persegi yang harganya diketahui. Siswa juga akan mengerjakan beberapa soal berkaitan dengan pola pengubinan sederhana untuk membuat mereka lebih memahami konsep reallotment.

Perencanaan:
- Diskusikan pekerjaan rumah yang dibuat siswa di awal pertemuan.
- Siswa dapat bekerja secara individu atau berpasangan dalam pertemuan ini.
- Sebelum siswa mengerjakan suatu soal, diskusikan soal tersebut dengan siswa untuk memotivasi dan menarik minat mereka. Guru dapat meminta satu atau dua orang siswa untuk menjelaskan secara lisan apa yang dimaksud dalam soal, kemudian menanyakan apa rencana atau cara yang akan mereka tempuh untuk menyelesaikan soal.
- Latihan 1 nomor 2 - 4 diberikan setelah siswa mengerjakan soal nomor 7
- Diskusikan secara klasikal jawaban siswa untuk soal-soal Latihan.

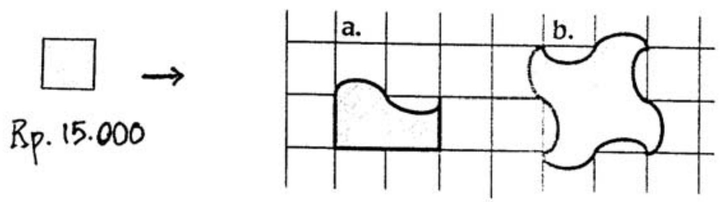
Pertemuan 2

Halaman 3 Buku Siswa

6. Di bawah ini terdapat gambar ubin-ubin dengan bentuk yang berbeda beda. Jika harga sebuah ubin kecil berbentuk persegi adalah Rp. 8.000, tentukanlah harga untuk ubin-ubin yang lain. Jelaskan caramu dalam mendapatkan tiap jawaban dengan menggunakan Lembar Kerja 7!



7. Pengubinan a dan b di bawah ini dibuat dari ubin-ubin berbentuk persegi. Jika harga sebuah ubin persegi adalah Rp.15.000, berapakah biaya membuat masing-masing pengubinan a dan b?



Komentar tentang Soal-soal dan Penyelesaian

6. Soal ini memberi siswa ide tentang reallotment. Harga tiap ubin dapat ditentukan dengan cara membandingkannya dengan ubin yang berharga Rp. 8.000. Guru dapat meminta siswa untuk menjelaskan jawaban-jawaban mereka, terutama untuk gambar h, i dan j. Jika siswa mengalami kesulitan, arahkan mereka untuk menggunakan cara menggunting dan menempel.

Penyelesaian:

a. Rp. 48.000 b. Rp. 88.000 c. Rp. 16.000
d. Rp. 72.000 e. Rp. 64.000 f. Rp. 16.000

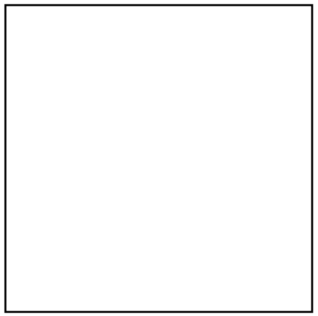
7. Guru dapat meminta siswa untuk menjelaskan bagaimana ubin semula berubah menjadi gambara a, dan bagaimana hubungan antara gambar a dan gambar b.

Penyelesaian: a. Rp. 30. 000,- b. Rp. 60. 000,-

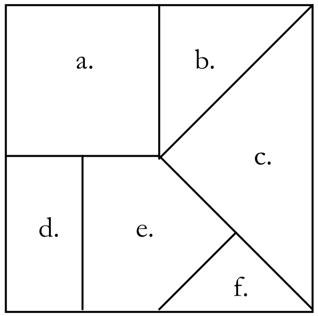
Halaman 4 Buku Siswa

Pekerjaan Rumah

8. Harga sepotong tripleks berbentuk persegi seperti terlihat pada gambar kiri bawah ini adalah Rp. 20.000. Jika tripleks itu dibagi menjadi beberapa bagian seperti terlihat pada gambar kanan bawah, tentukanlah harga tiap potong tripleks.



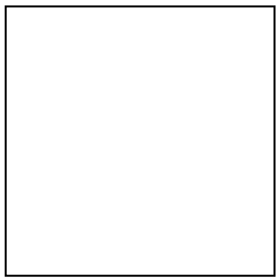
Sebelum Dipotong

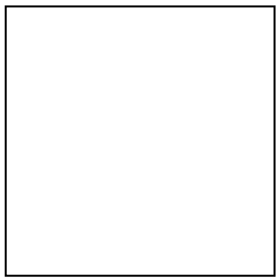


Setelah Dipotong

Membagi sebuah Persegi

9. Gambarlah empat buah persegi dengan ukuran sama pada buku latihanmu. Bagilah tiap persegi menjadi delapan bagian yang sama besar dimana bagian yang sama besar tersebut tidak perlu mempunyai bentuk yang sama. Gunakan cara yang berbeda untuk tiap persegi.





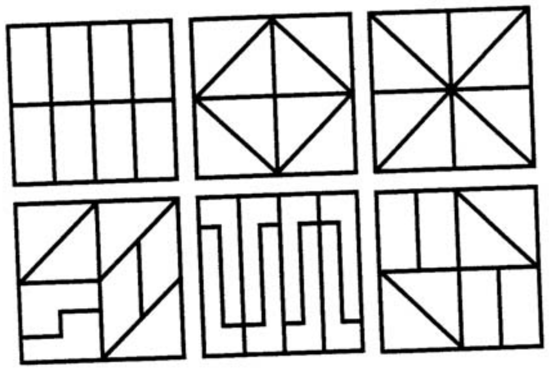
Komentar tentang Soal-soal dan Penyelesaian

8. Soal ini berkaitan dengan konsep proporsi dan luas. Diharapkan guru dapat memotivasi siswa untuk menemukan sebanyak mungkin hubungan antara satu bangun dengan bangun yang lain, misalnya bangun **b** atau **d** adalah setengah bangun **a**, bangun **c** dua kali bangun **b**, dan lain lain. Cara yang digunakan siswa dalam menjawab soal ini akan bervariasi. Misalnya, gambar **a** adalah ¼ dari keseluruhan tripleks sehingga harganya ¼ x Rp. 20.000 = Rp. 5.000. Gambar **d** adalah setengah gambar **a** sehingga harganya ½ x Rp. 5.000 = Rp. 2.500, dan lain-lain

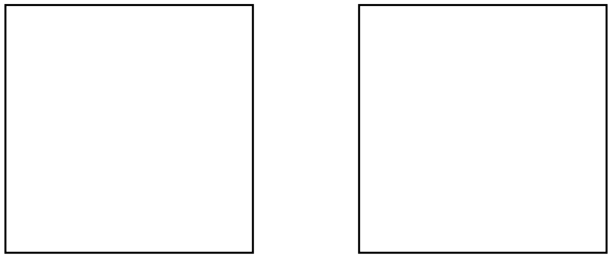
Penyelesaian:

a. Rp. 5.000 b. Rp. 2.500 c. Rp. 5.000
d. Rp. 2.500 e. Rp. 3.750 f. Rp. 1.250

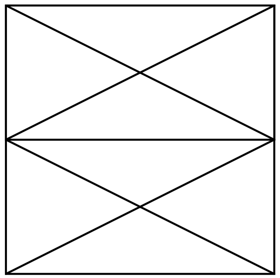
9. Diskusikan metode-metode yang digunakan siswa dalam membagi persegi pada pertemuan selanjutnya. Siswa dapat menunjukkan bahwa bagian-bagian pada persegi yang mereka bagi adalah sama dengan cara menjiplak, memotong, memisah-misahkan, atau menggabung (reallotment). Jawaban siswa untuk soal ini akan bervariasi. Contoh jawaban siswa:



Halaman 5 Buku Siswa



10. Jika Tuti membagi persegi seperti terlihat pada gambar berikut, apakah tiap bagian yang digambar Tuti sama besarnya? Jelaskan jawabanmu!

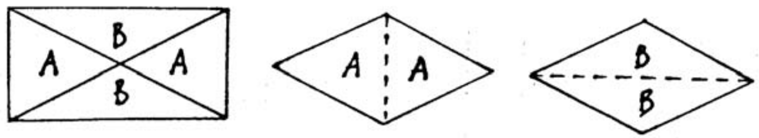


Ringkasan Pelajaran 1

Pelajaran ini adalah tentang perbandingan luas bangun-bangun. Kita dapat menggunakan berbagai cara untuk membandingkan luas berbagai bangun. Misalnya meletakkan gambar sebuah kue di atas gambar kue yang lain. Menghitung banyaknya rumpun padi/pohon jati yang terdapat ditiap sawah/hutan. Menaksir seperberapa luas permukaan sebuah kue/ubin jika dibandingkan dengan sebuah kue/ubin berbentuk persegi yang harganya diketahui. Kita juga membagi (menggunting) gambar suatu bangun kemudian menyusunnya (menempel) untuk membentuk suatu bangun baru yang luasnya tetap sama.

Komentar tentang Soal-soal dan Penyelesaian

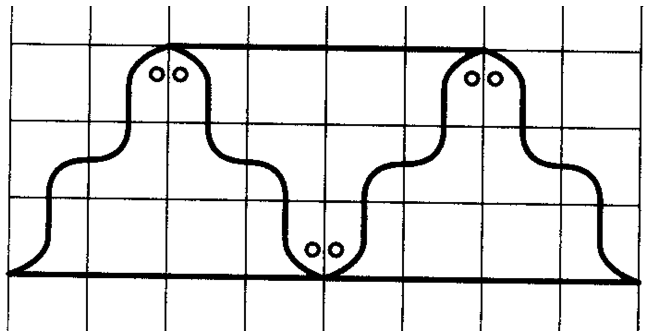
10. Tiap bagian yang digambar Tuti adalah sama. Jika ada siswa yang berpendapat demikian, minta mereka untuk menjelaskan jawaban mereka. Untuk membuktikan bahwa tiap bagian yang digambar Tuti adalah sama dapat dilakukan dengan cara: menunjukkan bahwa gabungan dua segitaga membentuk bangun yang sama, atau dengan cara menggunting dan menempel. Pada gambar di bawah ini terlihat bahwa jika dua segitiga A maupun B digandeng, maka diperoleh dua bangun yang sama.



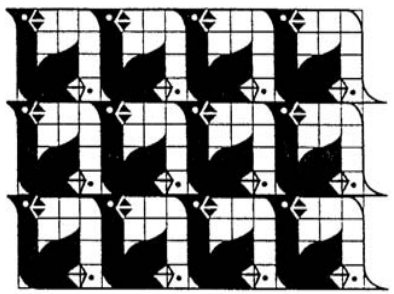
Halaman 6 Buku Siswa	*Komentar tentang Soal-soal dan Penyelesaian*

Pengayaan

1. Gambar berikut menunjukkan sebuah pengubinan yang dibuat dari ubin-ubin berbentuk persegi. Berapa banyakkah ubin persegi yang dibutuhkan untuk membuat pengubinan itu? Jelaskan jawabanmu.



2. Gambar di bawah ini adalah sebuah pengubinan bercorak angsa-angsa yang dibuat dari ubin-ubin (keramik) berbentuk persegi.



a. Berapakah banyaknya ubin persegi yang diperlukan untuk membuat seekor angsa hitam?

b. Berapakah banyaknya ubin persegi yang diperlukan untuk membuat seekor angsa putih?

1-2. Soal ini berkaitan dengan masalah reallotment. Guru dapat meminta siswa untuk menjelaskan dengan kata-kata atau gambar bagaimana mereka menemukan jawaban untuk soal ini.

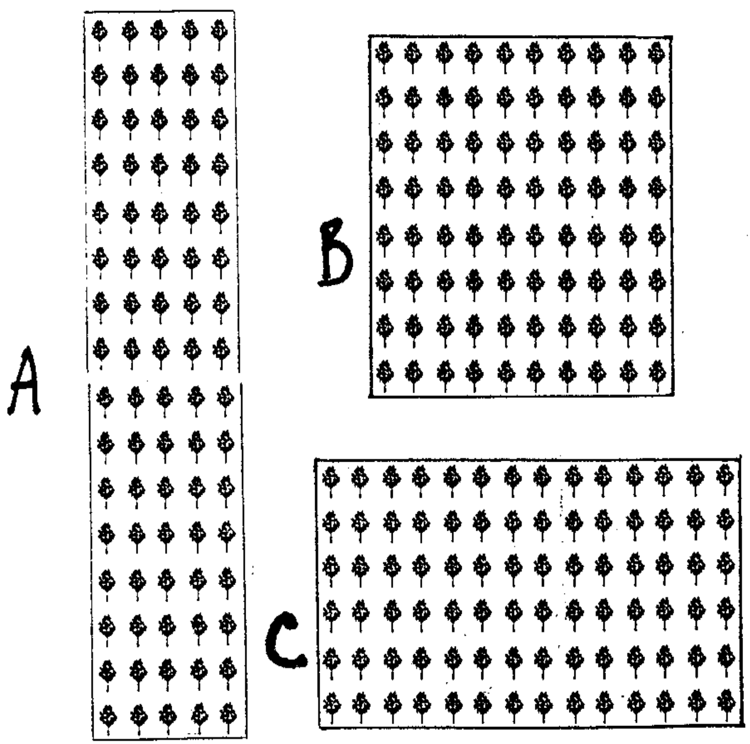
1.**_Penyelesaian:_** banyaknya ubin berbentuk persegi yang dibutuhkan untuk membuat pengubinan tersebut adalah 3 x 6 = 18 buah

2. **_Penyelesaian:_** a. 8 buah b. 8 buah

Latihan 1

Hutan Jati

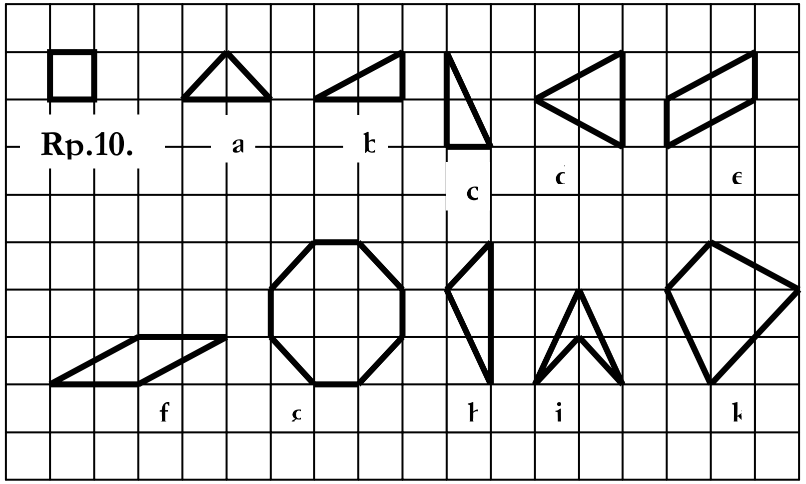
1. Gambar di bawah ini adalah tiga buah hutan jati. Tiap dua pohon pada hutan-hutan tersebut ditanam dengan jarak yang sama. Hutan manakah yang memiliki pohon jati lebih banyak? Jelaskan alasanmu!



Komentar tentang Soal-soal dan Penyelesaian

1. Jika siswa menghitung pohon jati satu persatu, motivasi mereka untuk menghitung jumlah pohon perbaris atau perkolom, atau menggunakan perkalian baris dan kolom. Hutan yang lebih luas adalah hutan C. Hutan tersebut ditumbuhi oleh 6 x 14 = 84 pohon jati. Sedangkan hutan A ditumbuhi 16 x 5 = 80 pohon jati dan hutan B ditumbuhi 8 x 10 = 80 pohon jati. Gambar di bawah ini menunjukkan bahwa hutan A dan B mempunyai luas yang sama

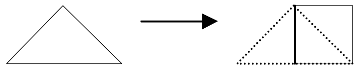
2. Lakukan pekerjaan yang sama seperti pada soal nomor 6 untuk gambar ubin-ubin berikut, dimana harga sebuah ubin kecil berbentuk persegi adalah Rp. 10.000. Jelaskan jawabanmu!



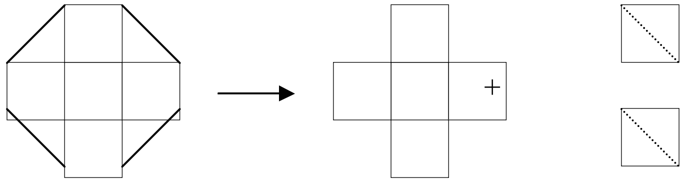
Komentar tentang Soal-soal dan Penyelesaian

2. Diskusikan beberapa strategi berbeda yang digunakan siswa dalam menyelesaikan soal ini, untuk memberikan kesempatan kepada mereka mengembangkan cara yang paling efisien. Cara-cara yang mungkin digunakan siswa dalam menyelesaikan soal ini, misalnya:

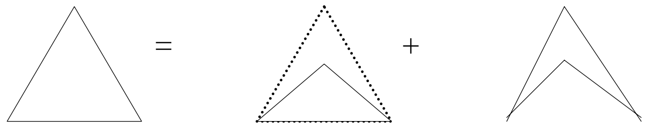
- Merubah bentuk bangun ke bentuk bangun yang harganya diketahui dengan cara menggunting dan menempel, contohnya bangun **b**:



- Membagi suatu bangun menjadi bangun-bangun yang lain. Strategi ini dapat digunakan untuk bagian **h**.



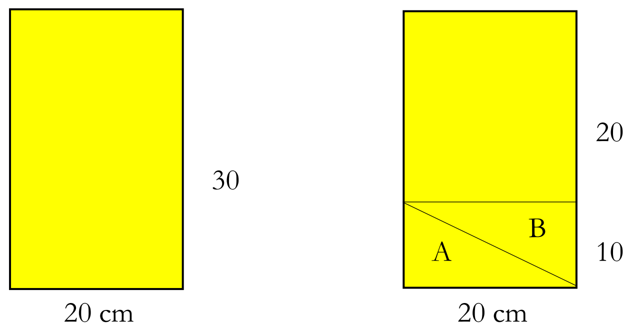
- Menentukan jumlah atau selisih luas dua buah bangun. Misalnya, luas bangun e sama dengan luas bangun **b** + luas bangun **j**



Penyelesaian

a. Rp. 10.000 b. Rp. 10.000 c. Rp. 10.000 d. Rp. 20.000
e. Rp. 20.000 f. Rp. 20.000 g. Rp. 70.000 h. Rp. 15.000
j. Rp. 10.000 k. Rp. 45.000

3. Sebuah kue "Lapis Legit" berbentuk persegipanjang dan berukuran 20 cm x 30 cm dipotong menjadi tiga bagian, seperti ditunjukkan pada gambar di bawah ini (ingat, gambar tidak dibuat dengan ukuran sebenarnya). Jika harga sebuah kue Rp. 60. 000, berapakah seharusnya harga tiap potong kue?

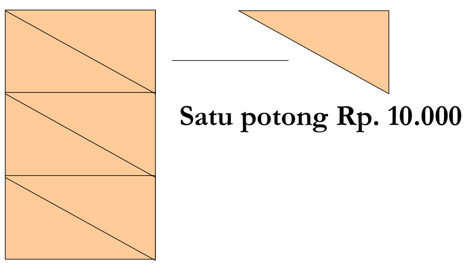


Komentar tentang Soal-soal dan Penyelesaian

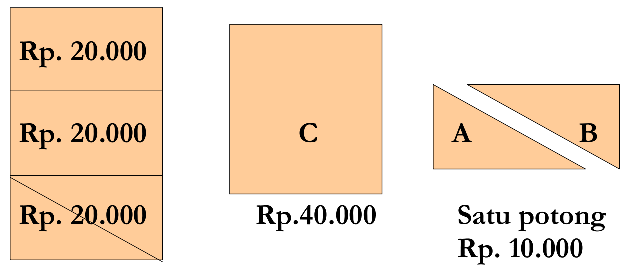
3. Harga potongan kue berbentuk persegi (bagian atas) adalah Rp. 40.000, dan harga tiap potong kue berbentuk segitiga adalah Rp. 10.000.

   Kemungkinan jawaban siswa:

   - Siswa membagi kue yang utuh menjadi 6 buah segitiga yang sama, kemudian membagi harga kue dengan 6 untuk menentukan harga satu potong kue berbentuk segitiga.

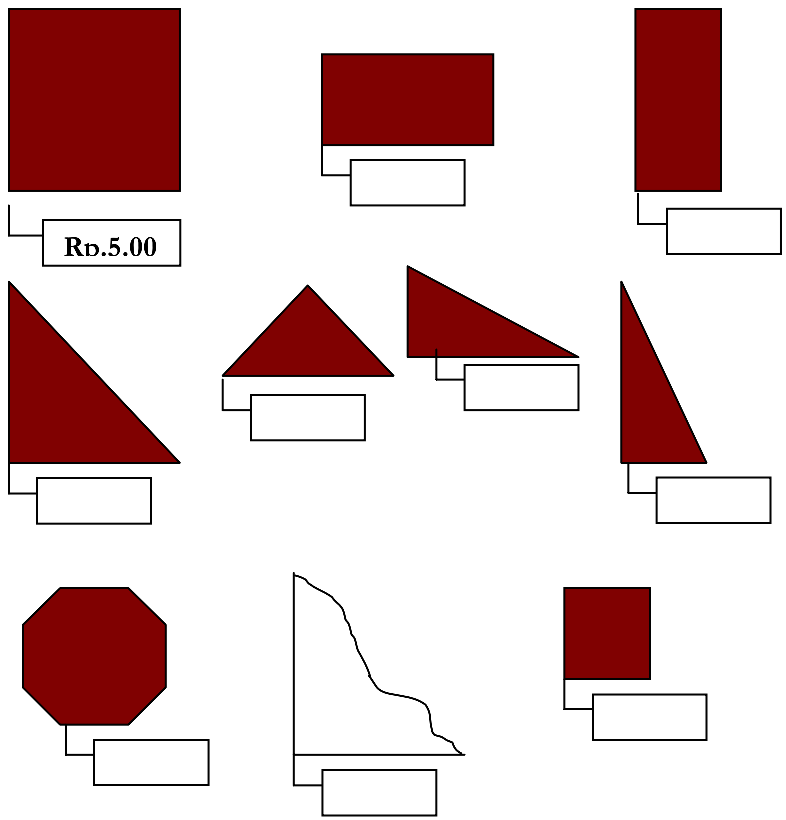


   - Siswa membagi kue yang utuh menjadi tiga buah persegipanjang yang masing-masing berukuran 10 cm x 20 cm. Karena satu kue berharga Rp. 60.000, maka harga tiap potong kue berukuran 10 cm x 20 cm adalah Rp. 20.000. Dengan demikian harga potongan kue bagian atas adalah 2 x Rp. 20.000 = Rp. 40.000. Potongan kue berbentuk segitiga adalah setengah potongan kue berbentuk persegi panjang, sehingga harganya adalah Rp. 10. 000.



Kue

4. Ayah Yono menjual kue yang memiliki berbagai ukuran, akan tetapi semua sama tebalnya. Beliau meminta Yono untuk memberi label harga pada tiap kue yang akan dijual. Harga sebuah kue besar berbentuk persegi (seperti terlihat pada gambar a) adalah Rp. 5.000. Bantulah Yono memberi label harga untuk kue yang lain. Jelaskan jawabanmu!



Komentar tentang Soal-soal dan Penyelesaian

4. Soal ini secara implisit mengaitkan antara konsep rasio (proporsi) dan luas. Arahkan siswa untuk menggunakan gambar kue **a** sebagai patokan untuk menaksir harga kue yang lain. Tetapi siswa dapat juga menggunakan kue yang lain sebagai patokan, misalnya: kue **j** seperempat kue **a**, setengah kue **b** dan **c**. Motivasi siswa untuk menemukan sebanyak mungkin hubungan antara gambar yang satu dengan yang lain. Jika siswa masih mengalami kesulitan, sarankan mereka untuk menjiplak kemudian menggunting gambar-gambar kue untuk menemukan hubungan antara kue yang satu dengan yang lain. Jika waktu tersedia, diskusikan strategi untuk menentukan harga kue **h** dan **j**. Kemungkinan jawaban siswa untuk soal ini akan bervariasi.

Penyelesaian:

b Rp. 2.500 c. Rp. 2.500 d. Rp. 2.500 e. Rp. 1.250
f. Rp.1.250 g. Rp. 1.250 h. Rp. 2.500 i. Rp. 2.500
j. Rp.1.250

Pertemuan 3: Ukuran Bangun-bangun

Material: lembaran kerja siswa, gunting, kertas tipis untuk menjiplak, kertas berpetak, lem, kertas gambar, mistar.

Ringkasan: Siswa membaca ringkasan yang menyarikan beberapa cara berbeda untuk membandingkan luas berbagai bangun. Kemudian siswa membandingkan luas dua buah pulau menggunakan cara-cara tersebut. Di samping itu, siswa juga menemukan harga potongan kue yang bentuknya berbeda-beda, dengan cara membandingkannya dengan harga kue secara keseluruhan. Mereka juga menjawab sebuah soal berkaitan dengan pengubinan sederhana.

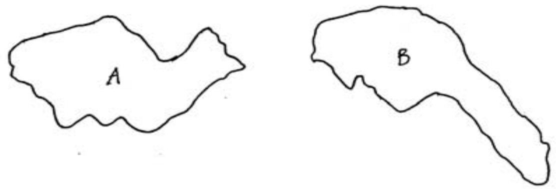
Perencanaan:
- Pada pertemuan ini siswa dapat bekerja secara individu atau berpasangan
- Soal nomor 14 dapat digunankan untuk menilai kemampuan siswa dalam menggunakan berbagai cara untuk membandingkan luas bangun-bangun
- Jika waktu tersedia, diskusikan secara klasikal semua soal-soal dalam pertemuan ini

Halaman 8 Buku Siswa

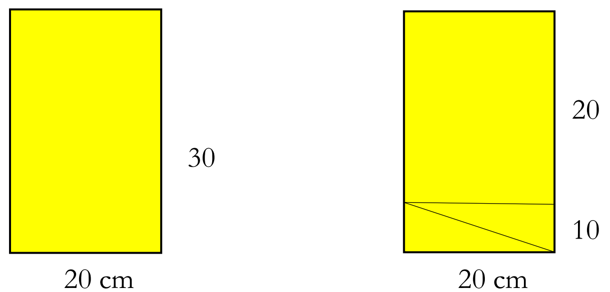
Pertemuan 3

Pertanyaan Simpulan

14. Cermati gambar dua buah pulau di bawah ini, kemudian temukan pulau manakah yang lebih luas. Gunakan Lembar Kerja 9 untuk menemukan jawabanmu!



15. Sebuah kue "Lapis Legit" berbentuk persegipanjang dan berukuran 20 cm x 30 cm dipotong menjadi tiga bagian, seperti ditunjukkan pada gambar di bawah ini (ingat, gambar tidak dibuat dengan ukuran sebenarnya). Jika harga sebuah kue Rp. 60. 000, berapakah seharusnya harga tiap potong kue?

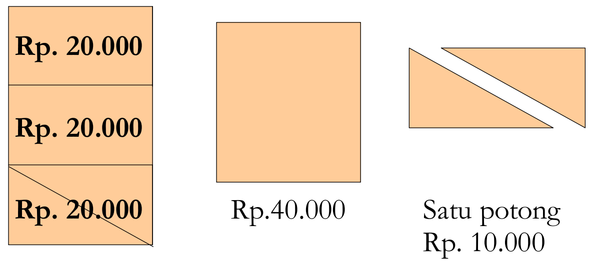


Komentar tentang Soal-soal dan Penyelesaian

14. Yang lebih luas adalah pulau A. Siswa mungkin akan membandingkan luas kedua pulau dengan beberapa cara, antara lain:
   - Menjiplak salah satu gambar kemudian menempatkannya di atas gambar yang lain, lalu mengamati bagian yang berimpit. Jika siswa tidak menemukan cara ini, guru dapat menunjukkannya melalui OHP.
   - Menggunting salah satu gambar kemudian menempatkannya (menempelkannya) di atas gambar yang lain. Setelah menemukan bagian yang tidak berimpit siswa melanjutkan pekerjaan menggunting dan menempel.
   - Menggambar ulang kedua gambar laut pada kertas berpetak), kemudian menghitung persegi satuan yang menutupi tiap gambar.

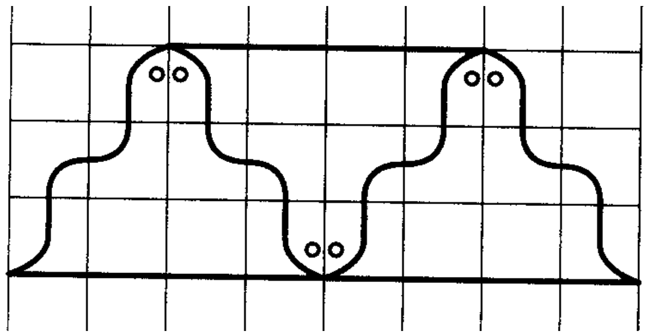
15. Harga potongan kue berbentuk persegi (bagian atas) adalah Rp. 40.000, dan harga tiap potong kue berbentuk segitiga adalah Rp. 10.000.

Kemungkinan jawaban siswa:
- Siswa membagi kue yang utuh menjadi 6 buah segitiga yang sama, kemudian membagi harga kue dengan 6 untuk menentukan harga satu potong kue berbentuk segitiga.
- Siswa membagi kue yang utuh menjadi tiga buah persegipanjang yang masing-masing berukuran 10 cm x 20 cm. Karena satu kue berharga Rp. 60.000, maka harga tiap potong kue berukuran 10 cm x 20 cm adalah Rp. 20.000. Dengan demikian harga potongan kue bagian atas adalah 2 x Rp. 20.000 = Rp. 40.000. Potongan kue berbentuk segitiga adalah setengah potongan kue berbentuk persegi panjang, sehingga harganya adalah Rp. 10. 000.

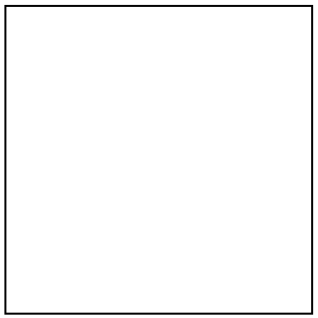


Halaman 9 Buku Siswa

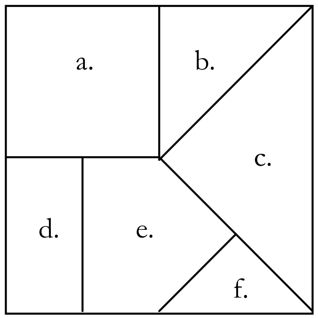
16. Gambar berikut menunjukkan sebuah pengubinan yang dibuat dari ubin-ubin berbentuk persegi. Berapa banyakkah ubin persegi yang dibutuhkan untuk membuat pengubinan itu? Jelaskan jawabanmu.



17. Harga sepotong tripleks berbentuk persegi seperti terlihat pada gambar kiri bawah ini adalah Rp. 20.000. Jika tripleks itu dibagi menjadi beberapa bagian seperti terlihat pada gambar kanan bawah, tentukanlah harga tiap potong tripleks.



Sebelum Dipotong



Setelah Dipotong

Komentar tentang Soal-soal dan Penyelesaian

16. Soal ini berkaitan dengan masalah reallotment. Guru dapat meminta siswa untuk menjelaskan dengan kata-kata atau gambar bagaimana mereka menemukan jawaban untuk soal ini.
Penyelesaian: banyaknya ubin berbentuk persegi yang dibutuhkan untuk membuat pengubinan tersebut adalah 3 x 6 = 18 buah

17. Soal ini berkaitan dengan konsep proporsi dan luas. Diharapkan guru dapat memotivasi siswa untuk menemukan sebanyak mungkin hubungan antara satu bangun dengan bangun yang lain, misalnya bangun **b** atau **d** adalah setengah bangun **a**, bangun **c** dua kali bangun **b**, dan lain lain. Cara yang digunakan siswa dalam menjawab soal ini akan bervariasi. Misalnya, gambar **a** adalah ¼ dari keseluruhan tripleks sehingga harganya ¼ x Rp. 20.000 = Rp. 5.000. Gambar **d** adalah setengah gambar **a** sehingga harganya ½ x Rp. 5.000 = Rp. 2.500, dan lain-lain
Penyelesaian:
a. Rp. 5.000 b. Rp. 2.500 c. Rp. 5.000
d. Rp. 2.500 e. Rp. 3.750 f. Rp. 1.250

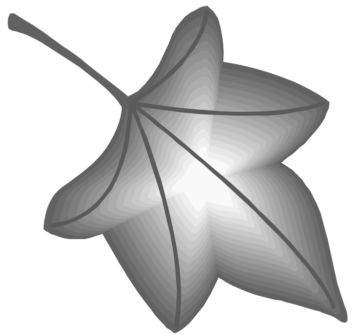
Halaman 10 Buku Siswa

<u>Pengayaan</u>

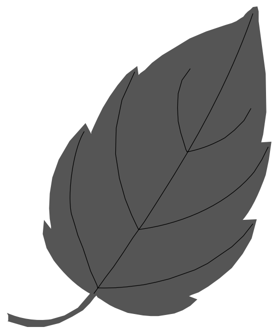
Daun

1. Bekerjalah dengan teman disampingmu. Cermati gambar dua buah daun kering di bawah ini. Permukaan ke dua daun akan di cat untuk dibuat hiasan. Jika daun kembang sepatu dicat dengan warna merah dan daun kapas dengan warna biru, maka cat warna apakah yang dibutuhkan lebih banyak? Gunakan lembaran kerja 1b, kemudian jelaskan alasanmu.

Daun Kapas



Daun Kembang Sepatu



Komentar tentang Soal-soal dan Penyelesaian

Soal ini dapat diberikan sebagai pengayaan kepada siswa yang masih mempunyai sisa waktu setelah menyelesaikan soal-soal wajib di kelas.

- Cat yang lebih banyak dibutuhkan adalah cat warna biru. Strategi yang digunakan siswa akan bervariasi. Salah satunya adalah dengan cara sebagai berikut:

Pelajaran 2: Luas Daerah

1. Tujuan

Siswa akan:

- Membandingkan luas bangun-bangun menggunakan berbagai cara dan satuan pengukuran.
- Memahami satuan-satuan dan alat-alat pengukuran yang cocok untuk menaksir atau mengukur luas suatu bangun.
- Menemukan konsep luas sebagai jumlah satuan-satuan pengukuran yang dibutuhkan untuk menutupi suatu bangun.
- Menaksir dan menghitung luas bangun-bangun geometri

2. Aktivitas Siswa

- Siswa mengembangkan pengertian mereka lebih jauh tentang konsep luas dengan membandingkan luas beberapa propinsi di Jawa dengan pulau Madura. Kemudian mereka menggunakan buah baju untuk menentukan luas beberapa danau, dan menggunakan kertas berpetak (transparansi berpetak) untuk membandingkan luas pulau Hayalan dan pulau Impian.
- Siswa membentuk persegipanjang dan persegi dari 12 buah persegi kecil
- Siswa menyelesaiakn soal tentang luas sebidang tanah dari berbagai bentuk menggunakan ide reallotment, yaitu dengan jalan merubah bentuk bangun semula (dengan cara menggunting dan menempel), sampai diperoleh bangun baru yang lebih mudah ditentukan luasnya.
- Siswa membandingkan dan menaksir luas bangun-bangun geometri mengunakan berbagai cara.
- Siswa secara informal menemukan rumus luas persegi dan persegipanjang
- Siswa menentukan harga tripleks dari berbagai bentuk dan ukuran berdasarkan harga sebuah triplek yang bentuk dan ukurannya diketahui.
- Siswa menemukan luas segitiga dengan cara menggambar sebuah persegipanjang yang menjadi bingkai dari segitiga tersebut.

3. Waktu: lebih kurang tiga kali 80 menit (tiga kali pertemuan)

4. Tentang Matematika:

Jika suatu kertas berpetak (transparansi berpetak) digunakan untuk membandingkan dan memperkirakan luas suatu bangun, maka dalam hal ini satu satuan persegi merupakan "satuan pengukuran" Untuk menentukan jumlah persegi satuan yang menutupi suatu bangun dapat digunakan beberapa cara, misalnya: (1) menghitung jumlah persegi satuan yang terdapat di dalam bangun, kemudian menaksir jumlah persegi untuk daerah yang masih tersisa; (2) membagi suatu bangun menjadi bagian-bagian tertentu sehingga memudahkan dalam menaksir luas nya; (3) membentuk suatu bangun baru dari bangun yang lama dengan cara menggunting kemudian menempel, sehingga luas bangun yang baru dapat ditemukan dengan lebih mudah (*seperti gambar di sebelah kiri bawah*); dan (4) meletakkan bangun yang akan dicari luasnya di dalam suatu persegi panjang, kemudian luas bangun didapat dengan cara mengurangkan luas persegipanjang dengan luas diluarnya (*seperti gambar sebelah kanan bawah*).

5. Material

- Lembar kerja siswa, gunting, kertas tipis untuk menjiplak, kertas grafik, lem, mistar, buah baju, kertas gambar, transparansi berpetak, transparansi dan OHP

6. Pekerjaan Rumah:

Pertemuan 3: soal nomor 7 - 9; Pertemuan 4: soal nomor 17; Pertemuan 5: soal nomor 21.

7. Rencana Penilaian Kemampuan Siswa

- Membandingkan luas bangun-bangun menggunakan berbagai cara dan satuan pengukuran, melalui soal nomor 1 – 6.
- Memahami satuan-satuan dan alat-alat pengukuran yang cocok untuk menaksir atau mengukur luas suatu bangun, melalui soal nomor 2-6.
- Menemukan konsep luas sebagai jumlah satuan-satuan pengukuran yang dibutuhkan untuk menutupi suatu bangun, melaui soal nomor 10-15.
- Menaksir dan menghitung luas bangun-bangun geometri, melalui Latihan 2 nomor 1 dan 2.

Pertemuan 3: Luas 1

Material: lembar kerja siswa, gunting, kertas tipis untuk menjiplak, kertas berpetak, lem, kertas gambar, transparansi berpetak, buah baju.

Ringkasan: Siswa membandingkan luas beberapa propinsi di Jawa dengan pulau Madura. Kemudian mereka menggunakan buah baju untuk menentukan luas beberapa danau, dan menggunakan kertas berpetak (transparansi berpetak) untuk membandingkan luas pulau Hayalan dan pulau Impian. Dari kegiatan ini siswa akan memahami satuan-satuan dan alat-alat pengukuran yang cocok untuk menaksir atau mengukur luas suatu bangun. Siswa juga akan menentukan luas beberapa kapling tanah yang bentuk geometrisnya bervariasi.

Tentang Matematika: Aktivitas yang dilakukan siswa pada pertemuan ini adalah aktivitas yang yang sangat berguna dalam menanamkan konsep luas sebagai jumlah satuan pengukuran yang diperlukan untuk menutupi suatu bangun. Melalui penggunaan berbagai satuan pengukuran siswa dapat memahami bahwa semakin besar satuan pengukuran yang digunakan semakin sedikit jumlahnya yang dibutuhkan untuk menutupi suatu bangun.

Dalam menyelesaikan soal nomor 8 beberapa siswa mungkin akan meletakkan bangun yang akan dicari luasnya dalam sebuah persegipanjang (persegipanjang akan menjadi bingkai dari bangun tersebut). Mereka kemudian dapat menghitung persegi satuan yang menutupi persegipanjang, kemudian menguranginya dengan persegi satuan yang terdapat di luar bangun, untuk mendapatkan luas bangun yang dicari.

Perencanaan:
- Siswa bekerja secara berkelompok dalam pertemuan ini
- Pajang dan diskusikan hasil-hasil pekerjaan siswa di papan tulis atau menggunakan OHP, terutama untuk soal nomor 1-6, dan 10-15.
- Siswa perlu mengetahui cara menentukan luas suatu bangun dengan menghitung jumlah persegi satuan yang menutupi bangun tersebut. Tetapi guru perlu memotivasi siswa untuk menggunakan cara-cara yang berbeda, kemudian minta siswa untuk berbagi ide dengan temannya. Cara untuk menghitung luas akan dipelajari lebih jauh pada pelajaran selanjutnya.
- Di akhir pertemuan guru harus mengingatkan siswa tentang konsep luas sebagai jumlah satuan pengukuran yang diperlukan untuk menutupi suatu bangun.

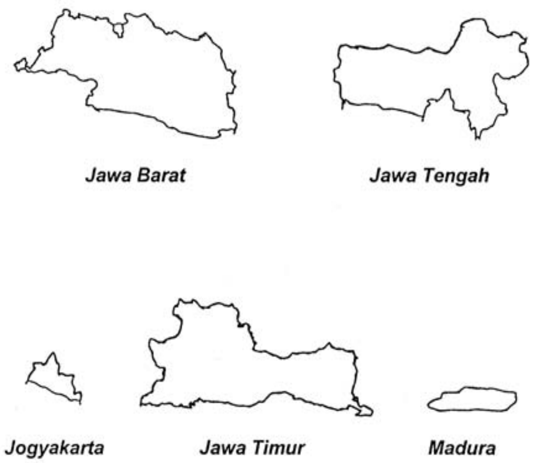
Halaman 7 Buku Siswa

Pelajaran 2: Luas

Pertemuan 3

Propinsi di Pulau Jawa

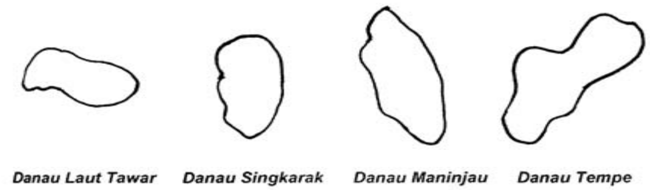
2. Di bawah ini terlihat gambar peta beberapa propinsi di Pulau Jawa serta gambar pulau Madura. Guntinglah gambar peta pulau Madura yang terdapat pada Lembaran Kerja 10, kemudian gunakan gambar tersebut untuk menaksir dan menjawab pertanyaan berikut.
   a. Luas Jawa Barat berapa kali luas Madura?
   b. Luas Jawa Tengah berapa kali luas Madura?
   c. Luas Jawa Timur berapa kali luas Madura?
   d. Luas Jogyakarta berapa kali luas Madura?



Halaman 8 Buku Siswa

Danau

3. Cermatilah gambar beberapa danau (di Indonesia) berikut ini. Dengan menggunakan Lembar Kerja 11, tentukanlah banyaknya kancing (buah) baju yang dibutuhkan untuk menutupi gambar tiap danau. Jelaskan jawabanmu! (*Kancing baju akan dipinjamkan guru*)



4. Gunakanlah kancing baju dengan ukuran yang sama untuk menutupi gambar danau Tempe. Bandingkanlah jawabanmu dengan teman-teman yang lain. Apakah kesimpulanmu?
5. Selidikilah danau manakah yang paling luas? Jelaskanlah caramu dalam menjawab soal ini.
6. Menurutmu kancing baju manakah yang lebih cocok untuk menetukan luas gambar dari tiap danau? Apa alasannya?
7. Sebutkanlah benda lain selain kancing baju yang menurutmu lebih cocok untuk mengukur luas gambar dari danau-danau di atas. Jelaskan alasanmu mengapa benda tersebut kamu anggap lebih cocok!

Komentar tentang Soal-soal dan Penyelesaian

1. Jawaban siswa akan bervariasi, Diskusikan semua jawaban tersebut, terutama jawaban siswa yang ganjil, sehingga mereka dapat memahami dan menilai sendiri jawaban mana yang lebih akurat.

2-5. Soal ini memperkenalkan siswa pada satuan pengukuran yang tidak baku. Makin kecil buah baju yang digunakan makin banyak buah baju yang dibutuhkan untuk menutupi gambar danau, dan semakin akurat hasil pengukuran yang diperoleh. Diskusikan jawaban-jawaban siswa untuk memberi mereka pengertian tentang satuan pengukuran yang lebih cocok dalam mengukur luas suatu bangun.

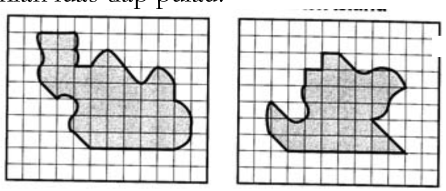
6. Persiapkan satuan-satuan pengukuran berbentuk persegi, kemudian minta siswa untuk membandingkannya dengan buah baju yang digunakan sebelumnya.

Halaman 9 Buku Siswa

Pekerjaan Rumah

Pulau Hayalan dan Pulau Impian

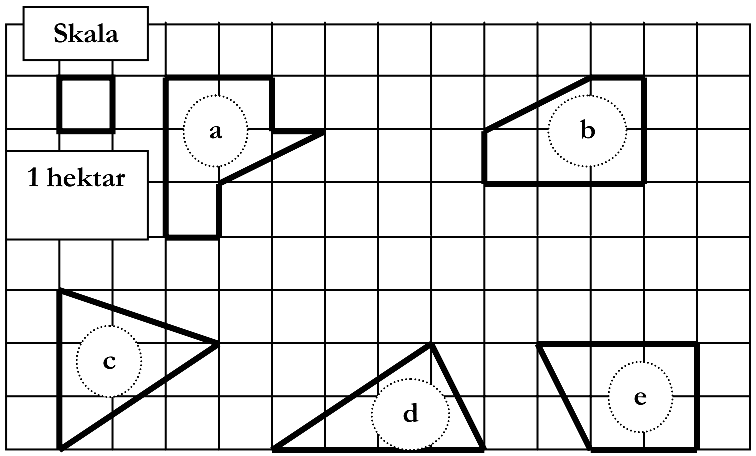
7. Gambar di bawah ini menunjukkan peta pulau Hayalan dan pulau Impian.
   a. Selidikilah pulau manakah yang lebih luas? (Jelaskan alasanmu)
   b. Tentukanlah luas tiap pulau!



Pulau Hayalan Pulau Impian

Tanah untuk Dijual

8. Pak Cahyono mempunyai enam bidang tanah yang mau dijual. Sebelum dijual, beliau meminta bantuanmu untuk mengukur luas tiap bidang tanah menggunakan skala yang terdapat pada gambar. Tuliskan hasil pengukuranmu!



9. Jika harga satu hektar tanah adalah Rp. 5.000.000, tanah manakah yang harganya paling murah? Jelaskan jawabanmu!

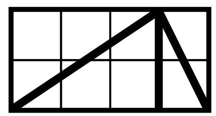
Komentar tentang Soal-soal dan Penyelesaian

7. Motivasi siswa untuk menggunakan jumlah kotak persegi dalam membandingkan luas ke dua pulau. Jawaban siswa untuk soal ini akan bervariasi (tidak fix)

Penyelesaian:

a. Yang lebih luas adalah pulau Hayalan
b. Luas pulau Hayalan adalah 35 sampai 41 satuan persegi
   Luas pulau Impian adalah 28 sampai 34 satuan per**segi**

8-9. Soal ini dapat digunakan untuk menilai kemampuan siswa dalam menaksir dan menghitung luas bangun-bangun geometri. Di samping itu, soal ini dapat juga digunakan untuk menilai kemampuan mereka dalam menyelesaikan soal menggunakan model-model geometri. Siswa mungkin akan menggunakan berbagai cara berbeda dalam menjawab soal ini. Misalnya untuk gambar **d**, siswa mungkin menggambar sebuah persegipanjang dengan panjang 4 satuan dan lebar 2 satuan untuk membingkai segitiga. Kemudian persegipanjang dibagi menjadi dua seperti ditunjukkan pada gamabr berikut ini.



Luas segitiga adalah 8 - 1/2(6) - 1/2(2) = 8 - 3 - 1 = 4

Penyelesaian:

8. a. 5 hektar b. 5 hektar c. 4,5 hectar d. 4 hektar e.5 hektar
9. a. 25 juta b. 25 juta c. 22,5 juta d. 20 juta e. 25 juta

Pertemuan 4: Luas

Material: lembar kerja siswa, gunting, kertas tipis untuk menjiplak, kertas berpetak, lem, kertas gambar.

Ringkasan: Siswa akan menemukan luas persegi dan persegi panjang berdasarkan konsep luas sebagai jumlah persegi satuan yang diperlukan untuk menutupi suatu persegi atau persegi panjang. Mereka juga akan menaksir dan menemukan luas beberapa bangun geometri. Di samping itu, siswa juga akan menentukan harga sepotong tripleks berdasarkan dimensi (keliling) dan harga sebuah tripleks lain yang diketahui.

Tentang Matematika: Aktivitas yang dilakukan siswa membentuk berbagai persegipanjang dan persegi dari beberapa persegi satuan akan memberi mereka pemahaman tentang rumus luas persegipanjang dan persegi. Untuk menemukan luas beberapa tripleks pada Latihan 2 soal nomor 1 siswa mungkin menempuh berbagai cara, antara lain: membagi dua, mengurangkan, membentuk bingkai (berbentuk persegipanjang), menghubungkan soal yang satu dengan yang lain, dan lain-lain.

Perencanaan:
- Siswa bekerja secara berkelompok untuk soal nomor 10-15, dan secara individu atau berpasangan untuk soal-sol lainnya.
- Diskusikan hasil kerja siswa secara klasikal menggunakan papan tulis atau OHP
- Beri siswa motivasi untuk menggunkan cara-cara yang berbeda dalam menentukan luas, dan minta mereka untuk memberi tahu cara yang mereka temukan kepada teman-teman lain di kelas.
- Latihan 2 nomor 1 diberikan setelah siswa mengerjakan soal nomor 16

Halaman 10 Buku Siswa

Pertemuan 4

Menemukan Luas Persegipanjang dan Persegi

10. Guru akan memberimu dua belas buah persegi kecil yang sama bentuknya. Buatlah sebanyak mungkin persegipanjang dengan menggunakan ke-dua belas persegi kecil tersebut, kemudian gambarkan hasil-hasilmu pada buku latihan.

> *Gambar pulau Madura, kancing (buah) baju, atau persegi kecil yang digunakan dalam soal-soal di atas disebut* **"Satuan Pengukuran"***. Banyaknya "satuan pengukuran yang diperlukan untuk menutupi suatu bangun di sebut* **"Luas Daerah"** *dari bangun tersebut. Istilah "Luas Daerah" selanjutnya kita singkat menjadi* **"Luas"***.*

11. Apakah pendapatmu tentang luas tiap persegipanjang yang kamu gambar? Jelaskan jawabanmu.

12. Menurutmu bagaimanakah cara termudah untuk menentukan luas persegipanjang-persegipanjang tersebut?

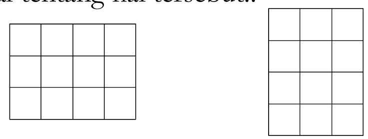
13. Lakukan kegiatan yang sama untuk membuat sebanyak mungkin persegi tanpa harus menggunakan ke-dua belas persegi kecil.

14. Dapatkah kamu membuat persegi menggunakan ke-dua belas persegi kecil? Mengapa?

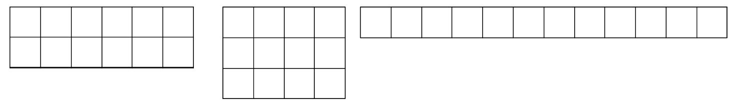
15. Bagaimanakah cara termudah untuk menentukan luas sebuah persegi?

Komentar tentang Soal-soal dan Penyelesaian

10-15. Soal ini mengarahkan siswa untuk menemukan rumus luas persegi dan persegi-panjang. Guru hendaknya memberi perhatian terhadap masalah kemampuan keruangan yang mungkin muncul. Sebagai contoh, beberapa siswa mungkin beranggapan bahwa dua buah bangun berikut ini adalah berbeda. Oleh karena itu sebaiknya dilaksanakan diskusi secara klasikal tentang hal tersebut..

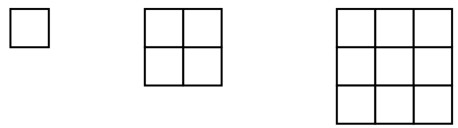


10. Contoh persegi panjang yang dapat dibuat :



11. Luas tiap persegipanjang di atas adalah sama karena jumlah persegi kecil yang menutupi tiap persegipanjang adalah sama.

12. Jawaban siswa akan bervariasi. Contoh jawaban siswa: mengalikan banyaknya persegi satuan pada satu baris dengan banyaknya persegi satuan pada satu kolom.

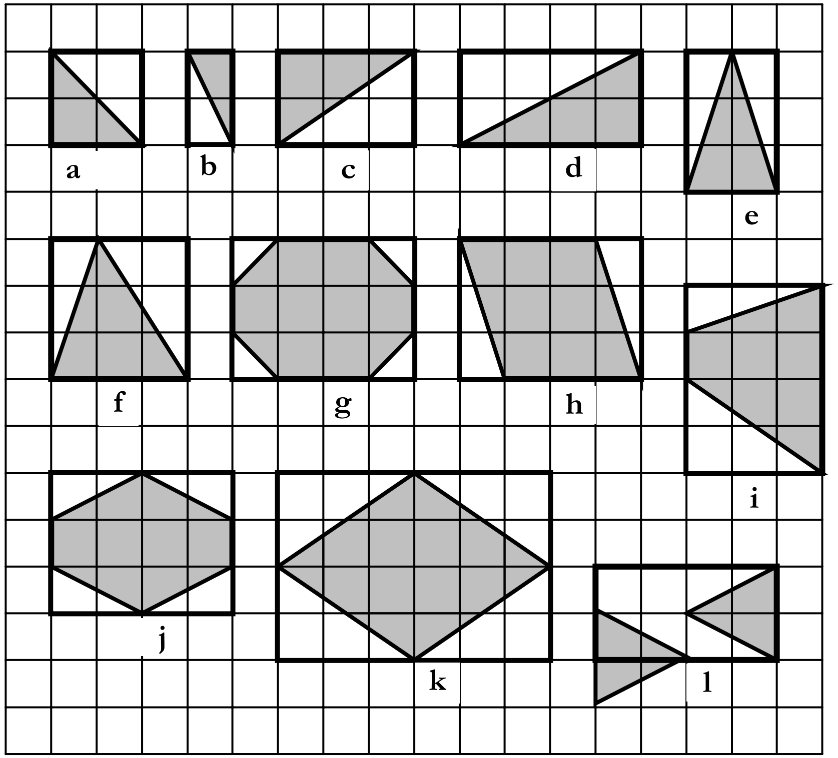
13. 

14. Tidak. Alasan siwa akan bervariasi. Misalnya, luas persegi yang dapat dibuat hanyalah: 1 satuan persegi, 4 satuan persegi dan 9 satuan persegi.

15. Terima semua istilah yang digunakan siswa untuk menentukan luas persegi, kemudian arahkan ke penemuan istilah sisi x sisi (secara informal)

Halaman 11 Buku Siswa

16. Tentukanlah luas tiap bangun yang dihitamkan pada gambar di bawah ini. Gunakan Lembar Kerja 12 untuk membantumu, kemudian berikan jawabanmu dalam satuan persegi (*karena pada soal in digunakan persegi kecil sebagai unit pengukuran*). Berikan alasan untuk tiap jawabanmu!



Komentar tentang Soal-soal dan Penyelesaian

16. Soal ini dapat digunakan untuk menilai kemampuan siswa dalam menaksir dan menghitung luas berbagai bangun-bangun geometri. Pada soal **a-d** dapat digunakan cara membagi dua persegi panjang. Beberapa siswa mungkin akan menjawab soal **g – l** dengan cara mengurangi luas persegipanjang dengan luas bangun yang tidak dihitamkan. Pada soal ini ingatkan siswa untuk menggunakan satuan persegi.

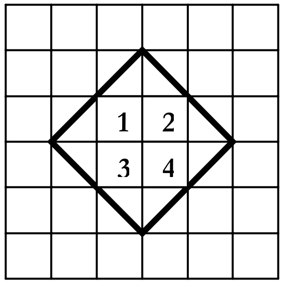
<u>Penyelesaian</u>

a. 2 satuan persegi	b. 1 satuan persegi	c. 3 satuan persegi
d. 4 satuan persegi	e. 3 satuan persegi	f. 4,5 satuan persegi
g. 10 satuan persegi	h. 9 satuan persegi	i. 7,5 satuan persegi
j. 8 satuan persegi	k. 12 satuan persegi	l. 4 satuan persegi

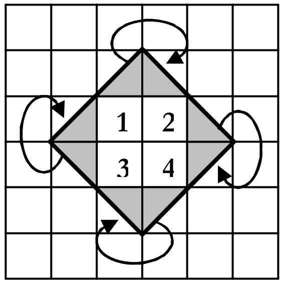
Halaman 12 Buku Siswa

Ringkasan Pelajaran 2

Dalam pelajaran ini kamu membandingkan luas beberapa propinsi, danau dan kapling tanah. Kamu juga telah menggunakan ***satuan persegi*** *sebagai satuan pengukuran. Ada beberapa cara dalam menentukan luas bangun-bangun, misalnya: menghitung jumlah persegi satuan yang utuh dalam suatu bangun kemudian menggabungkan sisanya untuk membentuk persegi satuan yang utuh, seperti terlihat pada gambar di bawah ini.*

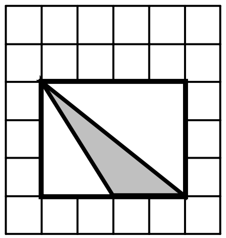


Ada empat persegi satuan yang utuh di dalam bangun



Daerah yang belum dihitung dapat dikombinasikan menjadi empat buah persegi satuan

Kamu juga dapat meletakkan bangun dalam suatu persegipanjang kemudian menghitung luas bangun dengan cara mengurangi luas persegipanjang dengan luas daerah di luar bangun seperti terlihat pada gambar berikut.

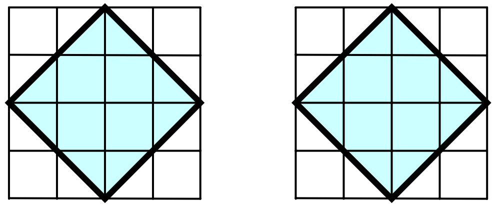


Luas bangun yang dihitamkan adalah luas persegipanjang dikurangi luas dua buah segitiga yang tidak dihitamkan

Halaman 13 Buku Siswa

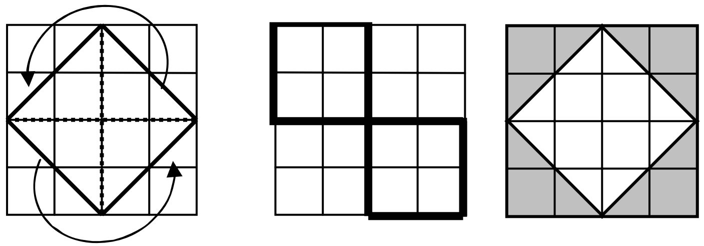
Pekerjaan Rumah

17. Tentukanlah luas (dalam satuan persegi) bangun-bangun di bawah ini menggunakan cara yang berbeda dengan cara yang dijelaskan pada ***ringkasan***.



Komentar tentang Soal-soal dan Penyelesaian

17. Soal ini dapat digunakan untuk menilai kemampuan siswa menerapkan cara-cara yang telah mereka pelajari dalam pelajaran 2. Siswa mungkin akan melihat bangun ini sebagai empat buah segitiga yang sama. Segitiga-segitga ini dapat dibentuk menjadi dua buah persegi yang luas masing-masingnya 4 satuan persegi, seperti terlihat pada gambar berikut.



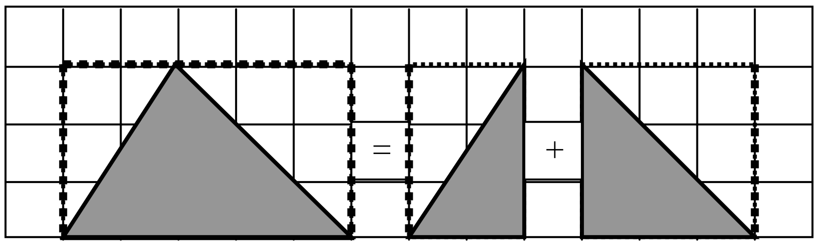
Siswa yang lain mungkin akan menggambar sebuah persegi sebagai bingkai dari bangun, kemudian mereka akan dapat melihat bahwa luas bangun sebagai setengah dari luas persegi, seperti ditunjukkan pada gambar paling kanan atas

Pertemuan 5: Luas

Material: lembar kerja siswa, gunting, kertas tipis untuk menjiplak, kertas berpetak, lem, kertas gambar .

Ringkasan: Siswa mengkaji kesamaan empat buah segitiga, kemudian menemukan luas masing-masingnya. Mereka juga akan menentukan harga-harga dari objek-objek menggunakan ukuran dan harga dari suatu objek yang diketahui.

Tentang Matematika: Kegitan yang dilakukan siswa dalam menyelesaikan Latihan 2 nomor 2 akan mengarahkan siswa ke penemuan rumus luas segitiga. Rumus itu sendiri akan diperkenalkan pada pertemuan 8. Di sini siswa dapat melihat bahwa luas sebuah segitiga siku-siku adalah setengah luas suatu persegipanjang (gambar **a** dan **b**). Cara ini juga dapat digunakan untuk menghitung luas segitiga yang lain, seperti ditunjukkan pada gambar di bawah ini.



Luas masing-masing segitiga di sebelah kanan adalah setengah dari luas persegipanjang/persegi yang membingkainya. Dapat juga dikatakan bahwa luas segitiga yang dicari sama dengan luas persegipanjang dikurangi luas dua segitiga di luar segitiga yang dicari. Cara ini dapat digunakan untuk menyelesaiakn soal e, **g, j**, dan lain-lain.

Akan tetapi perlu diingat bahwa pernyataan: "*luas suatu segitiga adalah setengah luas persegipanjang*" tidak selalu benar. Contohnya adalah gambar **n**.

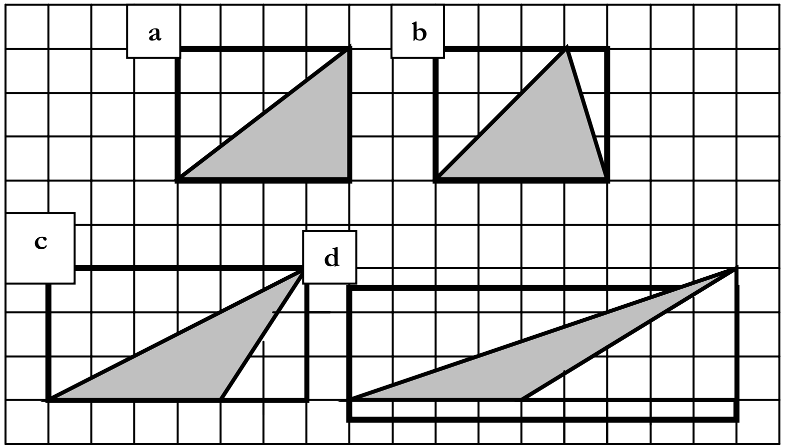
Perencanaan:

- Siswa bekerja secara individu untuk semua soal dalam pertemuan ini.
- Latihan 2 nomor 2 diberikan setelah siswa mengerjakan soal nomor 20
- Diskusikan secara klasikal cara-cara yang digunakan siswa dalam menyelesaikan soal-soal nomor 18 - 20 dan Latihan 2 nomor 2.

Halaman 14 Buku Siswa

Pertemuan 5

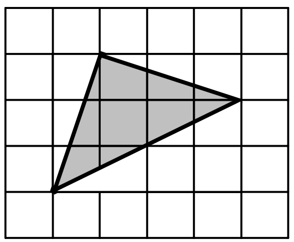
18. Pada gambar di bawah ini terdapat empat buah segitiga yang masing-masing digambar dalam sebuah persegipanjang.



a. Apakah kesamaan yang terlihat olehmu pada keempat segita tersebut?

b. Berapakah luas tiap segitiga tersebut? Jelaskan caramu untuk mendapatkan jawaban.

19. Tentukanlah luas segitiga berikut ini (dalam satuan persegi). Jelaskan caramu dalam menemukan jawaban!



Komentar tentang Soal-soal dan Penyelesaian

18. Mungkin siswa belum akan menggunakan kata-kata "*alas* dan *tinggi*" pada soal ini. Biarkan siswa menggunakan istilah mereka sendiri. Contoh jawaban siswa:
   a. Semua segitiga mempunyai alas 3 satuan; semua segitiga mempunyai tinggi 3 satuan, atau semua segitiga mempunyai luas 6 satuan persegi.
   b. Luas tiap segitiga adalah 6 satuan persegi. Cara siswa mungkin akan bervariasi, misalnya dengan cara pengurangan, merubah segitiga menjadi bangun yang lebih mudah dihitung luasnya, mengalikan alas dengan tinggi: karena alas tiap segitiga adalah empat satuan dan tinggi tiap segitiga tiga satuan, maka luas tiap segitiga adalah setengah dari 12 satuan persegi atau 6 satuan persegi.

19. Karena alas dan tinggi segitiga tidak diketahui, sarankan siswa untuk menempuh cara yang lain. Misalnya dengan menggambar persegi-panjang sebagai bingkai dari segitiga. Luas segitiga adalah luas persegipanjang dikurangi luas tiga buah segitiga di luar segitiga yang dicari.

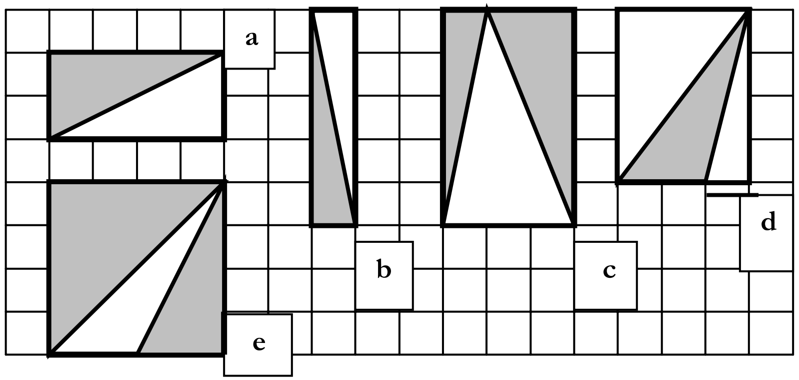
Penyelesaian: Luas segitiga 5 ½ satuan persegi. Penjelasan siswa akan bervariasi, misalnya: siswa menggambar sebuah persegi panjang sebagai bingkai dari segitiga. Luas persegipanjang tersebut adalah 3 x 4 = 12 satuan persegi. Luas tiga buah segitiga kecil di luar segitiga yang dicari masing-masing adalah ½ x 4 = 2, ½ x 3 = 1 ½ , dan ½ x 6 = 3 cm. Jadi luas segitiga yang dicari adalah 12 – 6 ½ = 5 ½ satuan persegi.

Halaman 15 Buku Siswa

Pekerjaan Rumah

20. Gambarlah pada buku latihanmu tiga buah segitiga yang masing-masing luasnya sama. Kemudian hitamkan tiap daerah segitiga yang kamu gambar.

21. Harga sebuah kaca jendela yang luasnya 4 satuan persegi adalah Rp. 60. 000. Tentukanlah harga tiap kaca jendela yang luasnya seperti gambar yang dihitamkan berikut ini!



Komentar tentang Soal-soal dan Penyelesaian

20. Soal ini menuntut pemahaman lebih jauh tentang hubungan antara luas suatu segitiga dengan persegipanjang (yang menjadi bingkainya) dan jajargenjang. Beberapa siswa mungkin akan menggambar tiga buah segitiga yang sama, tetapi tampilannya berbeda. Diskusikan dengan mereka tentang hal tersebut.. Siswa yang lain mungkin akan menggambar tiga persegipanjang atau jajargenjang yang berbeda, kemudian mendapatkan segitiga-segitiga yang dimaksud pada soal dengan cara membagi dua persegipanjang atau jajargenjang. Contoh jawaban siswa:

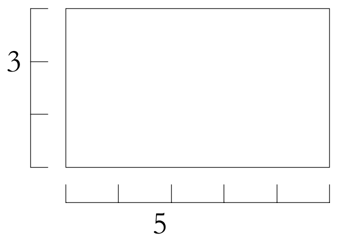
21. Pada soal ini konsep luas dikaitkan dengan perbandingan harga.

Penyelesaian: a. Rp. 60.000 b. Rp. 37.500 c. Rp. 112. 500
d. Rp. 60.000 e. Rp. 180. 000

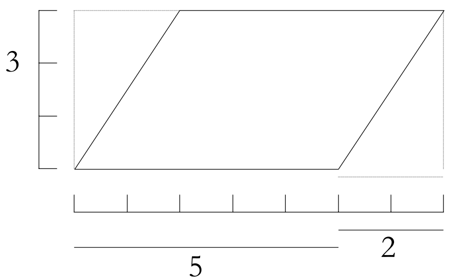
Halaman 16 Buku Siswa

22. Determine the area of each shape below, and explain your strategy in finding each answer.

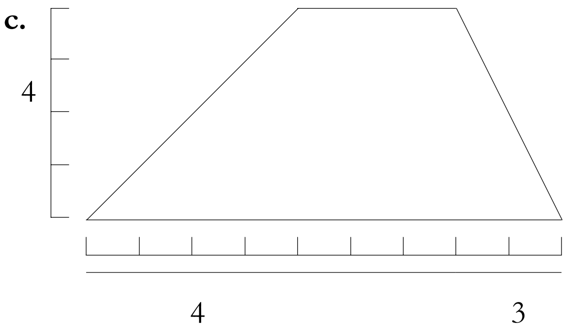
a.



b.



c.

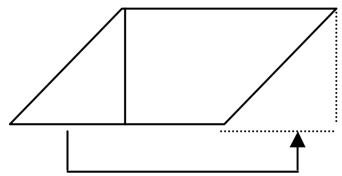


KOMENTAR TENTANG SOAL-SOAL DAN PENYELESAIAN

22. Minta siswa untuk menjelaskan secara verbal atau menggunkan gambar dalam menyelesaiakn soal-soal ini!

   a. Beberapa siswa mungkin akan langsung menggunakan ukuran-ukuran pada gambar untuk mendapatkan luas masing-masing bangun (mengunakan rumus atau mengacu pada soal nomor 10 -12). Tetapi beberapa siswa yang lain tetap akan menggunakan cara menggunting dan menempel atau menggambar persegi-persegi satuan.

   b. Siswa mungkin akan menggunkan salah satu cara berikut dalam menentukan luas jajargenjang:
      - Menghitung luas persegipanjang yang dibentuk oleh garis putus-putus, kemudian mengurangkannya dengan luas dua segitiga di luar jajargenjang.
      - Merubah jajargenjang menjadi persegipanjang dengan cara menggunting dan menempel.



      - Menggunakan rumus untuk menentukan luas jajargenjang
      - Menggambar persegipersegi kecil di dalam jajargenjang kemudian menghitungnya

Bebrapa siswa mungkin akan beranggapan bahwa alas jajargenjang adalah 7 (5 +2) atau hanya 5 atau 2.

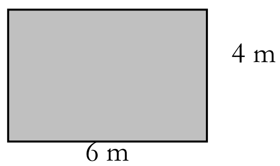
   c. Beberapa siswa mungkin akan membagi tiga trapesium menjadi dua buah segitiga dan satu persegipanjang, kemudian menjumlahkan luas masing-masing untuk mendapatkan luas trapesium. Siswa yang lain mungkin akan menggambar persegipanjang untuk membingkai trapesium, kemudian mendapatkan luas trapesium dari luas jajargenjang dikurangi luas dua buah segitiga di luar trapesium.

<u>Penyelesaian:</u> Luas persegipanjang: 15 satuan persegi; luas jajargenjang: 15 satuan persegi; luas trapesium 18 satuan persegi

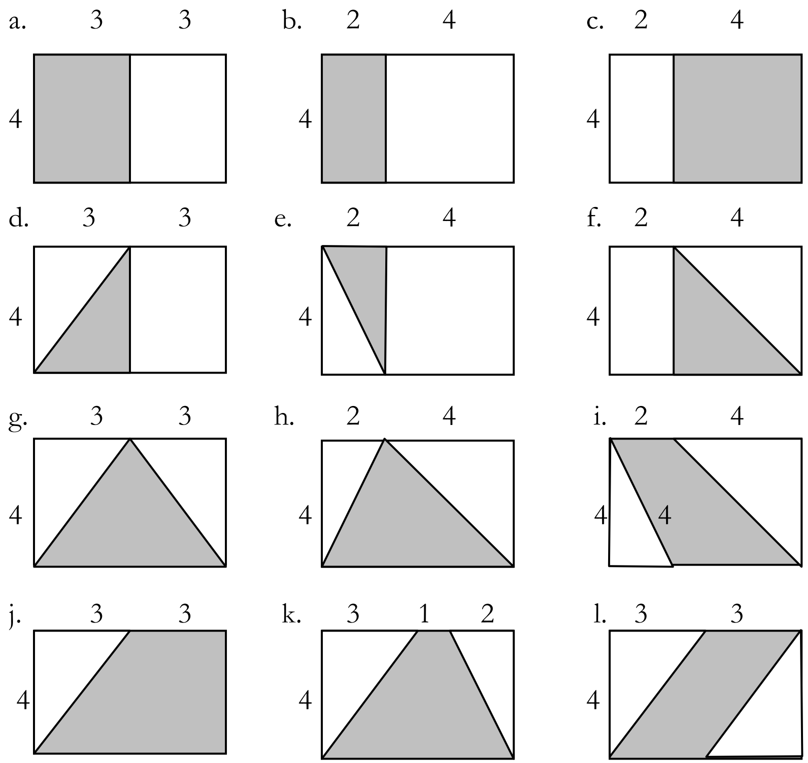
Latihan 2

Tripleks

1. Harga sebuah tripleks berukuran 4m x 6m adalah Rp. 48. 000.

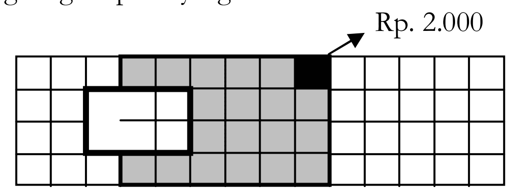


Hitunglah harga tiap tripleks dengan ukuran (dalam meter) seperti ditunjukkan pada bagian gambar yang dihitamkan berikut!



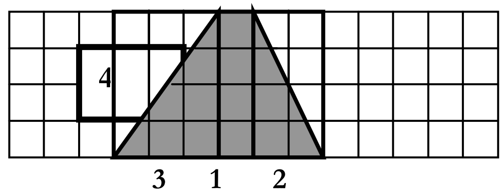
Komentar tentang Soal-soal dan Penyelesaian

1. Soal ini menuntut pengetahuan tentang konsep keliling, dan luas dalam menyelesaikan masalah dalam kehidupan sehari-hari. Untuk menemukan jawaban, beberapa siswa mungkin akan membagi tripleks menjadi 24 buah persegi kecil (seperti terlihat pada gambar berikut) dan menemukan harga tripleks persegi kecil: Rp. 48.000 : 24 = Rp. 2.000. Kemudian siswa menggunakan temuan ini untuk menghitung harga tripleks yang lain.



Misalnya untuk gambar **b**, harganya adalah 8 x Rp. 2. 000 = Rp. 16. 000 Siswa mungkin juga membagi gambar-gambar menjadi bagian-bagian yang lebih kecil dan sederhana, misalnya untuk gambar **k**:

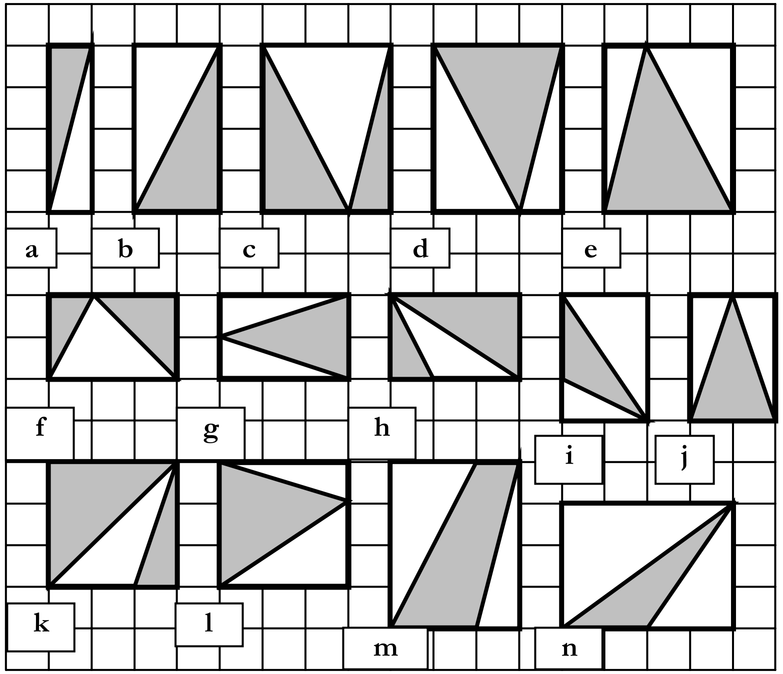
- Persegipanjang besar dibagi menjadi tiga buah persegipanjang kecil yang masing-masing ukurannya 3 x 4, 1 x 4 dan 2 x 4:



- Luas persegipanjang yang di tengah adalah 1 x 4 = 4 satuan, sehingga harganya 4 x Rp. 2.000 = Rp. 8.000. Dengan cara yang sama diperoleh harga yang lain ½(3 x 4) x Rp. 2.000 = Rp. 12.000, dan ½ (2 x 4) x Rp. 2.000 = Rp. 8.000, Guru dapat juga menyarankan siswa untuk membandingkan gambar bangun pada baris pertama dengan baris ke dua. Akan terlihat bahwa tripleks **d**, **e**, dan **f** adalah setengah tripleks **a, b,** dan **c.** Hal ini diharapkan dapat membantu siswa dalam mengembangkan cara untuk menemukan luas segitiga.

Penyelesaian: a. Rp. 30.000 b. Rp.20.000 c. Rp.40.000
d. Rp. 15.000 e. Rp. 10.000 f. Rp. 20.000 g. Rp. 30.000
h. Rp. 30.000 i. Rp. 30.000 j. Rp. 45.000 k. Rp. 35.000
l. Rp. 30.000

2. Tentukanlah luas bangun yang dihitamkan (dalam satuan persegi) pada tiap gambar di bawah ini.



Komentar tentang Soal-soal dan Penyelesaian

2. Jika siswa hanya menghitung persegi satuan dalam menentukan luas, arahkan mereka untuk menggunakan cara lain, seperti membagi dua, atau mengurangi seluruh bangun dengan bagian yang tidak dihitamkan (putih). Beberapa siswa mungkin akan mengetahui bahwa bangun **c** dapat digunakan untuk menemukan jawaban untuk bangun **d,** menggunakan cara pengurangan**.**

Penyelesaian

a. 2 satuan persegi	b. 4 satuan persegi	c. 6 satuan persegi
d. 6 satuan persegi	e. 6 satuan persegi	f. 3 satuan persegi
g. 3 satuan persegi	h. 4 satuan persegi	i. 2 satuan persegi
j. 3 satuan persegi	k. 6 satuan persegi	l.4,5 satuan persegi
m. 6 satuan persegi	n. 3 satuan persegi	

Pelajaran 3: Luas 2

1. ***Tujuan***

Siswa akan:

- Menaksir dan menghitung luas berbagai bangun-bangun geometri.
- Menggeneralisasi rumus-rumus dan prosedur untuk menentukan luas persegipanjang, jajargenjang dan segitiga.

2. ***Aktivitas Siswa***

- Siswa merubah sebuah jajargenjang menjadi sebuah persegipanjang untuk menemukan luasnya. Mereka menggunakan berbagai cara dalam melakukan perubahan tersebut, misalnya dengan cara menggunting satu bagian berbentuk segitiga pada jajargenjang kemudian menempelkannya pada bagian lain untuk mendapatkan sebuah persegipanjang.
- Siswa menemukan berbagai bangun yang mempunyai luas yang sama. Mereka juga akan mengenaralisasi aturan atau rumus untuk menentukan luas persegipanjang, jajargenjang dan segitiga, menggunakan konsep tentang "alas" dan "tinggi
- Siswa menggunakan berbagai satuan pengukuran untuk menyelidiki luas dari suatu bangun.

3. Waktu: lebih kurang tiga kali 80 menit (tiga kali pertemuan)

4. Tentang Matematika:

Luas adalah suatu ukuran dari daerah dimana sebuah bangun dua dimensi tercakup didalamnya. Satuan yang biasa digunakan untuk menghitung/mengukur luas adalah persegi. Namun demikian, daerah dapat juga diukur menggunakan segitiga, segi enam, atau bangun lain yang dapat digandengkan (dibuat untuk pengubinan).

Cara untuk menaksir dan menghitung luas yang dikembangkan oleh siswa dalam pelajaran 2 menjadi lebih eksplisit dalam pelajaran ini. Luas dari persegipanjang, segitiga dan jajargenjang dapat ditemukan dengan cara menghitung, menggunting dan menempel, serta mengurangi. Penggunaan istilah alas dan tinggi membawa siswa ke penemuan rumus luas persegipanjang, segitiga dan jajargenjang.

Dalam rangka menemukan rumus luas jajargenjang dari persegipanjang, beberapa cara dapat digunakan, misalnya dengan membentuk kembali (menggunting dan menempel), atau shifting. Luas segitiga dapat ditemukan dengan cara pengurangan atau membagi dua suatu jajargenjang yang bersesuaian.

5. Material

- Lembar kerja siswa, gunting, kertas tipis untuk menjiplak, kertas grafik , lem, mistar, kertas gambar, transparansi, OHP

6. Pekerjaan Rumah:

Pertemuan 6: soal nomor 4-8, Pertemuan 7: soal nomor 12; pertemuan 8: soal nomor 13 - 15.

7. Rencana Penilaian Kemampuan Siswa

- Menaksir dan menghitung luas berbagai bangun-bangun geometri, melalui Latihan 3 nomor 1 - 3.
- Menggeneralisasi rumus-rumus dan prosedur untuk menentukan luas persegipanjang, jajargenjang dan segitiga, melalui soal nomor 2, 3 dan Latihan 3 nomor 3.

Pertemuan 6: Luas 2

Material: lembar kerja siswa, gunting, kertas tipis untuk menjiplak, kertas berpetak, lem, kertas gambar, transparansi, OHP.

Ringkasan: Siswa diperkenalkan pada istilah segiempat dan jajargenjang. Mereka menemukan suatu cara untuk menentukan luas jajargenjang. Siswa juga akan menggunting dan menempel untuk merubah jajargenjang menjadi persegipanjang dan sebaliknya. Mereka juga akan menggambarkan cara-cara untuk menentukan luas persegipanjang, jajargenjang dan segitiga. Terakhir, siswa akan menggambar 5 buah bangun yang mempunyai luas lima satuan persegi.

Tentang Matematika: Umumnya luas jajargenjang dapat ditentukan dengan cara menggunting satu bagian berbentuk segitiga pada jajargenjang kemudian menempelkannya pada bagian lain untuk mendapatkan suatu persegipanjang. Tetapi cara ini tidak berlaku untuk soal nomor 1e. Untuk itu perlu dilakukan pekerjaan yang sama sebanyak dua kali. Cara lain, yaitu dengan menggambar bingkai berbentuk persegipanjang, dapat juga digunakan untuk menentukan luas suatu jajargenjang.

Aktivitas pada halaman 18 buku siswa menunjukkan bahwa diagonal suatu jajargenjang membagi jajargenjang menjadi dua buah segitiga yang sama. Dengan demikian dapat dikatakan bahwa setiap segitiga adalah setengah dari suatu jajargenjang. Dari aktivitas tersebut dapat juga dipahami bahwa luas bangun baru yang terbentuk tetap sama dengan bangun semula. Barangkali siswa tidak menyadari bahwa alas dan tinggi bangun juga tetap sama, untuk itu perlu penjelasan dari guru.

Perencanaan:
- Siswa bekerja secara berkelompok atau berpasangan dalam pertemuan ini.
- Diskusikan istilah dan sifat-sifat (secara umum): "persegipanjang, jajargenjang, segitiga dan persegi". Kemudian minta mereka untuk mengemukakan pemahaman mereka tentang garis sejajar, dan kapan dua buah garis dikatakan sejajar atau tidak sejajar.
- Beri siswa kesempatan untuk mendiskusikan ide-ide mereka dalam menemukan luas bangun-bangun dalam rangka mengembangkan kemampuan mereka untuk memahami dan menggunakan berbagai cara dalam menghitung luas.
- Latihan 3 nomor 1 dan 2 diberikan setelah siswa mengerjakan soal nomor 3.

Halaman 17 Buku Siswa

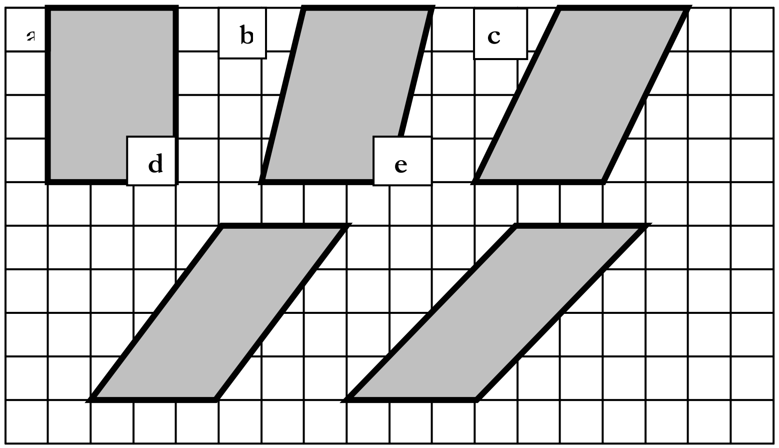
Pelajaran 3: Luas (Lanjutan)

Pertemuan 6

Jajargenjang, Persegipanjang dan Segitiga

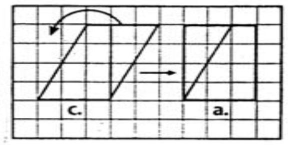
Sebuah bangun segi empat dimana sisinya yang berhadapan sejajar disebut **jajargenjang.** Jika semua sudutnya juga siku-siku maka bangun itu disebut **persegipanjang.** Melalui beberapa kegiatan yang akan kamu lakukan dalam pertemuan ini, kamu akan mengetahui bahwa sebuah jajar genjang dapat diubah menjadi sebuah persegipanjang, dan sebaliknya.

a. Jelaskan bagaimana agar tiap jajargenjang **b** sampai **e** dapat diubah menjadi gambar **a**.
b. Jelaskan bagaimana cara yang kamu gunakan itu dapat dipakai untuk menentukan luas sebarang jajargenjang?
c. Bagaimanakah luas bangun-bangun **a** sampai **e**? Jelaskan jawabanmu!



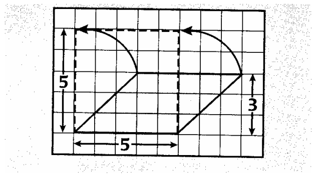
Komentar tentang Soal-soal dan Penyelesaian

1. a. Jawaban siswa akan bervariasi. Misalnya, mereka memotong bagian berbentuk segitiga dari sebelah kanan jajargenjang kemudian menempelkannya pada bagian sebelah kiri, seperti terlihat pada gambar berikut.



Siswa mungkin akan mengalami kesulitan untuk merubah gambar **e** menajdi gambar

a. Untuk itu guru dapat memotivasi mereka untuk melakukan proses yang sama seperti di atas sebanyak dua kali. Beberapa siswa mungkin juga akan menyelesaikan soal-soal dengan cara meletakkan (merubah bentuk) jajargenjang dengan cara seperti terlihat pada gambar berikut ini.



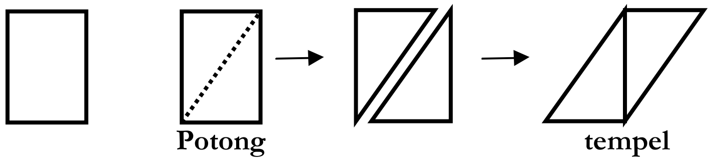
Dengan melakukan transformasi seperti ini, luas bangun yang diperoleh selalu lebih besar dari luas jajargenjang semula. Diskusikan hal ini dengan siswa

b. Jawaban siswa juga akan bervariasi. Misalnya: kita dapat menemukan luas sebarang jajargenjang dengan cara merubahnya menjadi persegipanjang, kemudian menghitung jumlah persegi satuan pada gambar. Siswa lain mungkin akan menjawab: sebarang jajargenjang dengan alas dan tinggi yang sama dengan sebuah persegipanjang, maka luasnya juga akan sama dengan luas persegipanjang tersebut.
c. Luas semua bangun adalah sama

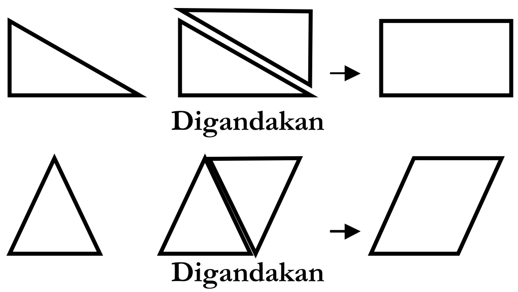
Halaman 18 Buku Siswa

2. Kamu dapat mengubah sebuah persegi atau persegipanjang menjadi beberapa jajargenjang yang berbeda dengan cara menggunting dan menempel beberapa kali. Lakukanlah kegiatan berikut!
   i. Gambarlah pada kertas berpetak sebuah persegi dengan ukuran dua satuan ke kanan dan tiga satuan ke bawah.
   ii. Potonglah sepanjang diagonal kemudian tempelkan satu bagian ke bagian lain untuk membentuk sebuah jajargenjang
   iii. Ulangi langkah **ii** beberapa kali!
   Cermati bagaimana jajargenjang yang terakhir berbeda dari persegipanjang semula. Apa persamaannya?

Sebuah persegipanjang dapat dipotong menjadi dua buah segitiga yang sama. Dari kedua segitiga tersebut dapat dibentuk sebuah jajargenjang, seperti terlihat pada gambar berikut ini.



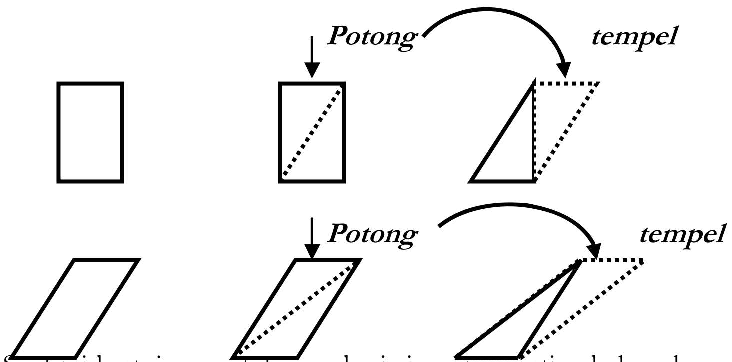
Sebaliknya, kita dapat membuat sebuah persegipanjang atau jajargenjang dengan cara menggandakan sebuah segitiga.



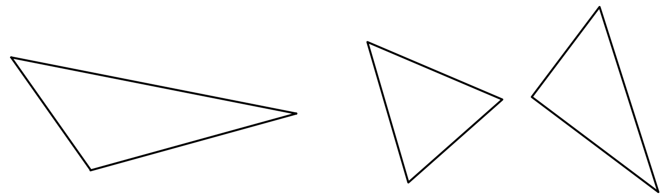
3. Bagaimanakah menurutmu luas dari segitiga-segitiga di atas jika dibandingkan dengan luas persegipanjang atau jajargenjang?

Komentar tentang Soal-soal dan Penyelesaian

2. Beberapa siswa mungkin akan berpendapat bahwa bangun terakhir yang terbentuk berbeda dari bangun semula. Ketika mendiskusikan soal ini, minta pendapat siswa tentang alas, tinggi dan luas bangun setiap kali dilakukan proses menggunting dan menempel (membentuk bangun baru). Contoh jawaban siswa: Jajargenjang berbeda dari persegipanjang semula karena bentuknya berbeda, atau, Sepertinya jika bagian atas persegipanjang miring ke kanan maka terbentuklah jajargenjang, atau, semua gambar adalah sama karena mempunyai alas dan luas yang sama, dan lain-lain.



3. Soal ini bertujuan untuk memberi siswa pengertian bahwa luas suatu segitiga adalah setengah dari luas suatu persegipanjang atau jajargenjang. Sebaliknya, setiap persegipanjang atau jajar genjang dapat dibagi menjadi dua segitiga yang sama. Guru perlu menunjukkan beberapa contoh dari kondisi ini pada papan tulis atau OHP. Sebagai contoh dapat digunakan beberapa segitiga berikut ini.



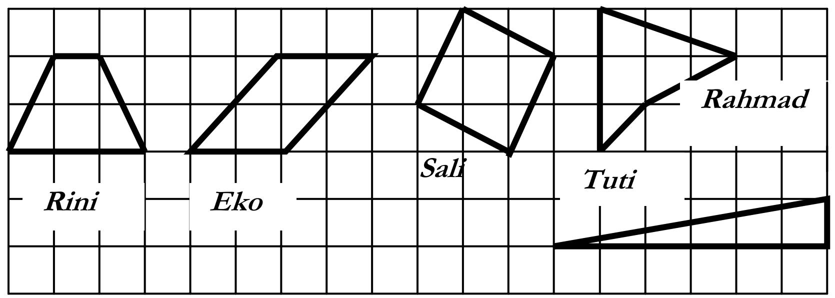
Halaman 19 Buku Siswa

Pekerjaan Rumah

Lima Satuan Persegi

4. Gambarlah lima buah bangun yang berbeda dan masing-masingnya mempunyai luas lima satuan persegi pada buku latihanmu!

5. Rini, Eko, Tuti, Salim dan Rahmad masing-masing menggambar bangun seperti terlihat di bawah ini. Selidiki apakah mereka menggambar bangun yang luasnya lima satuan persegi? Jelaskan caramu dalam memeriksa tiap jawaban mereka.



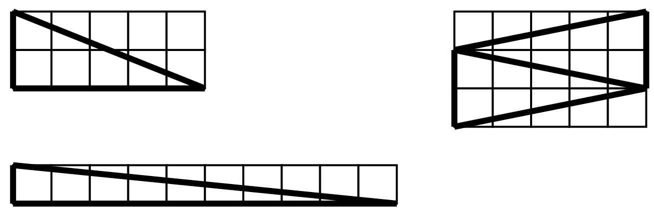
6. Gambarlah sebuah segitiga yang mempunyai luas lima satuan persegi!

Komentar tentang Soal-soal dan Penyelesaian

4. Guru dapat menyuruh siswa untuk menunjukkan jawaban-jawaban mereka di papan tulis, kemudian minta mereka menjelaskan bahwa gambar yang mereka gambar adalah luasnya lima satuan. Contoh jawaban siswa:

5. Hanya Salim dan Rahmad yang menggambar bangun dengan luas lima satuan. Sama halnya dengan soal nomor 6, guru dapat meminta siswa untuk menjelaskan bahwa gambar yang diabuat Salim dan Rahmad luasnya lima satuan, sedang gambar –gambar yang lain luasnya tidak lima satuan.

6. Umumnya siswa mungkin akan menggambar persegipanjang atau jajargenjang dengan luas 10 satuan, kemudian membagi dua bangun-bangun tersebut. Contoh jawaban siswa:



Pertemuan 7 dan 8: Luas 2

Material: lembar kerja siswa, gunting, kertas tipis untuk menjiplak, kertas berpetak, lem, kertas gambar.

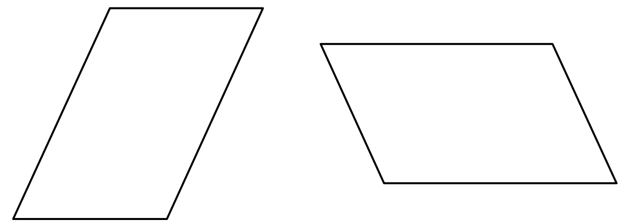
Ringkasan: Siswa diperkenalkan pada konsep-konsep *alas, tinggi, panjang* dan *lebar* .Setelah mengerjakan soal Latihan 3 nomor 3, siswa diharapkan mampu menemukan sendiri rumus-rumus untuk menentukan luas persegipanjang, jajargenjang dan segitiga. Pada soal nomor 10 siswa akan melihat bahwa tidak selalu mudah untuk menentukan alas dan tinggi suatu segitiga, sehingga cara menggunting dan menempel lebih baik untuk digunakan dalam menyelesaikan soal ini. Terakhir, siswa akan mencermati ringkasan pelajaran yang menyarikan beberapa cara untuk menentukan luas bangun-bangun.

Tentang Matematika: Pada pertemuan ini perlu ditekankan kepada siswa bahwa lebih penting bagi mereka untuk memahami konsep luas dari persegipanjang, jajargenjang dan segitiga, daripada penggunaan rumus-rumus untuk menentukan luas bangun-bangun tersebut.

Perencanaan:

- Setelah mempelajari konsep: alas, tinggi, panjang dan lebar, minta beberapa siswa untuk menentukan alas dan tinggi atau panjang dan lebar dari bangun-bangun pada Latihan 3 nomor 3. Kemudian arahkan mereka ke penemuan rumus untuk menentukan luas persegipanjang, jajargenjang dan segitiga.

- Sebelum siswa mengerjakan soal nomor 14 (pekerjaan rumah), tunjukkan kepada siswa suatu model jajargenjang dengan posisi seperti terlihat pada gambar disebelah kiri bawah. Tanyakan kepada siswa cara menetukan luas jajargenjang tersebut. Kemudian jajargenjang diputar sehingga sisi yang lain menjadi alas (seperti terlihat pada gambar disebelah kanan bawah). Tanyakan lagi kepada siswa bagaimana cara menentukan luas jajargenjang ini, dan bagaimana luas kedua jajargenjang?



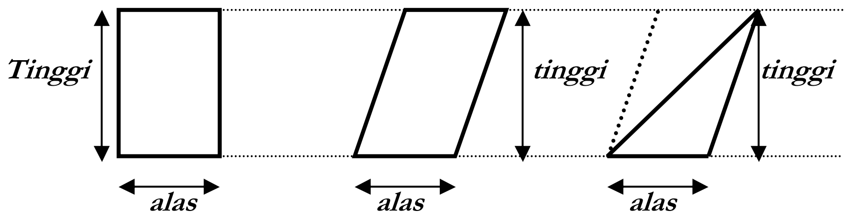
- Diskusikan beberapa konsep penting seperti diungkapkan pada ringkasan pelajaran ini, serta rumus-rumus untuk menghitung luas bangun-bangun yang terdapat pada pelajaran ini.
- Diskusikan secara klasikal cara-cara yang digunakan siswa dalam menyelesaikan soal-soal.
- Siswa dapat bekerja secara individu atau berpasangan untuk seluruh soal dalam pertemuan ini.
- Latihan 3 nomor 3 diberikan sesudah siswa mengerjakan soal nomor 9
- Latihan 3 nomor 4 diberikan sesudah siswa mengerjakan soal nomor 12

Halaman 20 Buku Siswa

Pertemuan 7

Alas dan Tinggi

Gambar di bawah ini menunjukkan bangun-bangun yang sering kamu temukan dalam pelajaran sampai sekarang ini. Jika kamu menggambar sebuah persegi, jajargenjang atau segitiga, kamu dapat menggunakan beberapa istilah; **alas** menunjukkan berapa lebar bangun itu; **tinggi** menunjukkan berapa tinggi bangun tersebut. Untuk persegi panjang, "tinggi" dapat juga disebut sebagai **panjang** dan "alas" sebagai **lebar**.



Halaman 26 Buku Siswa

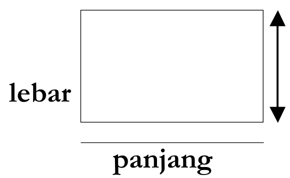
Cara dan Rumus

Luas persegipanjang adalah sama dengan luas jajargenjang jika alas dan tingginya sama. Dengan kata lain, Luas (**L**) persegipanjang/ jajargenjang adalah sama dengan alas (**a**) dikali tinggi (**t**).

L persegipanjang = L jajargenjang = a x t

Untuk persegi panjang dapat juga dikatakan bahwa: Luas (**L**) adalah sama dengan panjang (**p**) dikali lebar (**l**).

L persegipanjang = p x l

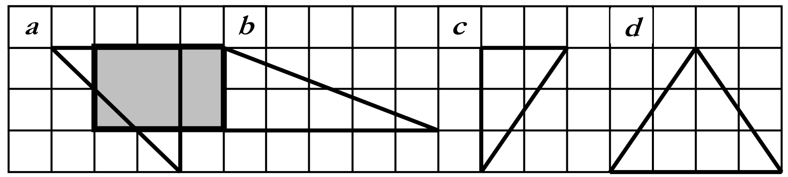


Halaman 21 Buku Siswa

Sebuah segitiga selalu setengah dari sebuah persegipanjang atau jajargenjang, jadi luas sebuah segitiga dapat ditentukan dengan rumus:

L segitiga = ½ a x t

8. Dengan mencermati rumus-rumus di atas, coba kamu temukan rumus untuk menghitung luas persegi.
9. Tentukanlah luas tiap segitiga berikut ini dengan menggunakan rumus di atas.



Komentar tentang Soal-soal dan Penyelesaian

8. Guru dapat menggambar sebuah persegi di papan tulis atau menunjuk-kannya melalui OHP. Kemudian tanyakan kepada siswa mengenai sifat-sifat persegi. Pada awalnya biarkan siswa untuk menggunakan istilah-istilah mereka sendiri dalam menentukan luas sutu persegi. Setelah itu guru beserta siswa secara klasikal membuat kesepakatan tentang penggunaan simbol **s** untuk panjang sisi persegi, sehingga nantinya diperoleh:

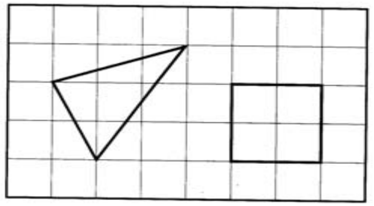
   L persegi = s x s
9. Arahkan siswa untuk menggunakan rumus dalam menyelesaikan soal ini (dalam kondisi jika masih ada siswa yang masih menggunakan cara-cara yang lain). Jika ada siswa yang mengalami kesulitan, diskusikan dengan mereka tentang alas dan tinggi dari tiap segitiga. Di akhir pembahasan, tunjukkan segitiga-segitiga yang sama melalui OHP, lakukan rotasi terhadap tiap segitiga, kemudian minta siswa untuk menentukan alas dan tinggi dari tiap segitiga.

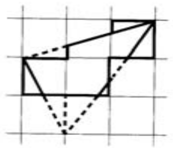
Penyelesaian: Luas segitiga:

a. ½ x 3 x 3 = 4,5 satuan
b. ½ x 5 x 2 = 5 satuan
c. ½ x 2 x 3 = 3 satuan
d. ½ x 4 x 3 = 6 satuan

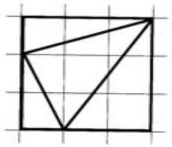
Halaman 22 Buku Siswa

Kadang-kadang tidak mudah untuk menentukan alas dan tinggi dari sebuah segitiga seperti terlihat pada gambar di bawah ini. Tetapi kita masih bisa menentukan luasnya dengan menggunakan cara yang lain. Untuk itu kerjakanlah soal nomor 10!





a

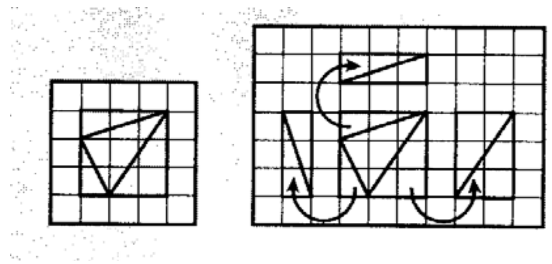


b

10. Misalnya segitiga dan persegi pada gambar di samping terbuat dari triplek dengan ketebalan yang sama.
    a. Jika berat persegi adalah 40 gram, berapakah berat segitiga?
    b. Elis menyelesaikan soal tersebut dengan cara memotong dan menempel empat bagian kecil pada segitiga, seperti terlihat pada gambar **a**. Apakah menurutmu jawaban yang ditemukan Elis?
    c. Yoyok menggambar sebuah persegi, kemudian menghitung luas segitiga dengan cara mengurangkan luas persegi dengan luas tiga buah segitiga seperti terlihat pada gambar **b**. Jelaskanlah cara yang dilakukan Yoyok dan hasil yang diperolehnya.
    d. Apakah mereka memperoleh hasil yang sama?

Komentar tentang Soal-soal dan Penyelesaian

10. Siswa dapat menyelesaiakn soal ini dengan menggunakan berbagai cara. Minta mereka untuk menunjukkan perhitungan-perhitungan yang mereka lakukan. Guru dapat meminta siswa untuk menunjukkan pekerjaan mereka di papan tulis atau menggunankan tranparansi. Untuk soal nomor **c,** siswa dapat memeriksa jawaban Yoyok dengan cara membuat gambar seperti berikut:



Luas tiap segitiga masing-masing adalah setengah dari luas persegipanjang. Luas segitiga yang dicari adalah luas persegi yang digambar Yoyok dikurangi luas ketiga segitiga.

Penyelesaian:

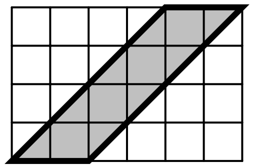
a. 35 gram (Persegi luasnya 4 satuan persegi, jadi berat satu satuan persegi adalah 10 gram. Sedangkan luas segitiga adalah 3 ½ satuan persegi, sehingga beratnya adalah 35 gram)
b. Elis akan menemukan luas segitiga adalah 3 ½ satuan persegi sehingga beratnya adalah 3 ½ x 10 = 35 gram
c. Yoyok akan mendapatkan bahwa luas persegi yang membingkai segitiga adalah 3 x 3 = 9 satuan persegi. Luas tiap segitiga di luar segitiga yang dicari masing-masing ½ x 2 x 1 = 1 satuan persegi, ½ x 2 x 3 = 3 satuan persegi dan ½ x 1 x 3 = 1 ½ satuan persegi. Sehingga luas segitiga yang dicari adalah 9 – 5 ½ = 3 ½ satuan persegi. 5 ½ berasal dari 1 + 3 + 1 ½ .
d. Ya

Halaman 23 Buku Siswa

Pertemuan 8

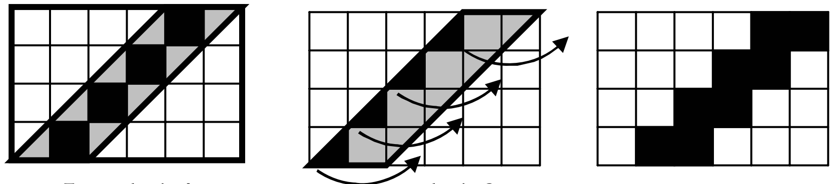
Ringkasan Pelajaran 3

Pada pelajaran ini kamu telah mempelajari berbagai cara untuk menghitung luas bangun-bangun geometri. Misalnya, untuk menghitung luas bangun berikut ini kamu dapat menggunakan cara-cara seperti berikut:



1. Menghitung, memotong dan menempel bagian tertentu.

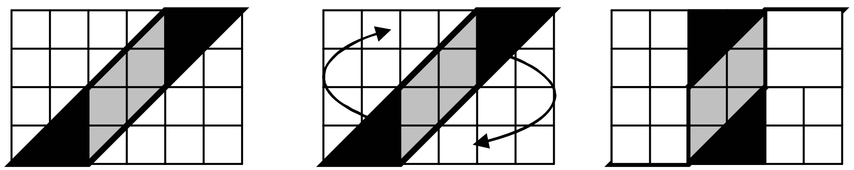
Hitunglah jumlah persegi yang utuh di dalam bangun (langkah 1), kemudian potonglah sisanya dan tempelkan dibagian lain untuk memperoleh persegi baru yang utuh (langkah 2).



Langkah 1 **Langkah 2**

2. Mengubah Bentuk Bangun

Gunting bagian tertentu dari gambar awal (langkah 1), kemudian tempelkan pada bagian lain, seperti terlihat pada gambar berikut (langkah 2).

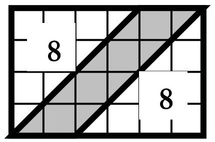


Langkah 1 **Langkah 2**

Halaman 24 Buku Siswa

3. Membingkai bangun dan mengurangi bagian sisa

Gambarlah sebuah persegipanjang sebagai bingkai dari bangun, sedemikian sehingga kamu dapat lebih mudah menghitung luas bangun. Caranya adalah dengan mengurangi luas persegipanjang dengan luas dua segitiga di luar bangun.

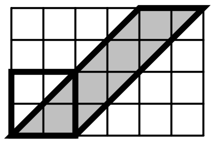


Dalam hal ini, luas jajargenjang adalah sama dengan luas persegi panjang dikurangi luas dua segitiga:

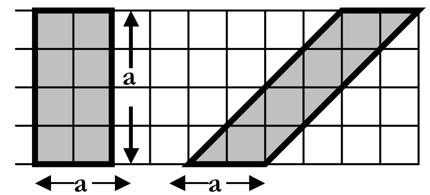
$24 - 8 - 8 = 24 - 16 = 8$ *satuan persegi*

4. Menggandakan Bentuk atau Memotong Sebagian

Luas segitiga yang dihitamkan adalah setengah luas persegi.



Melalui beberapa cara di atas dapat diketahui bahwa luas jajargenjang adalah 8. Jajargenjang tersebut mempunyai alas 2 dan tinggi 4. Kamu juga dapat menggunakan aturan bahwa: luas jajargenjang adalah sama dengan luas persegipanjang jika masing-masing alas dan tingginya sama.



Halaman 25 Buku Siswa

Aturan ini membawa kita ke suatu rumus: Luas jajargenjang/ persegipanjang adalah sama dengan alas dikali tinggi:

L jajargenjang = a x t ***L persegipanjang = a x t***

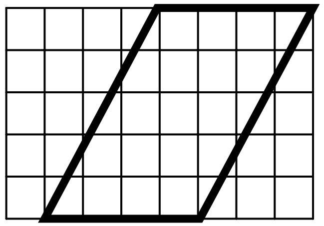
Untuk luas persegipanjang dapat juga digunakan rumus: Luas adalah sama dengan panjang dikali lebar:

L persegipanjang = p x l.

Karena luas suatu segitiga selalu setengah dari luas suatu jajargenjang/persegipanjang, maka luas segitiga dapat ditentukan dengan rumus:

L segitiga = ½ a x t

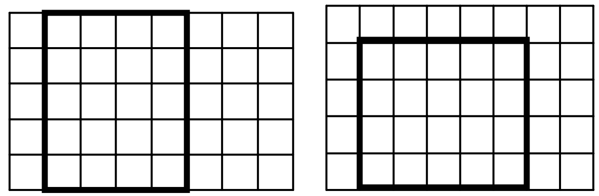
11. Jiplaklah jajargenjang berikut pada pada buku latihanmu, kemudian temukan sebuah persegipanjang yang luasnya sama dengan luas jajargenjang tersebut.



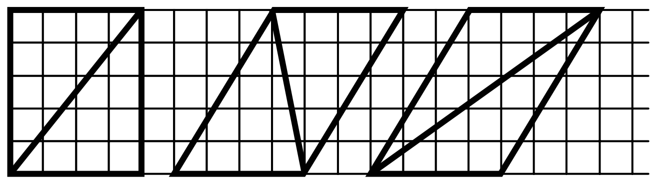
12. Dengan menggunakan jajargenjang yang sama seperti pada soal nomor 11, temukanlah sebuah segitiga yang luasnya setengah dari luas jajargenjang tersebut!

Komentar tentang Soal-soal dan Penyelesaian

11. Guru dapat meminta beberapa siswa untuk menjukkan pekerjaan mereka di papan tulis atau melalui OHP pada pertemuan selanjutnya. Motivasi mereka untuk menjelaskan prinsip umum (berkaitan dengan alas dan tinggi) untuk mendapatkan suatu persegipanjang yang luasnya sama dengan suatu jajargenjang yang diketahui, dan sebaliknya. Jika ada siswa yang mengalami kesulitan, minta mereka untuk melihat kembali ke soal-soal tentang merubah suatu persegipanjang menjadi suatu jajagenjang. Mereka dapat menggunakan kebalikan dari cara tersebut untuk menyelesaiakn soal ini. Beberapa siswa mungkin dapat memahami secara langsung bahwa jajargenjang mempunyai alas 4 satuan dan tinggi 5 satuan. Menggunakan pengertian: persegipanjang dan jajar genjang yang memiliki alas dan tinggi yang sama akan mempunyai luas yang sama, mereka dapat menemukan persegipanjang yang dicari. Contoh jawaban siswa:



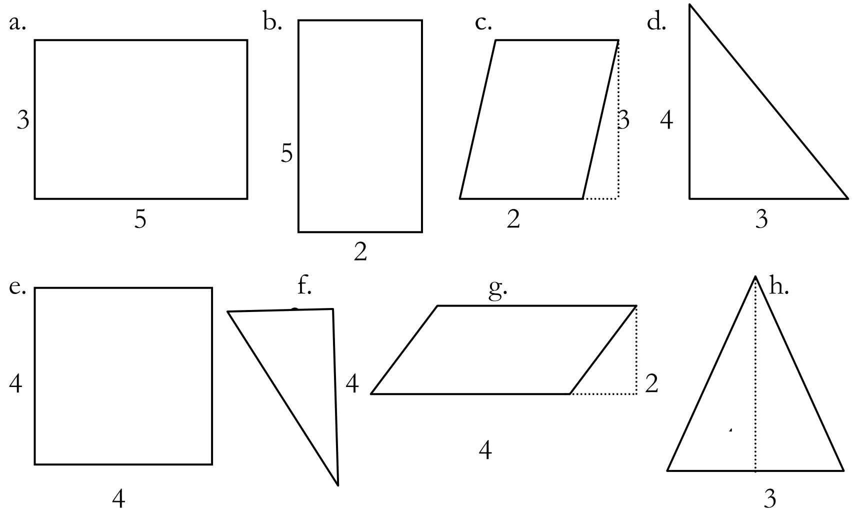
12. Pertama siswa mungkin akan menggambar jajargenjang yang sama atau menggambar persegipanjang yang mereka peroleh pada soal nomor 13, kemudian baru menggambar segitiga yang diminta dengan membagi dua jajargenjang atau persegipanjang. Siswa yang lain mungkin secara langsung dapat menggambar segitiga dengan alas 4 satuan dan tinggi 5 satuan. Contoh jawaban siswa:



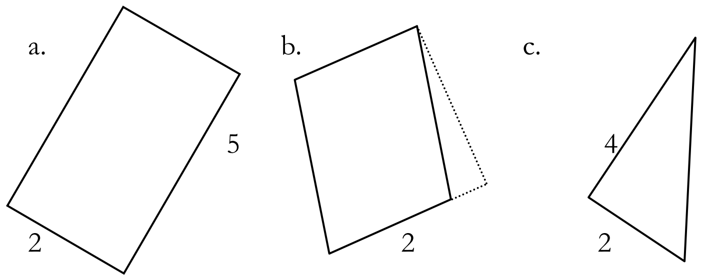
Halaman 26 Buku Siswa

13. Gambarlah pada kertas berpetak tiga buah jajargenjang yang berbeda tetapi masing-masing mempunyai luas yang sama. Bagaimanakah alas dan tinggi tiap jajargenjang?

14. Tentukanlah luas tiap bangun di bawah ini!

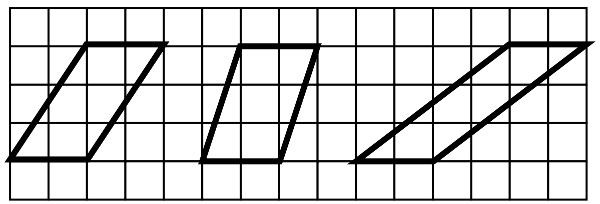


15. Bangun-bangun berikut diperoleh dengan cara memutar beberapa bangun pada soal nomor 14. Tentukanlah luas tiap bangun serta jelaskan alasanmu!



Komentar tentang Soal-soal dan Penyelesaian

13. Minta siswa untuk menjelaskan bagaimana mereka menemukan jawaban untuk soal ini. Sebagian besar siswa mungkin akan menggambar jargenjang-jajargenjang yang masing-masing mempunyai alas dan tinggi yang sama. Guru perlu memberikan perhatian tentang kemampuan keruangan siswa, karena mungkin ada siswa yang hanya menggambar satu jajargenjang, kemudian mendapatkan jajargenjang kedua dan ketiga dengan cara memutar gambar yang pertama. Contoh jawaban siswa:



14. Soal ini memberi kesempatan kepada siswa untuk latihan mengguna-kan rumus-rumus. Diskusikan dengan siswa tentang alas dan tinggi tiap bangun sehingga mereka memahami bahwa alas dan tinggi suatu bangun tidak berubah setelah bangun tersebut dirotasi.

Penyelesaian: a. 15 satuan b. 10 satuan c. 6 satuan d. 6 satuan e. 16 satuan f. 4 satuan g. 8 satuan h. 6 satuan

15. Soal ini memberi pemahaman kepad siswa bahwa pemutaran tidak merubah luas suatu bangun. Minta beberapa siswa untuk memberikan pendapat mereka tentang alas dan tinggi dari tiap bangun jika dibandingkan dengan alas dan tinggi masing-masingnya sebelum pemutaran.

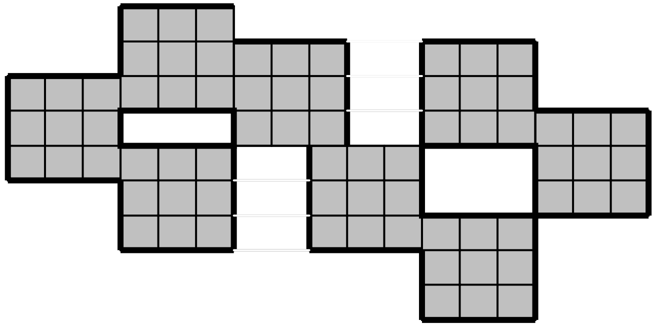
Penyelesaian: a. 10 satuan b. 6 satuan c. 4 satuan

Halaman 27 Buku Siswa

Pengayaan

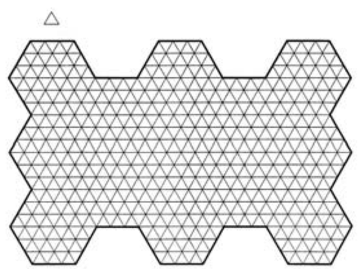
Menghitung dengan Cerdik

1. Gambar di bawah ini menunjukkan pengubinan di sebuah teras. Dapatkah kamu melihat pola pengubinan itu? Pola apakah itu?



2. Temukanlah suatu cara untuk menghitung jumlah ubin yang ada di teras tanpa menghitung satu persatu!

3. Pada jalan di sebuah taman akan dipasang tegel agar tampak seperti gambar berikut ini. Gunakanlah Lembar Kerja 16 untuk menghitung jumlah tegel kecil berbentuk segitiga yang dibutuhkan dalam pekerjaan itu (pikirkanlah cara yang paling cepat dalam melakukan penghitungan).



Komentar tentang Soal-soal dan Penyelesaian

Soal-soal pengayaan nomor 1 – 3 hanya diberikan kepada siswa yang telah selesai mengerjakan soal wajib di kelas.

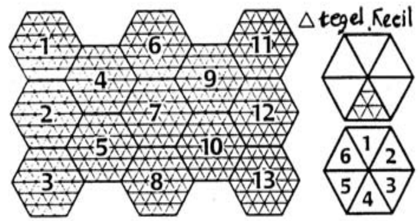
1. Jawaban siswa akan bervariasi. Misalnya, teras terbuat dari beberapa kelompok ubin. Jumlah ubin pada tiap kelompok adalah sama. Ada 8 persegi besar dan pada tiap persegi besar terdapat 9 persegi kecil.

2. Jawaban siswa juga akan bervariasi. Misalnya, siswa melihat 8 persegi besar dan 9 persegi kecil di dalamnya, sehingga jumlah ubin adalah 8 x 9 = 72 ubin

3. Soal tentang pengubinan menuntut pemahaman siswa tentang luas dan juga keterampilan dalam aritmatika. Di sini siswa juga akan melihat bahwa tidak hanya bangun berbentuk persegi yang dapat dijadikan satuan pengukuran. Motivasi siswa untuk tidak menghitung tegel satu persatu. Beberapa siswa mungkin akan kesulitan untuk melihat pola segienam, dan akan menggunakan cara yang lain.

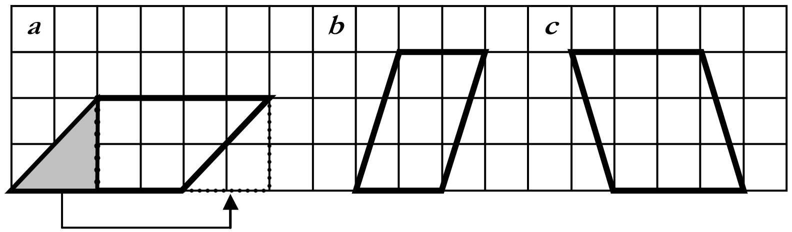
Penyelesaian:

Tegel yang diperlukan berjumlah 702 buah. Cara yang digunakan siswa akan bervariasi, misalnya: ada 13 segienam besar. Tiap segienam terdiri daei enam segitiga besar, dan tiap segitiga besar terdiri dari 9 segitiga kecil. Sehingga jumlah tegel adalah 13 x 6 x 9 = 702 tegel.



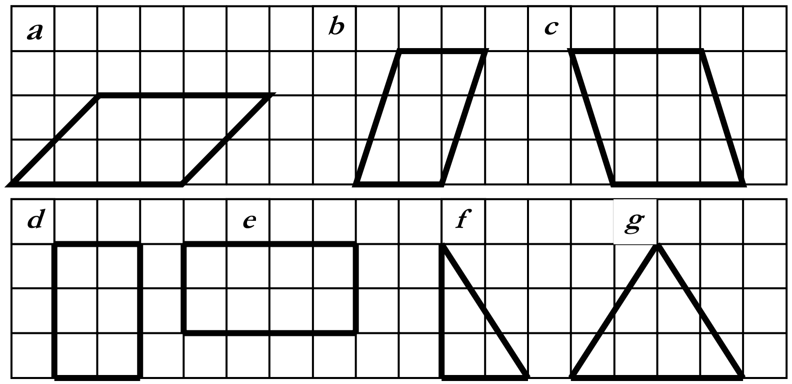
Latihan 3

1. Di bawah ini terdapat tiga buah jajargenjang. Pada gambar **a** diperlihatkan cara membentuk persegipanjang dari jajargenjang. Gunakanlah Lembar Kerja 14, kemudian tunjukkanlah cara merubah dua jajargenjang yang lain agar menjadi persegi atau persegipanjang.



2. Tentukanlah luas tiap-tiap jajargenjang di atas!

3. Tentukanlah "alas" dan "tinggi" tiap bangun berikut, kemudian hitunglah luasnya.



4. Sebuah lantai kamar mandi akan dipasangi 600 buah ubin kecil seperti terlihat pada gambar di bawah ini. Berapakah banyaknya ubin yang dibutuhkan seandainya yang dipasang adalah ubin yang besar?

Komentar tentang Soal-soal dan Penyelesaian

1-2. Soal ini bertujuan untuk memberi siswa pengertian bahwa tiap jajargenjang dapat ditransformasi menjadi persegipanjang yang luasnya sama. Beberapa

Penyelesaian soal no 2:

a. 8 satuan persegi (4 x 2 = 8 satuan persegi)
b. 6 satuan persegi (2 x 3 = 6 satuan persegi)
c. 9 satuan persegi (3 x 3 = 8 satuan persegi)

3. Soal ini memberi siswa arah ke penemuan rumus untuk mementukan luas persegipanjang, jajargenjang dan segitiga. Jika siswa masih menggunakan cara menggunting dan menempel dalam menyelesaikan soal ini, motivasi mereka untuk menggunakan istilah alas dan tinggi, atau panjang dan lebar. Tunjukkan juga melalui OHP bahwa luas tiap bangun tetap sama meski bangun-bangun itu diputar (dirotasi). Hal ini membawa ke satu kesimpulan bahwa luas tiap bangun tetap sama (tidak berubah) meski bangun itu disajikan dalam berbagai posisi.

Penyelesaian: Luas bangun:

a. 8 satuan	b. 6 satuan	c. 9 satuan	d. 6 satuan
e. 8 satuan	f. 3 satuan	g. 6 satuan	

4. Pada soal ini siswa akan melihat hubungan antara perbesaran sisi dengan pertambahan luas (lebih detail tentang hal ini akan ditemui pada Pelajaran 5). Motivasi siswa untuk menemukan bahwa panjang sisi ubin besar berbentuk persegi adalah dua kali panjang sisi ubin kecil yang juga berbentuk persegi, sedangkan luas ubin besar adalah empat kali luas ubin kecil. Jika siswa memahami soal ini dengan baik maka dia akan dengan mudah memahami pergantian satuan pengukuran yang akan dipelajari pada pertemuan berikutnya.

Penyelesaian:

Karena luas ubin besar adalah empat kali luas ubin kecil, maka banyaknya ubin besar yang dibutuhkan adalah 600 : 4 = 150 ubin besar

Pelajaran 4: Mengukur Luas

1. Tujuan:

Siswa akan:

- Memahami satuan-satuan dan alat-alat yang cocok untuk menaksir dan mengukur luas dan keliling.
- Memahami struktur dan penggunaan satuan-satuan pengukuran.

2. Aktivitas Siswa:

- Siswa menemukan benda-benda di sekitar mereka yang mempunyai ukuran panjang 1 cm, 1 m, atau 1 km.
- Siswa menentukan luas dari berbagai daerah (permukaan) menggunakan satuan pengukuran mm^2, cm^2, m^2 atau km^2, dan melihat hubungan antara satuan pengukuran yang satu dengan yang lain.
- Siswa menyelesaikan masalah-masalah realistik seperti pemasangan karpet/keramik di lantai dan juga menentukan jumlah orang yang dapat tertampung pada daerah tertentu.

3. Waktu: lebih kurang satu kali 80 menit (1 kali pertemuan)

4. Tentang Matematika:

Dalam pelajaran ini akan dibahas perbedaan satuan pengukuran yang linier (misalnya: cm, m dan km) dengan satuan persegi (misalnya: cm^2, m^2 dan km^2). Hubungan antara suatu satuan persegi dengan yang lain dapat ditemukan dengan menghitung berapa banyak satuan-satuan yang lebih kecil dibutuhkan untuk menjadi satu satuan yang lebih besar. Misalnya, $1cm^2$ terdiri dari 10 baris yang memuat 10 milimeter persegi, sehingga totalnya terdapat 100 mm^2 persegi di dalam 1 cm^2.

Pengetahuan tentang satuan-satuan pengukuran serta perubahannya sangat penting bagi siswa. Mereka harus memahami ukuran relatif dari suatu objek yang berukuran satu sentimeter, satu meter, dan lain-lain. Misalnya, jika siswa memahami ukuran relatif dari objek-objek yang berukuran satu sentimeter dan satu meter, maka dia akan dapat memperkirakan bahwa satu meter sama dengan 100 sentimeter.

5. Material: Kertas milimeter, kertas berpetak, mistar (30 cm dan 1 m), kertas karton berukuran 1m x 1m, kertas untuk menggambar

6. Pekerjaan Rumah: soal nomor 6-8

7. Rencana Penilaian Kemampuan Siswa:

- Memahami satuan-satuan dan alat-alat yang cocok untuk menaksir dan mengukur luas dan keliling, melalui soal nomor 2, 3 dan 6.
- Memahami struktur dan penggunaan satuan-satuan pengukuran, melalui Latihan 4 nomor 1 dan 2.

8. Rencana Pengajaran:

- Pelajaran ini dapat dimulai dengan mendiskusikan sesuatu yang berukuran panjang 1 cm, 1 m atau 1 km. Dilanjutkan dengan sesuatu yang berukuran 1 cm^2, 1 m^2 atau 1 km^2. Untuk menunjukkan panjang 1 meter minta siswa untuk merentangkan kedua tangan mereka, atau dengan cara mebuat jarak dari lantai ke tangan mereka. Untuk menunjukkan panajang 1 sentimeter, minta siswa untuk mencermati lebar salah satu jari tangan mereka.
- Jika perlu demonstrasikan bagaimana cara mengukur panjang sesuatu menggunakan mistar 30 cm dan mistar 1 m.
- Selanjutnya guru dapat meminta siswa untuk menaksir ukuran benda-benda di dalam kelas. Misalnya: tinggi pintu, panjang dan lebar meja siswa, dll.
- Guru dapat juga menunjukkan kepada siswa selembar kertas/karton yang luasnya 1 cm^2 dan 1 m^2.
- Jika waktu tersedia, diskusikan jawaban siswa untuk setiap soal.
- Siswa dapat bekerja secara berpasangan atau berkelompok untuk semua soal.
- Sebagai tambahan pekerjaan rumah, minta siswa untuk mengukur beberapa benda-benda yang terdapat di rumah mereka.

Halaman 28 Buku Siswa

Pertemuan 9

Satuan Pengukuran

Apakah kamu masih ingat pelajaran pengukuran di Catur Wulan I? Waktu itu kamu telah mempelajari beberapa satuan pengukuran untuk mengukur panjang seperti sentimeter (cm), meter (m) dan kilometer (km). Untuk mengingatkanmu perhatikan beberapa contoh di bawah ini.

- *lebar jari tanganmu kira-kira 1 sentimeter*
- *tinggi pintu rumah kita kira-kira 2 meter*
- *jarak dari sekolah in ke Rumah Sakit Islam (RSI) Surabaya kira-kira 2 kilometer*

Untuk lebih mengetahui tentang satuan-satuan ini, selesaikanlah soal-soal berikut!

1. Tuliskanlah benda apa saja yang ukurannya kira-kira:
   a. satu sentimeter b. satu meter c. satu kilometer

2. Tuliskanlah benda apa saja yang ukuranya bisa kamu nyatakan dalam satuan:
   a. sentimeter b. meter c. kilometer

3. Berilah contoh benda yang ukurannya kira kira:
   a. satu sentimeter persegi
   b. satu meter persegi
   c. satu kilometer persegi

Komentar tentang Soal-soal dan Penyelesaian

Jawaban siswa pada soal nomor 1 – 3 menunjukkan pemahaman mereka tentang berbagai satuan pengukuran. Mungkin mereka akan mengalami kesulitan untuk menjawab pertanyaan yang berkaitan dengan kilometer, karena kekurangan pengalaman tentang hal-hal tersebut. Untuk itu guru dapat mendiskusikan lebih jauh tentang objek-objek yang ukurannya dinyatakan dalam kilometer atau kilometer persegi.

Penyelesaian:

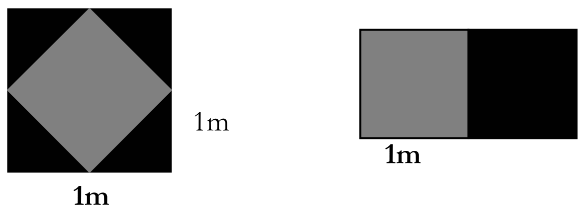
1. Jawaban siswa akan bervariasi. Contoh jawaban siswa:
   a. lebar dari pensil/pena
   b. lebar pintu atau jendela
   c. jarak antara sekolah dengan rumah saya

2. Jawaban siswa akan bervariasi dan mungkin sama dengan nomor 1

3. Jawaban siswa akan bervariasi. Contoh jawaban siswa:
   a. kuku jari jempol,
   b. permukaan meja
   c. kebun jati/karet

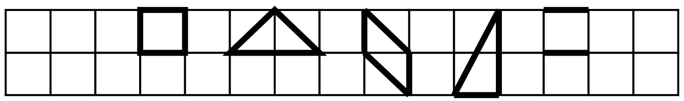
Halaman 29 Buku Siswa

Suatu benda yang luasnya satu meter persegi tidak mesti berbentuk persegi. Pada gambar di sebelah kiri bawah terlihat sebuah keramik berbentuk persegi dengan luas satu meter persegi (*Ingat, gambar tidak dibuat dengan ukuran sebenarnya).* Jika keramik itu dipotong-potong, kemudian disusun menjadi bentuk lain (lihat gambar sebelah kanan bawah) maka luasnya akan tetap satu meter persegi, meski bentuknya bukan persegi.



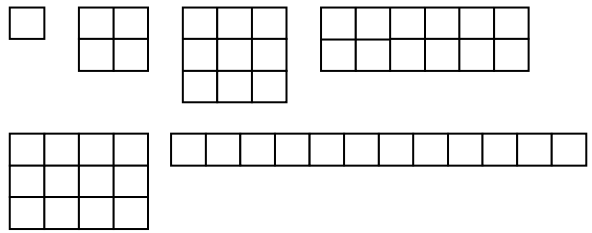
Luas masing-masing gambar di atas adalah 1 meter persegi (ditulis: 1m²)

Tiap gambar di bawah ini mempunyai luas satu sentimeter persegi (*ditulis: 1cm²*).



Satuan-satuan persegi seperti milimeter persegi (mm^2) sentimeter persegi (cm^2), meter persegi (m^2) atau kilometer persegi (km^2) adalah satuan-satuan yang umumnya sering digunakan untuk mengukur luas. Untuk itu kita perlu mengetahui hubungan antara satuan pengukuran yang satu dengan satuan-satuan pengukuran yang lain.

Apakah kamu masih ingat beberapa persegipanjang dan persegi yang dibuat menggunakan 12 buah persegi kecil pada pelajaran yang lalu? Pada waktu itu kita menemukan beberapa persegi dan persegipanjang sebagai berikut.



Halaman 30 Buku Siswa

4. Jika ukuran sebuah persegi kecil yang digunakan adalah 1 sentimeter persegi, tentukanlah luas masing-masing bangun di atas dalam satuan sentimeter persegi (cm^2)!

5. Di bawah ini terlihat sebuah gambar persegi panjang dengan ukuran panjang (alas) 4 cm dan lebar (tinggi) 3 cm.

1 cm = 10 mm

a. Berapakah luas gambar dalam satuan sentimeter persegi?
b. Berapakah luas gambar dalam satuan milimeter persegi?

Komentar tentang Soal-soal dan Penyelesaian

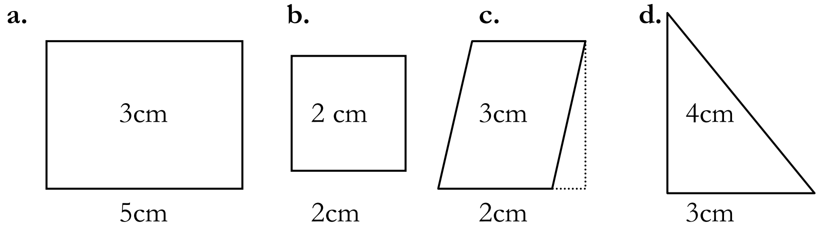
4. Beri siswa motivasi untuk menemukan cara yang lebih cepat dalam menghitung jumlah persegi kecil dalam setiap bangun. Perlu diingatkan kepada siswa bahwa satuan cm^2 diperoleh bukan dari cm dikali cm, melainkan karena satuan yang digunakan sebagai satuan pengukuran adalah persegi kecil yang luasnya $1cm^2$.
   Penyelesaian: Luas persegi masing-masing $1cm^2$, 4 cm^2 dan 9 cm^2. Luas persegipanjang masing-masing: 12 cm^2

5. Jika siswa mengalami kesulitan untuk melakukan perkalian langsung, arahkan mereka untuk membagi persegipanjang menjadi 12 buah persegi kecil, seperti terlihat pada soal nomor 4. Diskusikan juga dengan siswa cara mendapatkan luas bangun dalam satuan milimeter persegi.
   Penyelesaian: a. 12 cm^2 b. 1200 mm^2

Halaman 31 Buku Siswa

Pekerjaan Rumah

6. Tentukanlah luas bangun-bangun berikut dalam satuan mm²!



7. Berdasarkan soal-soal di atas, lengkapilah pernyataan berikut!
   a. 1 m^2 = ……….. cm^2 = ….………… mm^2
   b. 1 km^2 = ………….. m^2 = …………………… cm^2

8. Gambarlah suatu persegi dengan luas 16 cm^2.
   a. Berapakah panjang sisinya?
   b. Tentukanlah luas dan panjang sisi persegi menggunakan satuan milimeter!

Ringkasan Pelajaran 4

Dalam pelajaran ini kamu telah mempelajari beberapa satuan pengukuran untuk luas, misalnya ***milimeter persegi (mm^2), sentimeter persegi (cm^2), meter persegi (m^2),*** *dan* ***kilometer persegi (km^2)***. *Kamu juga telah melihat hubungan antara satuan pengukuran yang satu dengan yang lain.*

Kamu harus ingat, suatu kebun dengan luas 1 kilometer persegi (km^2) tidak harus berbentuk persegi dengan ukuran 1 km × 1 km. Kebun itu bisa berbentuk apa saja, tetapi luasnya sama dengan daerah yang berukuran 1 km × 1 km.

Komentar tentang Soal-soal dan Penyelesaian

6. Ingatkan siswa untuk menggambar tiap bangun dengan ukuran sebenarnya pada buku latihan mereka. Pada soal ini guru dapat meminta beberapa siswa untuk menjelaskan jawaban mereka dalam diskusi kelas pada pertemuan selanjutnya.

   Penyelesaian: a. 15 cm^2 b. 4 cm^2 c. 6 cm^2 b. 6 cm^2

7. ***Penyelesaian:***

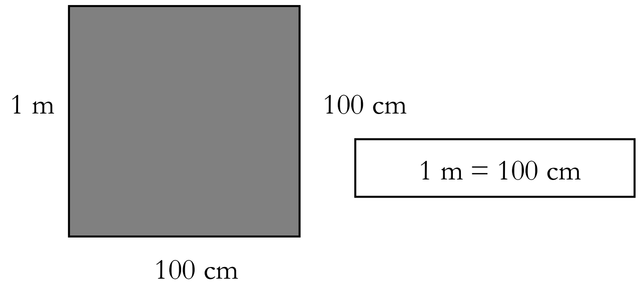
   a. 1 m^2 = 10. 000 cm^2 = 1. 000. 000 mm^2
   b. 1 km^2 = 1. 000. 000 m^2 = 10. 000. 000. 000 cm^2

8. Jika masih ada siswa yang membuat kesalahan dalam menjawab soal ini, diskusikan kembali dengan mereka pengertian persegi serta kaitannya dengan luas persegi.
Penyelesaian:

   a. Panjang sisi persegi adalah 4 cm
   b. Luas persegi dalam satuan milimeter persegi adalah 1. 600 mm^2, dan panjang sisi persegi dalam satuan milimeter adalah 40 mm.

Latihan 4

1. Gambar berikut menunjukkan sebuah persegi dengan panjang sisi 1 meter (*Ingat, gambar tidak dibuat dengan ukuran sebenarnya*).



a. Berapakah luas gambar dalam satuan meter persegi?
b. Berapakah luas gambar dalam satuan sentimeter persegi?

2. Lengkapilah pernyataan berikut! (kamu dapat menggunakan bantuan gambar persegipanjang jika diperlukan).
   a. 3 kilometer persegi = …………………….. meter persegi
   b. 5 meter persegi = …………………… sentimeter persegi
   c. 50 sentimeter persegi = ………………… milimeter persegi

Komentar tentang Soal-soal dan Penyelesaian

1. Gambar yang disajikan pada soal ini tidak sesuai dengan skala sebenarnya. Untuk memberikan gambaran kepada siswa tentang ukuran 1 m^2 dan 1 cm^2, guru dapat membuat gambar di papan tulis atau menunjukkan karton yang masing-masing berukuran 1 m^2 dan 1 cm^2 . Tanyakan kepada siswa berapa banyaknya kertas dengan ukuran 1 cm^2 yang diperlukan untuk menutupi gambar/karton berukuran 1 m^2 ?

   Penyelesaian: a. 1 m^2 b. 10. 000 m^2

2. Minta beberapa siswa untuk menunjukkan hasil perhitungan mereka dalam menjawab soal ini.

   Penyelesaian:
   a. 3 kilometer persegi = 3. 000. 000 meter persegi
   b. 5 meter persegi = 50. 000 sentimeter persegi
   c. 50 sentimeter persegi = 5. 000 milimeter persegi

Pelajaran 5: Keliling dan Luas

1. Tujuan:

Siswa akan:

- Menggunakan konsep luas dan keliling untuk menyelesaikan masalah-masalah realistik.
- Menganalisa hubungan antara perubahan keliling dengan perubahan luas suatu bangun
- Menemukan rumus untuk menentukan keliling persegi dan persegipanjang.

2. Aktivitas Siswa:

- Siswa menentukan keliling sawah, taman dan beberapa objek di dalam kelas.
- Siswa menemukan rumus untuk menentukan keliling persegi dan persegipanjang.
- Siswa mengamati perbesaran suatu bangun dan pengaruhnya terhadap perubahan keliling dan luas dari bangun tersebut.

3. Waktu: lebih kurang satu kali 80 menit (1 kali pertemuan)

4. Tentang Matematika:

Konteks seperti sawah dan pagar yang digunakan dalam soal-soal pada pertemuan ini akan membantu siswa memahami konsep keliling. Selanjutnya, pembicaraan tentang keliling dari beberapa bangun akan membawa siswa ke penemuan rumus keliling persegi (**4s**) jika panjang sisinya **s**, dan rumus keliling persegipanjang **2p + 2l**, jika panjangnya **p** dan lebarnya **l**.

Siswa juga akan menemui bahwa bangun-bangun yang memiliki keliling yang sama tidak mesti mempunyai luas yang sama. Begitu juga halnya, bangun-bangun yang memiliki luas yang sama tidak mesti memiliki keliling yang sama. Juga dibahas hubungan antara keliling dan luas suatu bangun. Jika keliling suatu persegipanjang digandakan secara sistematis, maka luasnya akan menjadi empat kali luas semula.

5. Material: Kertas milimeter, kertas berpetak, mistar (30 cm, 1 m), kertas untuk menggambar, benang/tali rafia.

6. Pekerjaan Rumah: soal nomor 4 – 6.

7. Rencana Penilaian Kemampuan Siswa:

- Menggunakan konsep luas dan keliling untuk menyelesaikan masalah-masalah realistik, melalui Latihan 5 nomor 1 – 3.
- Menganalisa hubungan antara perubahan keliling dengan perubahan luas suatu bangun, melalui Latihan 5 nomor 3
- Menemukan rumus untuk menentukan keliling persegi dan persegipanjang, melalui soal nomor 3.

8. Rencana Pengajaran:

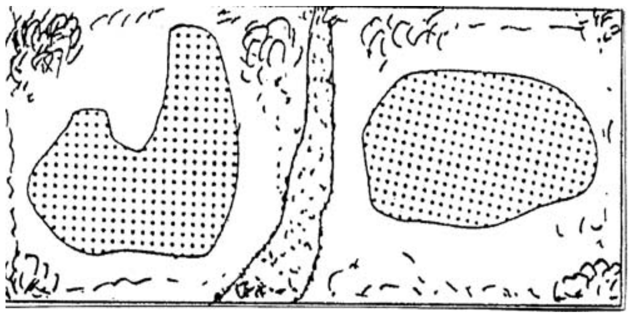
- Di awal pelajaran minta siswa untuk mengemukakan pengertian mereka tentang "keliling"
- Diskusikan secara klasikal tentang:
  - hubungan antara keliling dan luas suatu bangun
  - apa yang terjadi terhadap luas suatu bangun jika kelilingnya diubah dan sebaliknya.
- Siswa dapat bekerja secara berpasangan atau berkelompok dalam pertemuan ini.

Halaman 32 Buku Siswa

Pertemuan 10

Pelajaran 5: Keliling dan Luas

1. Jika kamu berjalan mengelilingi kedua sawah yang terlihat pada gambar berikut, di sawah manakah perjalananmu yang lebih jauh?



Panjang jalan disekeliling pulau atau jarak yang kamu tempuh waktu mengelilingi tiap sawah di atas disebut keliling dari pulau/sawah

2. Tentukanlah keliling dari benda-benda berikut, kemudian jelaskan bagaimana caramu memperoleh tiap jawaban!
   a. buku latihan matematika
   b. 1 kotak persegi dalam buku latihan matematika
   c. permukaan meja murid
   d. papan tulis

3. Berdasarkan pengalamanmu mengukur keliling benda-benda di atas, coba kamu sebutkan cara yang lebih mudah untuk menentukan keliling dari suatu:
   a. persegi
   b. persegipanjang

KOMENTAR TENTANG SOAL-SOAL DAN PENYELESAIAN

1. Siswa dapat menggunakan benang atau tali rafia untuk menentukan keliling sawah. Diskusikan jawaban-jawaban siswa secara klasikal, kemudian beri perhatian ke jawaban siswa yang ganjil. Setelah siswa mengerjakan dua buah soal ini, minta mereka mengemukakan pendapat sendiri tentang pengertian "keliling"

   Penyelesaian:

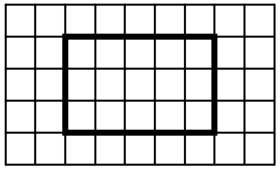
   Perjalanan yang lebih jauh adalah perjalanan mengelilingi sawah A.

2. Soal ini memberi arah kepada siswa untuk menemukan rumus keliling persegi dan persegipanjang. Beri siswa motivasi untuk melakukan pengukuran dan perhitungan se efisien mungkin. Jawaban siswa untuk soal ini akan bervariasi. Sekali lagi, diskusikan jawaban-jawaban siswa yang ganjil.
3. Diskusikan kembali cara-cara yang ditempuh siswa dalam menjawab soal nomor 3. Kemudian minta siswa untuk menyebutkan bentuk geometris dari objek-objek yang mereka ukur pada soal nomor 3. Terima semua istilah yang digunakan siswa untuk menentukan keliling persegi dan persegipanjang. Akan tetapi mungkin ada siswa yang secara langsung dapat menggunakan istilah panjang (p) dan lebar (l) untuk persegipanjang, dan sisi (s) untuk persegi, sehingga mereka memperoleh rumus: keliling persegi = **4s** dan keliling persegipanjang = **2p + 2l**

Halaman 33 Buku Siswa

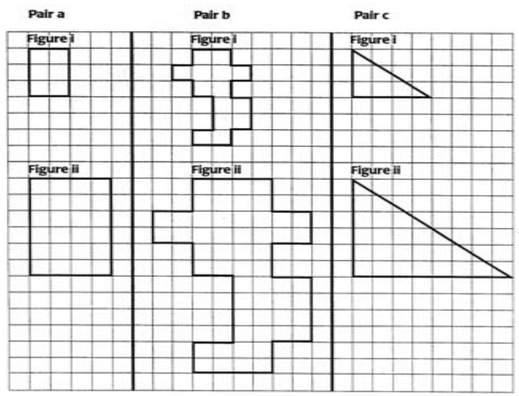
<u>Pekerjaan Rumah</u>

4. Gambar berikut ini menunjukkan suatu taman yang luasnya 15 satuan persegi. Gambarlah pada buku latihanmu sebuah taman lain yang luasnya juga 15 satuan persegi, tetapi kelilingnya berbeda.



5. Gambarlah paling sedikit tiga buah persegipanjang yang berbeda tetapi masing-masingnya mempunyai luas 16 sentimeter persegi. Berapakah keliling dari tiap persegipanjang tersebut?

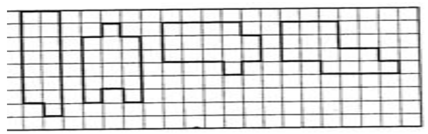
6. Di bawah ini terdapat empat pasang gambar. Tiap pasang gambar bentuknya sama, tetapi ukurannya berbeda. Untuk tiap pasang, gambar (ii) diperoleh dengan cara memperbesar gambar (i). Periksalah apa yang terjadi dengan keliling dan luas tiap pasang gambar setelah diperbesar.



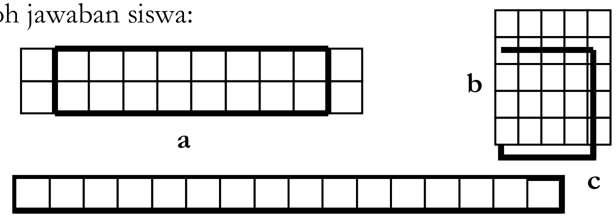
Komentar tentang Soal-soal dan Penyelesaian

4. Soal ini bertujuan untuk melihat kemampuan siswa dalam memahamii hubungan antara keliling dan luas suatu bangun.

<u>Penyelesaian:</u> Jawaban siswa akan bervariasi. Contoh jawaban siswa:



5. Contoh jawaban siswa:



Keliling masing-masing bangun:
a. 20 b. 16 c. 34

6. Soal ini dapat digunakan untuk melihat kemampuan siswa dalam menganalisa akibat perbesaran suatu bangun terhadap keliling dan luas dari bangun tersebut.

<u>Penyelesaian:</u>
Keliling bangun A: 8 satuan, luasnya 3 satuan persegi
Keliling bangun A*: 16 satuan, luasnya 12 satuan persegi
Keliling bangun B: 24 satuan, luasnya 14 satuan persegi
Keliling bangun B*: 48 satuan, luasnya 56 satuan persegi
Keliling bangun C: kira-kira 10 satuan, luasnya 4 satuan persegi
Keliling bangun C*:kira-kira 20 satuan, luasnya 16 satuan persegi

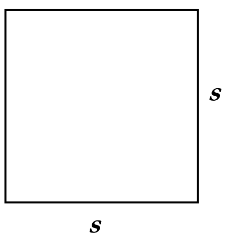
Jadi pada tiap pasang bangun, setelah perbesaran kelilingnya menjadi dua kali keliling semula, sedangkan luasnya menjadi empat kali luas semula.

Halaman 34 Buku Siswa

Ringkasan Pelajaran 5

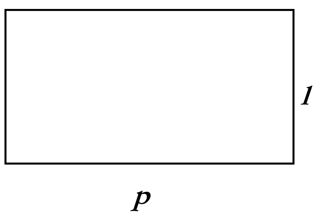
Pada pelajaran ini kamu mempelajari keliling suatu bangun dan kaitan antara keliling dan luas. Kamu harus ingat bahwa:

- *Dua buah bangun yang kelilingnya sama mungkin saja luasnya tidak sama, dan*
- *Dua buah bangun yang luasnya sama mungkin saja kelilingnya tidak sama.*
- *Perbesaran suatu bangun sehingga luasnya menjadi dua kali luas semula mengakibatkan keliling bangun tersebut menjadi empat kali keliling semula.*
- *Kamu juga telah menemukan bahwa:*
- *Jika panjang sisi suatu persegi adalah s maka keliling persegi tersebut adalah 4s*



Keliling Persegi = 4s

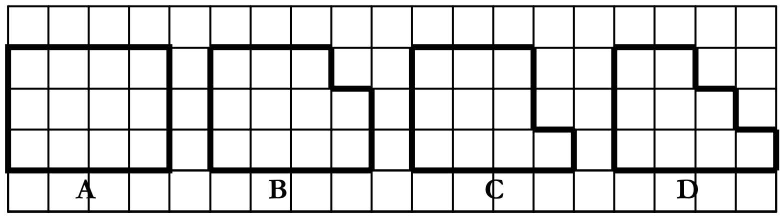
- *Jika panjang sisi suatu persegipanjang adalah* ***p*** *dan lebarnya* ***1*** *maka keliling persegipanjang tersebut adalah:* ***2p + 2l***



Keliling Persegipanjang = 2p + 2l

Latihan 5

1. Gambar berikut menunjukkan empat buah taman di pusat kota. Di tiap taman akan dipasang pagar (bentuk dan bahannya sama). Menurutmu pemasangan pagar di taman manakah yang biayanya paling murah? Jelaskan alasanmu!



2. Tentukanlah luas tiap taman!
3. Coba perhatikan dengan teliti keliling dan luas dari tiap taman di atas, apakah yang dapat kamu simpulkan?

Komentar tentang Soal-soal dan Penyelesaian

1. Beberapa siswa mungkin akan menemui kesulitan dalam membedakan antara satuan pengukuran keliling dengan satuan pengukuran luas. Untuk itu arahkan siswa untuk menggunakan sisi persegi sebagai satuan pengukuran keliling dan sebuah persegi sebagai satuan pengukuran luas.
   Penyelesaian: Biaya pemasangan pagar di tiap taman adalah sama karena kelilingnya sama.

2. Luas taman masing-masing:
   a. 12 satuan persegi b. 11 satuan persegi
   c. 10 satuan persegi d. 9 satuan persegi

3. Jawaban siswa akan bervariasi. Contoh jawaban siswa:
   Keliling tiap taman adalah 14 satuan tetapi luas taman dari A sampai D berkurang satu satuan persegi.

APPENDIX B

AN EXAMPLE OF STUDENTS' WORKSHEET

(for contextual problems 10 – 15 in lesson 4)

Nama: ……………………………….

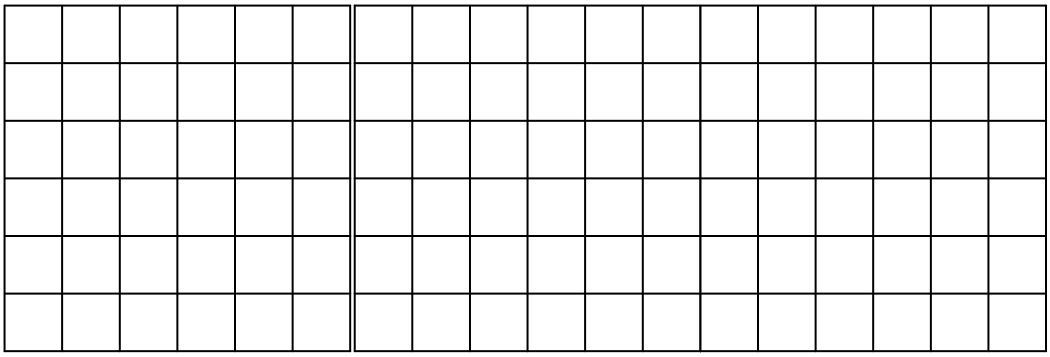
Menemukan Luas Persegipanjang dan Persegi

10. Guru akan memberimu dua belas buah persegi kecil yang sama bentuknya. Buatlah sebanyak mungkin persegipanjang dengan menggunakan ke-dua belas persegi kecil tersebut, kemudian gambarkan hasil-hasilmu!

11. Apakah pendapatmu tentang luas tiap persegipanjang yang kamu gambar?
    Jawab:
    …………………………………………………………………..………
    …………………………………………………………………………….
    …………………………………………………………………………….

12. Menurutmu bagaimanakah cara termudah untuk menentukan luas persegipanjang-persegipanjang tersebut?
    Jawab:
    …………………………………………………………………………….
    …………………………………………………………………………….
    …………………………………………………………………………….

13. Lakukan kegiatan yang sama untuk membuat sebanyak mungkin persegi tanpa harus menggunakan ke-dua belas persegi kecil.



14. Dapatkah kamu membuat persegi menggunakan kedua belas persegi kecil? Mengapa?

    <u>Jawab:</u>

    ………………………………………………………………………………….
    ………………………………………………………………………………….
    ………………………………………………………………………………….

15. Bagaimanakah cara termudah untuk menentukan luas sebuah persegi?

    <u>Jawab:</u>

    ………………………………………………………………………………….
    ………………………………………………………………………………….
    ………………………………………………………………………………….

APPENDIX C
THE TESTS

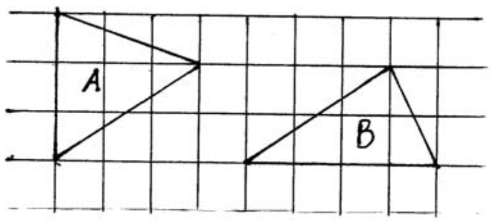
This appendix contains test materials used for:

- Post-test for Fieldwork I
- Pre-test and post-test for Fieldwork II
- Pre-test for Fieldwork III
- Post-test for Fieldwork III

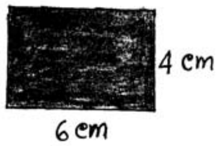
POST-TEST FOR FIELDWORK I

Ulangan Geometri

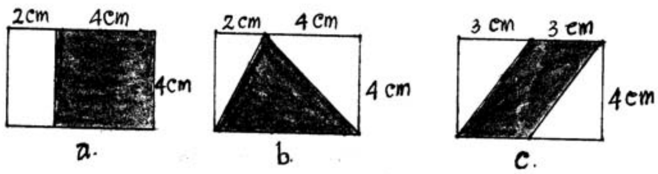
1. Ayah ingin membeli salah satu kapling tanah di bawah ini untuk membangun rumah. Jika harga kedua tanah adalah sama, tanah mana yang sebaiknya dibeli Ayah? Jelaskan alasanmu!



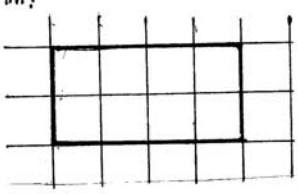
2. Harga sepotong coklat berbentuk persegi panjang seperti terlihat pada gambar berikut adalah Rp. 9.000,-



Tentukanlah harga tiap potong coklat yang besarnya terlihat seperti pada bagian yang dihitamkan berikut. Jelaskan caramu dalam menjawab.

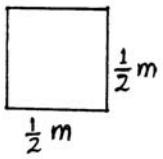


3 a. Gambarlah dua buah jajargenjang yang luasnya sama dengan persegi-panjang di bawah ini!



b. Gambarlah dua buah segitiga yang luasnya setengah luas jajargenjang!

4. Di ruang Kepala Sekolah terpasang 200 buah keramik berukuran $\frac{1}{2}$ m x $\frac{1}{2}$ m.



a. Berapakah kira-kira luas ruangan Kepala Sekolah?

b. Jika Kepala Sekolah ingin mengganti keramik lama dengan keramik baru yang ukurannya 25 cm x 25 cm (Ingat 1 m = 100 cm), berapakah jumlah keramik baru yang dibutuhkan?

5. a) Gambarlah sebuah bangun yang kelilingnya 12 satuan

b) Berapa satuan persegi luas bangun itu?

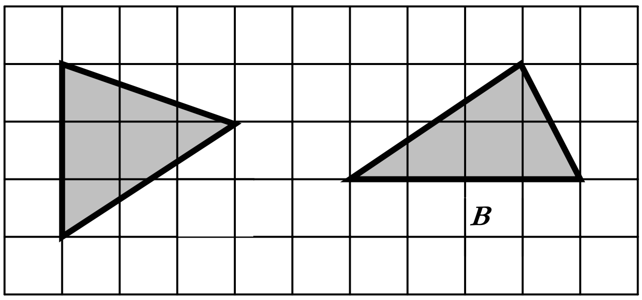
c) Perbesarlah bangun itu sehingga kelilingnya menjadi dua kali semula.

d) Apa yang terjadi dengan luasnya? Jelaskan jawabanmu

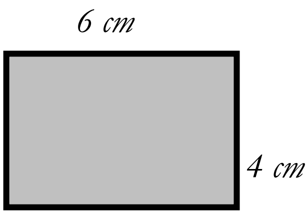
PRE-TEST AND POST-TEST FOR FIELDWORK II

Tes Geometri

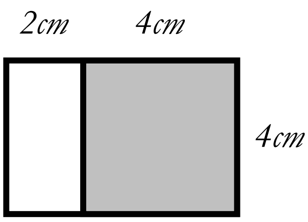
1. *Ayah ingin membeli salah satu dari tanah yang tampak pada gambar di bawah ini untuk membangun sebuah rumah. Jika harga kedua tanah adalah sama, tanah manakah yang sebaiknya dibeli Ayah? Jelaskan jawabanmu!*



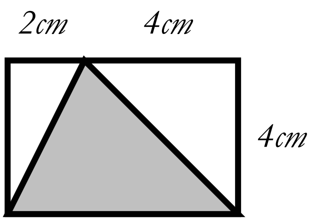
2. *Harga dari sepotong coklat dengan ukuran seperti yang tampak pada gambar di bawah ini adalah Rp. 12,000.*



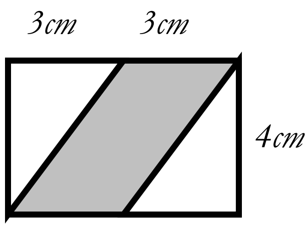
Tentukanlah harga tiap potong coklat yang besarnya seperti ditunjukkan pada bagian yang dihitamkan pada tiap gambar di bawah ini!



a.

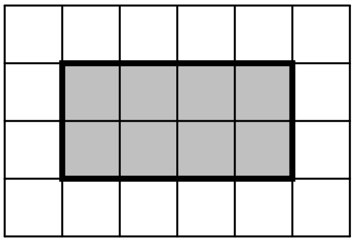


b.



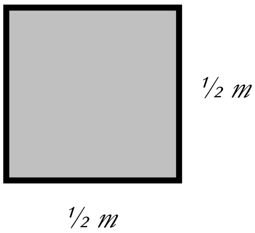
c.

3. a. *Gambarlah dua jajargenjang yang masing-masing luasnya sama dengan luas persegipanjang di bawah ini!*



   b. *Gambarlah dua segitiga yang masing-masing luasnya setengah luas jajargenjang!*

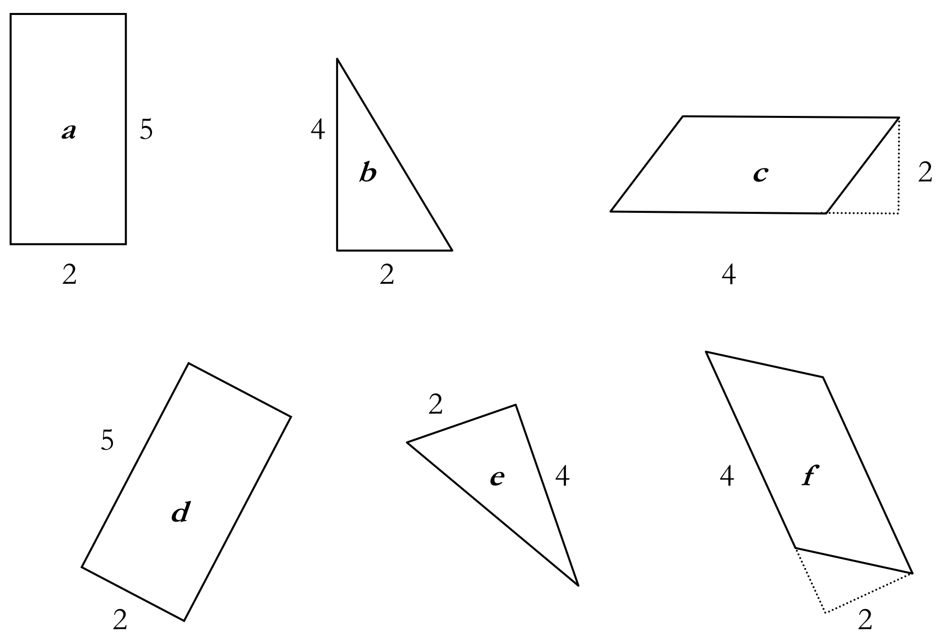
4. *Pada lantai di kantor Kepala Sekolah terpasang 200 buah keramik Ukuran dari tiap keramik adalah ½ m x ½ m.*



   a. *Berapakah luas lantai di kantor kepala sekolah?*
   b. *Jika keramik yang terpasang diganti dengan keramik baru berukuran 25cm x 25cm (ingat 1m = 100cm), berapakah banyaknya keramik baru yang diperlukan?*

5. *Kerjakanlah soal-soal berikut ini!*
   a. *Gambarlah sebuah bangun yang kelilingnya 12cm*
   b. *Berapakah luas dari bangun tersebut?*
   c. *Perbesarlah bangun tersebut sehingga panjang kelilingnya menjadi dua kali panjang keliling bangun semula!*
   d. *Apakah yang terjadi dengan luas setelah bangun diperbesar? Jelaskan jawabanmu!*

6. *Tentukanlah luas tiap bangun di bawah ini!*

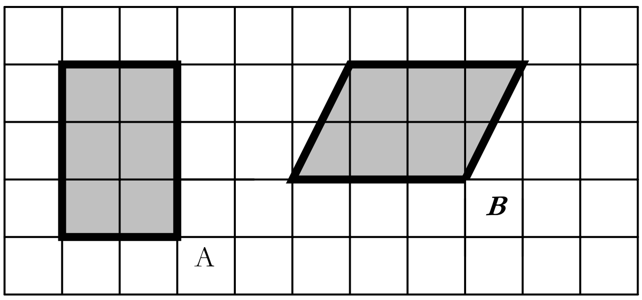


7. *Jika ukuran bangun pada gambar* ***a*** soal nomor ***6*** *adalah dalam satuan sentimeter berapa milimeter persegikah luas bangun tersebut? Jelaskan jawabanmu!*

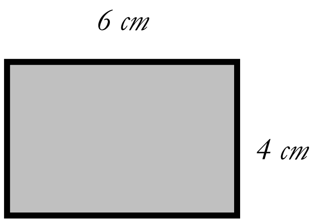
PRE-TEST FOR FIELDWORK III

Pretes Geometri

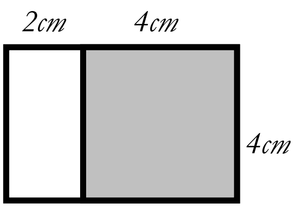
1. *Ayah ingin membeli salah satu dari tanah yang tampak pada gambar di bawah ini untuk membangun sebuah rumah. Jika harga kedua tanah adalah sama, tanah manakah yang sebaiknya dibeli Ayah? Jelaskan jawabanmu!*



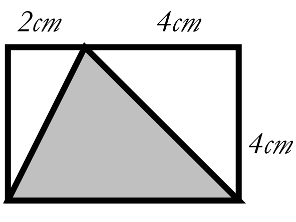
2. *Harga dari sepotong coklat dengan ukuran seperti yang tampak pada gambar di bawah ini adalah Rp. 12,000.*



Tentukanlah harga tiap potong coklat yang besarnya seperti ditunjukkan pada bagian yang dihitamkan pada tiap gambar di bawah ini!

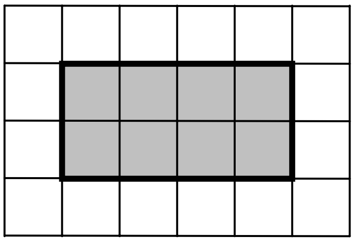


a.



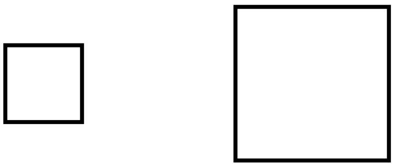
b.

3. *Gambarlah dua jajargenjang yang masing-masing luasnya sama dengan luas persegipanjang di bawah ini!*



4. *Gambarlah dua segitiga yang masing-masing luasnya setengah luas jajargenjang di atas!*

5. *Sebuah lantai kamar mandi akan dipasangi 600 buah ubin kecil seperti terlihat pada gambar di bawah ini. Berapakah banyaknya ubin yang dibutuhkan seandainya yang dipasang adalah ubin yang besar?*

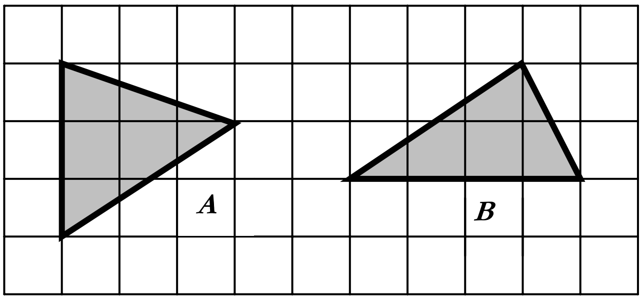


6. *Kerjakanlah soal-soal berikut ini!*
   e. *Gambarlah sebuah bangun yang kelilingnya 12cm*
   f. *Berapakah luas dari bangun tersebut?*
   g. *Perbesarlah bangun tersebut sehingga panjang kelilingnya menjadi dua kali panjang keliling bangun semula!*
   h. *Apakah yang terjadi dengan luas setelah bangun diperbesar? Jelaskan jawabanmu!*

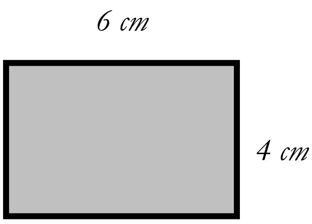
POST-TEST FOR FIELDWORK III

Postes Geometri

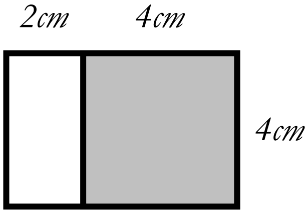
1. *Ayah ingin membeli salah satu dari tanah yang tampak pada gambar di bawah ini untuk membangun sebuah rumah. Jika harga kedua tanah adalah sama, tanah manakah yang sebaiknya dibeli Ayah? Jelaskan jawabanmu!*



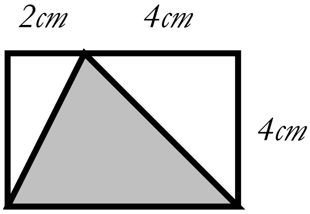
2. *Harga dari sepotong coklat dengan ukuran seperti yang tampak pada gambar di bawah ini adalah Rp. 12,000.*



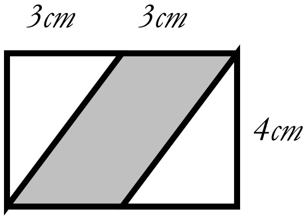
Tentukanlah harga tiap potong coklat yang besarnya seperti ditunjukkan pada bagian yang dihitamkan pada tiap gambar di bawah ini!



a.

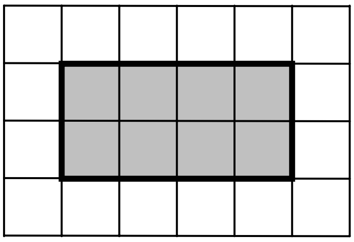


b.



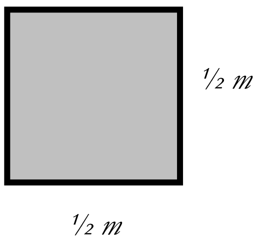
c.

3. *Gambarlah dua jajargenjang yang masing-masing luasnya sama dengan luas persegipanjang di bawah ini!*



4. *Gambarlah dua segitiga yang masing-masing luasnya setengah luas jajargenjang di atas!*

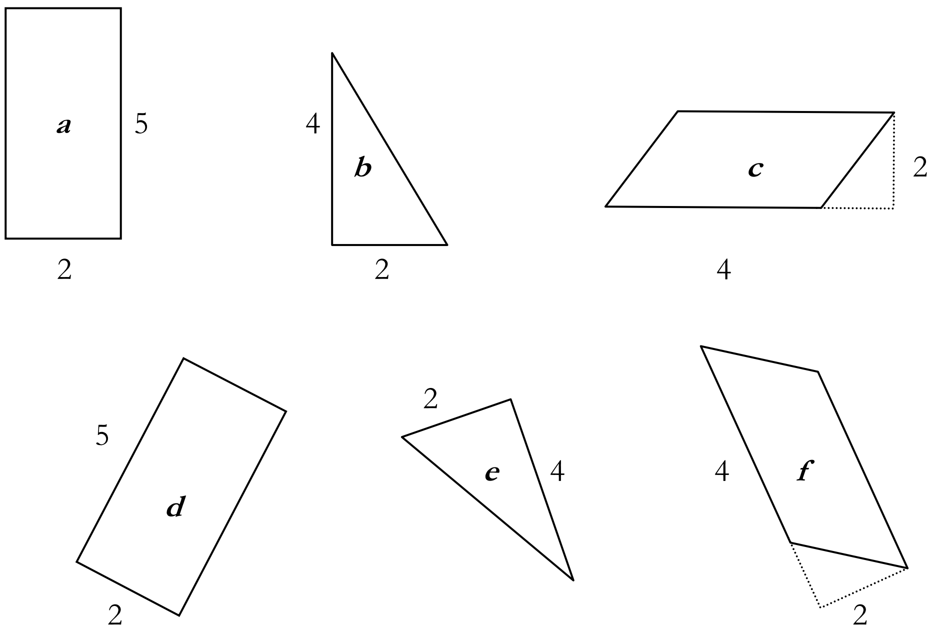
5. *Pada lantai di kantor Kepala Sekolah terpasang 200 buah keramik Ukuran dari tiap keramik adalah ½ m × ½ m.*



   c. *Berapakah luas lantai di kantor kepala sekolah?*
   d. *Jika keramik yang terpasang diganti dengan keramik baru berukuran 25cm × 25cm (ingat 1m = 100cm), berapakah banyaknya keramik baru yang diperlukan?*

6. *Kerjakanlah soal-soal berikut ini!*
   i. *Gambarlah sebuah bangun yang kelilingnya 12cm*
   j. *Berapakah luas dari bangun tersebut?*
   k. *Perbesarlah bangun tersebut sehingga panjang kelilingnya menjadi dua kali panjang keliling bangun semula!*
   l. *Apakah yang terjadi dengan luas setelah bangun diperbesar? Jelaskan jawabanmu!*

7. *Tentukanlah luas tiap bangun di bawah ini!*



8. *Jika ukuran bangun pada gambar* ***a*** soal nomor ***6*** *adalah dalam satuan sentimeter berapa milimeter persegikah luas bangun tersebut? Jelaskan jawabanmu!*

APPENDIX D

THE OBSERVATION SCHEME

This appendix contains:

- Observation Scheme used in Fieldwork I
- Observation Scheme used in Fieldwork II
- The examples of the specific aspects in observation scheme used in Fieldwork II
- Observation Scheme type 1 used in Fieldwork III
- Observation Scheme type 2 used in Fieldwork III
- The examples of the specific aspects in observation scheme type 1 and 2 used in Fieldwork III

OBSERVATION SCHEME USED IN FIELDWORK I

CATATAN OBSERVASI KELAS III..

Ibu/Bapak yth,

Mohon di isi catatan observasi kelas berikut berdasarkan keadaan sebenarnya.

1. Bagaimana pendapat Ibu/Bapak tentang **Aktivitas Siswa** dalam beberapa hal berikut:
   a. Memperhatikan/mendengarkan/menanggapi penjelasan guru
   ....Cukup baik..........
   b. Memperhatikan/mendengarkan/ menanggapi penjelasan teman
   ....Cukup baik..........
   c. Menyatakan ide
   ....cukup baik..........
   d. Mengajukan pertanyaan
   ....cukup baik..........
   e. Berperilaku yang tidak relevan dengan KBM
   ....cukup baik..........
   f. Kerja sama siswa dalam kelompok
   ....cukup baik..........
   g. Keantusiasan siswa belajar dengan menggunakan Modul Geometri
   ....cukup baik..........

2. Bagaimana pendapat Ibu/Bapak tentang **Aktivitas Guru** dalam beberapa hal berikut.
   a. Menyampaikan pendahuluan
   ....baik..........
   b. Mengajukan pertanyaan
   ....baik..........
   c. Mendengarkan dan menanggapi gagasan siswa
   ....baik..........
   d. Mengamati kegiatan siswa
   ....baik..........

e. Mendorong keterlibatan dan keikutsertaan siswa (memotivasi siswa)

baik

f. Membimbing kegiatan siswa (secara individu/kelompok)

baik

g. Membimbing diskusi kelas

baik

3. Berilah tanggapan/komentar Ibu/Bapak tentang beberapa hal berikut ini.

a. Bagaimana kesan umum Ibu/Bapak tentang pelajaran ini

Apakah: 1. berguna atau tidak .... berguna.

2. berjalan lancar atau tidak, ... lancar.

3. terjadi interaksi yang baik antara guru dengan siswa, atau siswa dengan siswa,........ berjalan lancar.

b. Masalah yang terjadi selama PMB

lancar.

c. Apa hal-hal yang mungkin akan meningkatkan partisipasi. Motivasi dan hasil belajar siswa?

Memberi nilai pada hasil kerja siswa

d. Menurut Ibu/Bapak bagaimana peranan pelajaran ini dalam mendorong siswa untuk berpikir kritis dan kreatif.

Mendukung.

e. Komentar dan saran-saran lain:

1. Tingkatkan cara belajar mengajar yang masih baik.

2. Materi jangan terlalu padat disesuaikan kemampuan siswa

Terima Kasih

OBSERVATION SCHEME USED IN FIELDWORK II

Lembaran Observasi

A. Aspek-aspek Umum

- Apakah siswa memahami "contextual problems" yang dikemukakan dalam soal-soal. Jika mereka tidak mengerti, apa masalah yang mereka hadapi?
  Apa yang dilakukan guru untuk mengatasi masalah ini?
- Apakah siswa menggunakan ide mereka sendiri dalam memecahkan suatu soal? Jika tidak, sejauh mana dan apa yang dilakukan guru untuk membantu mereka?
  Jika iya, jelaskan ide yang digunakan siswa dalam memecahkan suatu soal!
- Apakah siswa menggunakan cara/metode mereka sendiri dalam memecahkan soal-soal? Jika mereka menemukan satu cara, apakah mereka hanya terpaku pada cara tersebut? Jelaskan bagaimana siswa pindah dari satu cara ke cara yang lain!
- Dalam kerja kelompok/berpasangan, jelaskan apakah siswa berinteraksi satu sama lain atau hanya menunggu jawaban dari teman! Jelaskan juga cara mereka berinteraksi!
- Apakah konteks dalam soal cukup membantu siswa dalam menyelesaikan soal? Jika iya, bagaimanakan siswa dalam menggunakan konteks tersebut? Jika tidak, apa yang dilakukan siswa dalam menyelesaikan soal?
- Jelaskan bagaimana aktivitas dan kreativitas siswa dalam diskusi kelas!
- Gambarkan motivasi siswa dalam mengikuti proses belajar mengajar!
- Bagaimanakah kemampuan siswa dalam mengajukan alasan (reasoning) baik secara lisan maupun tulisan? Jelaskan argumen-argumen yang dikemukakan siswa.
- Bagaimanakah perhatian siswa terhadap proses mendapatkan hasil dalam memecahkan suatu soal? Apakah mereka hanya tertarik pada hasil akhir?

THE EXAMPLES OF THE SPECIFIC ASPECTS IN OBSERVATION SCHEME TYPE USED IN FIELDWORK II

B. Aspek-aspek khusus (for lesson 1)

- Bagaimanakah siswa menemukan cara/metoda dalam membandingan dan mengurutkan luas bangun-bangun?
- Bagaimanakah siswa menggunakan satuan-satuan pengukuran yang tidak baku (seperti titik-titik atau pohon) pada soal nomor 3 dan 4?
- Apakah ada siswa yang menemukan cara/metoda yang mengacu kepada rumus luas: ***Luas = panjang x lebar*** ketika mereka memecahkan soal nomor 4? Jelasakan temuan siswa!
- Jelaskan apakah siswa mengalami masalah berkaitan dengan kemampuan keruangan, terutama ketika mereka memecahkan soal nomor 2!
- Gambarkan pemahaman siswa tentang bangun-bangun tidak beraturan pada soal nomor 1 dan 3?

OBSERVATION SCHEME TYPE 1 USED IN FIELDWORK III

Lembar Observasi Kegiatan Siswa

Pertemuan: ....../Tempat: ..../Tanggal: ....
Observer: ....

A. Deskripsikanlah hal-hal berikut berdasarkan pengamatan *Observer* di kelas!

1. Pemahaman siswa tentang "konteks" yang dikemukakan dalam soal-soal.
2. Kemampuan siswa dalam menggunakan ide, cara/metode mereka sendiri dalam memecahkan soal-soal.
3. Kemampuan siswa dalam menemukan atau menggunakan strategi yang berbeda dalam memecahkan soal-soal.
4. Peranan konteks pada soal-soal dalam membantu siswa memilih strategi pemecahan.
5. Interaksi antar siswa ketika mereka bekerja secara berkelompok atau berpasangan.
6. Keaktifan siswa dalam bertanya, mengemukakan ide, atau memberikan pendapat.
7. Dampak diskusi kelas terhadap pemahaman siswa (misalnya dalam hal memahami berbagai cara pemecahan soal, atau dalam hal memahami suatu konsep)
8. Motivasi siswa selama proses pembelajaran.
9. Kemampuan siswa dalam mengemukakan alasan (lisan maupun tulisan).
10. Perhatian siswa terhadap proses mendapatkan hasil dalam memecahkan soal-soal.

B. Berikanlah kesan umum *Observer* tentang beberapa hal berikut, dengan cara menyilangi salah satu alternatif pilihan.

	Sangat tidak baik			**Sangat baik**
1. Pemahaman siswa terhadap soal-soal yang diberikan	O	O	O	O
2. Keaktifan siswa dalam proses pembelajaran	O	O	O	O
3. Motivasi siswa selama proses pembelajaran	O	O	O	O
4. Interaksi antar sesama siswa dalam kelompok	O	O	O	O
5. Kemampuan siswa dalam mengajukan alasan	O	O	O	O
6. Kreatifitas siswa dalam menemukan berbagai trategi dalam memecahkan soal-soal	O	O	O	O

OBSERVATION SCHEME TYPE 2 USED IN FIELDWORK III

Lembar Observasi Kegiatan Guru

Pertemuan: ……/Tempat: …………………………/Tanggal: …………………

Observer: ………………………………

A. Deskripsikanlah upaya/tindakan guru berkaitan dengan hal-hal berikut, berdasarkan pengamatan *Observer* di kelas!

1. Membantu siswa memahami "konteks" dalam soal-soal.
2. Mengarahkan siswa untuk menggunakan ide, cara/metode mereka sendiri dalam memecahkan soal-soal.
3. Mengarahkan siswa untuk menemukan atau menggunakan strategi yang berbeda dalam memecahkan soal-soal.
4. Mengarahkan siswa untuk menggunakan konteks dalam soal sedemikian sehingga siswa terbantu dalam memilih strategi dalam memecahkan soal-soal.
5. Memaksimalkan interaksi antar siswa ketika mereka bekerja secara berkelompok atau berpasangan.
6. Minciptakan situasi kelas yang mendorong siswa untuk saling bertanya, menjawab dan mengeluarkan pendapatnya.
7. Membantu siswa/kelompok yang menemukan masalah sewaktu memecahkan soal-soal.
8. Memimpin diskusi kelas (terutama dalam hal menindak lanjuti solusi-solusi yang berbeda yang dikemukakan siswa).
9. Memotivasi siswa selama proses pembelajaran.
10. Menstimulasi siswa untuk mengemukakan alasan (lisan maupun tulisan) dalam memecahkan soal-soal.
11. Menstimulasi siswa untuk menuliskan proses yang mereka lakukan dalam dalam memecahkan soal-soal.

B. Berikanlah kesan umum *Observer* tentang kualitas tindakan/kemampuan guru tentang hal-hal berikut, dengan cara menyilangi salah satu pilihan.

	Sangat tidak baik			**Sangat baik**
1. Memperkenalkan soal-soal	O	O	O	O
2. Mengarahkan siswa/kelompok dalam memecahkan soal	O	O	O	O
3. Menstimulasi siswa untuk:				
a. menggunakan ide mereka sendiri	O	O	O	O
b. menemukan strategi yang berbeda	O	O	O	O
c. bertanya atau menjawab pertanyaan	O	O	O	O
d. memberikan pendapat atau alasan	O	O	O	O
e. menuliskan proses dalam memecahkan soal	O	O	O	O
f. menjelaskan jawabannya	O	O	O	O
4. Memimpin diskusi kelas, terutama dalam hal mengarahkan perhatian siswa pada aspek yang penting	O	O	O	O
5. Memotivasi siswa selama proses pembelajaran	O	O	O	O
6. Memaksimalkan interaksi antar siswa dalam kelompok	O	O	O	O
7. Berinteraksi dengan siswa selama proses pembelajaran	O	O	O	O

THE EXAMPLES OF THE SPECIFIC ASPECTS IN OBSERVATION SCHEME TYPE 1 AND 2 USED IN FIELDWORK III

Deskripsikanlah hal-hal berikut berdasarkan pengamatan *Observer* di kelas! (for lesson 1)

1. *(Soal no. 1-3, hal. 3-4 buku guru)*. Bagaimana siswa menemukan cara/metoda dalam membandingan dan mengurutkan luas bangun-bangun.
2. *(Soal no. 1 dan 2, hal. 3 buku guru)* Pemahaman siswa tentang bangun-bangun tidak beraturan!
3. *(Soal no. 1 dan 2, hal. 3 buku guru, dan Latihan 1 no. 1, hal. 10 buku guru)* Pemahaman siswa tentang sifat: jika suatu bangun di bagi, digunting dan disusun kembali, maka luas bangun semula adalah tetap.
4. *(Soal no. 2, hal. 3 buku guru, dan Latihan 1 no. 1, hal. 10 buku guru)* Bagaimana siswa menggunakan satuan-satuan pengukuran yang tidak baku (seperti titik-titik atau pohon)
5. *(Soal no. 3, hal. 4 buku guru)* Kemampuan siswa dalam mengenali bentuk goemetris dari daerah di mana tiap kambing dapat memakan rumput.
6. *(Latihan 1 no. 1, hal. 10 buku guru)* Cara-cara yang digunakan siswa dalam memecahkan soal ini (apakah ada siswa yang menemukan cara/metoda yang mengacu kepada rumus luas: ***Luas = panjang x lebar***?)

Deskripsikanlah hal-hal berikut berdasarkan pengamatan *Observer* di kelas! (for lesson 2)

1. *(Soal no. 6, hal. 6 buku guru, dan Latihan 1 no. 2 and 4, hal. 11-13, buku guru)* Pemahaman siswa tentang konsep reallotment?
2. *(Latihan 1 no. 2, hal. 11 buku guru)* Pemahaman siswa tentang ide membentuk suatu bangun baru dari sebuah bangun lama, membagi suatu bangun menjadi bangun-bangun yang lain, menjumlah dan mencari selisih bangun-bangun, dan lain-lain.
3. *(Latihan 1 no.3, hal. 12 buku guru)* Cara yang digunakan siswa dalam menentukan harga masing-masing potongan kue.
4. *(Latihan 1 no.4, hal. 13 buku guru)* Cara yang digunakan siswa dalam menjawab setiap item (misalnya, apakah ada siswa yang menggunakan konsep proporsi, atau melihat hubungan antara gambar yang satu dengan gambar yang lain?).

APPENDIX E

THE INTERVIEW GUIDELINES

This appendix contains:

- The questions that were used as guidelines in conducting the interviews and discussions with the Dutch RME experts, Indonesian subject matter experts, inspector, principals and teachers.
- The questions that were used as guidelines to interview the pupils

EXPERT REVIEW

This instrument contains questions to evaluate validity and practicality of the IRME curriculum (student book and teacher guide) developed for the geometry instruction at Grade 4 in Indonesian elementary school. Please give your comments/answer on each item.

1. Does the content of the IRME curriculum include the subjects/topics that are supposed to be taught for the topic Area and Perimeter?
2. Does the content of the IRME curriculum reflect the RME's key principles?
3. Does the IRME curriculum reflect the RME's teaching and learning principle
4. Does the IRME curriculum reflect the important aspects of realistic geometry?
5. Is the content of the IRME curriculum sequenced properly?
6. Are the goals/objectives in each lesson clearly stated?
7. Are the relevance and importance of the topic explicit?
8. Is the content well chosen to meet the objectives/goals described in the beginning of each lesson?

Please give your comments and prediction about the statements below.

1. Has IRME curriculum potential for developing student's understanding?
2. Has IRME curriculum potential for developing student's activity and creativity?
3. Has IRME curriculum potential for developing student's motivation?
4. Has IRME curriculum potential for creating student-centered learning?
5. Is the student book easy to use?
6. Is the teacher guide useful for teachers?
7. Is the teacher guide easy to use?
8. Is the time mentioned in each lesson enough?
9. Do pupils learn as intended?
10. Do teachers use the teacher guide as intended?

Any other comments:

Thank you very much for giving your time to fill this instrument

THE GUIDELINE FOR THE INTERVIEWS WITH THE PUPILS:

1. Apakah kamu suka belajar dengan metode RME? Coba jelaskan pendapatmu!
2. Apakah kamu mengalami kesulitan dalam menggunakan buku siswa selama belajar?
3. Menurut pendapatmu bagaimana metode RME jika dibandingkan dengan metode yang biasanya digunakan oleh gurumu dalam mengajar matematika?
4. Menurutmu pendapatmu bagaimana cara guru mengajar sekarang dibandingan dengan gurumu waktu mengajar matematika sebelumnya?
5. Menurutmu pendapatmu bagaimana keaktifan kamu sekarang dalam mengikuti pelajaran dibandingan dengan waktu gurumu mengajar matematika sebelumnya? Bagaimana dengan teman-teman kamu yang lain?
6. Bagaimana keberanianmu sekarang dalam bertanya, atau menjawab pertanyaan jika dibandingan dengan sebelumnya?
7. Apakah kamu suka belajar kelompok? Mengapa?
8. Bagaimana pendapatmu tentang soal-soal yang disajikan dalam buku siswa?
9. Bagamana dengan gambar-gambar yang disajikan di sana, apakah cukup menarik?
10. Apakah soal-soal yang diberikan sulit? Coba jelaskan!
11. Coba kamu baca soal nomor…………, kemudian jelaskan dengan kalimatmu sendiri apa yang dimaksud dalam soal.

APPENDIX F

THE GEOMETRY CURRICULUM FOR INDONESIAN PRIMARY SCHOOLS

THE GEOMETRY CURRICULUM FOR INDONESIAN PRIMARY SCHOOLS.

Grade 1

Goal 1: The students are able to recognize and differentiate between geometry objects such as circles, squares, spheres and cylinders.

- Recognizing circles and non-circles, squares and non-squares, spheres and non-spheres, cylinders and non-cylinders.
- Drawing the squares and circles by tracing.

Goal 2: The students are able to recognize the area of 2-dimensional geometry objects and then make comparisons among them intuitively.

- Colouring the figures of 2-dimensional geometry objects.
- Comparing the areas of 2-dimensional geometry objects.
- Ordering 2-dimensional geometry objects based on their areas.

Grade 2

Goal: The students are able to recognize quadrangles, cubes and blocks.

- Recognizing quadrangles and non-quadrangles, cubes and blocks.

Grade 3

Goal 1: The students are able to differentiate between right angles and non-right angles.

- Recognizing right angles and non-right angles by using "sticks" and by folding paper.
- Showing objects from everyday life that have right angles.

Goal 2: The students are able to recognize squares and rectangles.

- Recognizing squares and rectangles (repeating).
- Creating new squares/rectangles from the smaller squares/rectangles.
- Drawing squares and rectangles by tracing.
- Drawing squares/rectangles on graphic paper.

Goal 3: The students are able to recognize 3-dimensional geometry objects.

- Recognizing spheres, cylinders, cubes, and blocks (repeating).
- Recognizing prisms, pyramids and cones.

Grade4

Goal 1: The students are able to determine the perimeter of triangles, squares, and rectangles.

- Determining the perimeter of triangles, squares, and rectangles by using measurement units.
- Recognizing the formulas to determine the perimeter of squares, and rectangles.

Goal 2: The students are able to recognize fold symmetry and reflection.

- Recognizing reflection (e.g. by folding the paper).
- Recognizing fold symmetry (e.g. butterfly, human body.)
- Drawing 2-dimentional geometry objects that have symmetries.
- Recognizing symmetry line.
- Finding the objects that have symmetries or non-symmetries.

Goal 3: The students are able to recognize trapezoids, parallelograms, the types of angles, the types of triangles, and recognizing sides, edges and corners in 3-dimentional objects.

- Recognizing trapezoids, parallelograms.
- Recognizing acute angles and obtuse angles.
- Grouping the angles based on their types and drawing right angles.
- Creating new triangles from small isosceles triangles.
- Drawing triangles and parallelograms on graph paper.
- Creating triangles and parallelograms (tangram).
- Recognizing sides, edges and corners in 3-dimentional objects (prisms, cubes, blocks, spheres, pyramids, cones, and cylinders).
- Drawing cubes and blocks.

Goal 4: The students are able to determine the areas of squares and rectangles

- Determining the areas of squares and rectangles that are drawn on graph paper.
- Determining the areas of squares and rectangles by using formulas.

Grade 5

Goal 1: The students are able to determine the area and circumstance.

- Recognizing the formula for counting the area of triangles.
- Determining the circumstances of union geometry objects (e.g. square and triangle).
- Determining the areas of union geometry objects (e.g. square and triangle).

Goal 2: The students are able to apply fold symmetry and manipulate 2-dimentional geometry objects

- Repeating fold symmetry.
- Recognizing fold symmetry and determining symmetry lines of rectangles squares triangles, trapezoids, parallelograms and circles.
- Producing 2-dimentional geometry objects on geoboard as a result of a reflection.
- Drawing 2-dimentional geometry objects on graph paper as a result of a reflection.
- Producing 2-dimentional geometry objects from the others (tangram).
- Tiling.

Goal 3: The students are able to recognize trapezoid and apply fold symmetry and rotation.

- Drawing circles, trapezoids, and rhombus on graph paper.
- Determining symmetry lines.
- Introduction to rotation.
- Determining the centre and the angle of rotation on 2-dimentional geometry objects.

Goal 4: The students are able to draw cylinders, pyramids, and cones.

- Recognizing "the nets " of cylinders, pyramids, and cones.
- Drawing cylinders, pyramids, and cones.
- Creating cylinders, pyramids, and cones by using thick paper.

Goal 5: The students are able to determine the volume of cubes and blocks.

- Determining the volume of cubes and blocks by using counting units.
- Recognizing the formulas for finding the volume of cubes and blocks.
- Determining the volume of cubes and bocks by using the formulas.
- Creating cubes and blocks by using thick paper.

Grade 6

Goal 1: The students are able to determine the area of circle and the other geometry objects.

- Comparing the areas of rectangle and parallelogram that have particular sizes.
- Recognizing the formula to determine the area of circles.
- Determining the areas of circles by using the formulas.
- Determining the areas of 3-dimentional geometry objects.
- Determining the areas of objects in everyday life.
- Determining the areas of objects that are drawn in particular scales.

Goal 2: The students are able to recognize regular pentagons and hexagons, also able to apply reflection and coordinate.

- Repeating fold symmetry and rotation.
- Recognizing regular pentagons and hexagons.
- Drawing regular pentagons and hexagons.
- Creating geometry objects (tangram).
- Drawing 2-dimentional geometry objects as a result of a reflection.
- Determining the coordinates of 2-dimentional geometry objects as a result of a reflection.

Goal 3: The students are able to determine the volume of 3-dimentional geometry objects

- Drawing and creating 3-dimentional geometry objects (repeating).
- Recognizing the formulas for finding the volumes of cylinders, prisms, pyramids and cones.
- Determining the volumes of cylinders, prisms, pyramids and cones.

Goals 4: The students are able to determine the area, circumstance and volume of various 2 and 3-dimentional geometry objects

- Determining the areas and circumstances of union 2-dimentional geometry objects (e.g. rectangles and triangles).
- Determining the areas and volumes of union 3-dimentional geometry objects (e.g. prisms and blocks).
- Determining the real areas of the figures that are drawn in particular scales.
- Drawing the figures in particular scales.