DEVELOPING A LEARNING ENVIRONMENT ON REALISTIC MATHEMATICS EDUCATION FOR INDONESIAN STUDENT TEACHERS

Zulkardi

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ter verkrijging van
de graad van doctor aan de Universiteit Twente,
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door

Zulkardi

geboren op 20 april 1961
te Gunung Raja, Prabumulih, Indonesia

Promoters: Prof. dr. Jan van den Akker
Prof. dr. Jan de Lange

Assistant-promoter: Dr. Nienke Nieveen

I dedicate this book to my wife (Ratu Ilma),
my two sons (Austin Al-hariz and Rizha Al-fajri),
my parents, my mother in law and specially to my father in-law (alm.)

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GLOSSARY

CASCADE	Computer Assisted Curriculum Analysis, Design and Evaluation
IMEI	CASCADE for Innovation in Mathematics Education in Indonesia
SEA	CASCADE for Science Education in Africa
MUCH	CASCADE for Multimedia curriculum in China
CIA	Center Intelligent Agent
CSCD	Computer Supported Curriculum Development
EPSS	Electronic Performance Support System
FKIP	Fakultas Keguruan dan Ilmu Pendidikan - Faculty of Teacher Training and Education
HTML	Hyper Text Mark up Language
IKIP	Institut Keguruan dan Ilmu Pendidikan - Institute of Teacher Training and Education
ITBS	Iowa Test of of Basic Skills
ITED	Iowa Test of Educational Development
LE	Learning Environment
MiC	Mathematics in Context
MIHMI	Majalah Ilmiah Himpunan Matematikawan Indonesia- Scientific Journal of Indonesian Mathematician Society
MONE	Ministry of National Education
NCTM	National Council of Teacher Mathematics
OECD	Organization for Economic Co-operation and Development
PGSD	Pendidikan Guru Sekolah Dasar - Primary School Teacher Education
PGSM	Pendidikan Guru Sekolah Menengah - Middle School Teacher Education
PISA	Program for International Student Assessment
PMRI	Pendidikan Matematika Realistik Indonesia - Indonesian Realistic Mathematics Education
RME	Realistic Mathematics Education
SLO	Instituut voor Leerplan Ontwikkeling - National institute for curriculum development in the Netherlands
SLTPN	Sekolah Lanjutan Tingkat Pertama Negeri - Public Junior Secondary School
SLPTP-KORPRI	Sekolah Lanjutan Tingkat Pertama KORPRI - A private Junior Secondary School KORPRI
SMUN	Sekolah Menengah Umum Negeri - Public Secondary High School
STKIP	Sekolah Tinggi Keguruan dan Ilmu Pendidikan - High School Teacher Training and Education
TIMSS	Third International Mathematics and Science Study
UPI	Universitas Pendidikan Indonesia - Indonesian Educational University
WWW	World Wide Web

PREFACE

This book is the culmination of a four-year study in the area of mathematics education at the University of Twente, in collaboration with the Freudenthal Institute, the Netherlands. It was aimed at developing and exploring a learning environment (le) in the form of a web site and a face-to-face course that can support student teachers with their learning of realistic mathematics education (rme) as an innovation in mathematics education in Indonesia. This book describes and discusses how the intervention with its main content was developed and evaluated using a development research approach.

During the study and writing of the dissertation, I was supervised by three experts: Prof. dr. Jan van den Akker, Prof. dr. Jan de Lange, and Dr. Nienke Nieveen. First, I would like to thank to the two professors who always stimulated and supervised me. As professors, both Jans showed me the right track to survival and how to make hard things become easy. One also can see how strongly they illustrated my professional growth through the list of their publications in the reference pages of this book. Furthermore, I wish to express my special thanks to Dr. Nienke Nieveen. She assisted me since the first week of my study when Susan McKenney brought me to her room. As the founder of cascade, she is like a true cascade until I found my own. She spent a lot of time in reading the draft of this book and writing her valuable comments. For all of you, often I heard people around me say the words that I am a lucky student. Indeed.

This study dealt with the design, development and evaluation of a learning environment on realistic mathematics education (rme) for Indonesian student teachers. To improve the quality of the learning environment, several experts with different expertise (rme, web design, course design, and computer support) were involved. They were Prof. Koeno Gravemeijer, Dr. Dick Slettenhaar, Dr. Koos Winnips, Dr. Susan McKenney and Dr. Q. Wang. Also, 34 student teachers at the Department of mathematics education in upi Bandung performed as the main target users as well as about 800 pupils in the 12 secondary schools. Therefore, I want to thank very much to all of you for your collaboration, comments, suggestions, energy and time.

The main content of the learning environment are rme exemplary lesson materials in the secondary level. These materials were mainly adapted from the Mathematics in Context textbooks. Therefore, I wish to thank the people from the University of Wisconsin and the Freudenthal Institute who developed the book including the publisher that gave me a permission to adapt the book as an initial use in the learning environment. Especially thank to Ms. E. Feijs, one of the authors, who spent her time in assisting and showing the right books.

I also would to thank Prof. Dr. Tjeerd Plomp and Prof. Dr. R.K. Sembiring. I remember April 1998 in ITB Bandung, a month before the 'big reformation' happened in Indonesia, when they selected me as one of the new PhD students. That time, in the first chat with Pak Tjeerd, I have already discussed about the cascade research. During the process of the PhD study, both of them often stimulated and supported me. For Pak Sembiring, being my Indonesian co-supervisor during my field works in Bandung, we discussed not only about my study but also about the future of mathematics education, especially the future of rme in Indonesia.

Moreover, I also wish to thank all people during my field work in Indonesia. First, to Indonesian co-supervisors: Prof. R. Soejadi, Dr. J. Marpaung, and Prof. Dr. Suryanto. They offered suggestions and comments like a father and old brothers to me in several seminars, conferences and informal meetings. Then I would like to thank a member of the selection team, Ms. Annie Kuiper, who also often gave stimulation and suggestions either in Enschede or Bandung. Also, to all P4M staff that served me as the guess researcher in ITB. At last, teacher educators at the Department of mathematics education in UPI Bandung: pak Kasim, pak Didi, pak Tatang, pak Dr. Joshua, Ibu Prof. Oetari, pak Prof. Ruseffendy and pak 'Seminar' for helping and hosting me while I was doing my field work in UPI Bandung.

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This study was funded by Indonesian government through the World Bank Indonesian Secondary Teacher Development (pgsm) project. Therefore, I wish to thank to my country as well as to the project staff especially to pak O. Simbolon, B. Karyadi, Pontas Hutagalung and bu Anita. To my Indonesian friends who were also sent by the PGSM project: Dian Armanto, Ahmad Fauzan, Sutarto Hadi, Turmudi and Ipung Yuwono, I am happy having friends in all of you and thank you for your help and critiques. And of course, an especially thank to all Indonesian friends in Enschede.

Moreover, I wish to express my gratefulness to my parents (Harun Agus dan Busroniah) who supported me from the time I was young to learn mathematics. Also, to my mother in-law (Drg. Ratu Zunaina) and specially to my father in-law (alm. H.Abdul Aziz Djapri) who deceised during the final year of this study. At last, to all brothers and sisters that were always ready for helping me whenever and wherever I need it. All of you will remain special to me.

Finally, warm and lovely thanks to my wife Ratu Ilma and my two sons: Austin Al-Hariz and Rizha Al-Fajri for their love and faithfulness. Especially to my wife who always took care of the two kids while I was far way. I knew how hard it was for you when I left, finishing your Master study while taking care of our sons. And I really understood that the situation became solid in the final year of my absence when you had to spend long and lonely days with the kids in the scary circumstances. From now on, I do promise to pay much time, to shield all of you, so we may being together again playing safely with our lovely kids.

Zulkardi

Enschede, August 2002

CHAPTER 1
INTRODUCING THE CASCADE-IMEI STUDY

This chapter introduces a study on designing, developing and evaluating a learning environment on Realistic Mathematics Education (RME) for student teachers in Indonesia. The full name of the study is: Computer ASsisted Curriculum Analysis, Design and Evaluation for an Innovation in Mathematics Education in Indonesia (acronym: CASCADE-IMEI). Section 1.1 presents the context of the CASCADE-IMEI study starting from some basic facts about Indonesia, recent curriculum reforms and current problems in mathematics education, and ending with background information on introducing RME in Indonesia. Section 1.2 describes a major educational program in Indonesian teacher education, which aimed to improve the quality of secondary education in Indonesia. The CASCADE-IMEI study is embedded in this program. Section 1.3 presents the origins of the CASCADE-IMEI study and section 1.4 presents the aims of this study and the research approach used. Finally, a preview of this dissertation is given in section 1.5.

1.1 CONTEXT OF THE STUDY

The CASCADE-IMEI study is tied to the current reform of mathematics education in Indonesia, specifically in the context of pre-service teacher education. This section first provides a quick snapshot of Indonesia, as well as presenting the current situation and perceived problems to be found in mathematics education. Subsequently, it lays out the background of introducing RME as a promising approach for improving mathematics education in Indonesia.

1.1.1 A few facts about Indonesia

Indonesia proclaimed its independence from the Netherlands on 17 August 1945, soon after the end of the World War II. Starting that time, the Indonesian government focused on the development and improvement of all aspects of people's lives, including education. In the 1950s, the government started focusing on the importance of education by developing schools, universities, and senior teacher education institutions or senior IKIPs (Institutes for teacher training and education). The school curriculum was mainly aimed at meeting the need of a newly independent country and a rural society. Fostering patriotism was a top priority for schools in this period. Other subjects, such as mathematics and science, were also taught but received less emphasis until the 1970s when the government conducted a reform in contents of the school curriculum.

Indonesia, the world's largest archipelago with Jakarta as its capital city (see also Figure 1.1), is comprised of more than 17,000 islands with nearly 6,000 of them inhabited.

Source: CIA world fact book, 2001.

Figure 1.1

Indonesian Archipelago

The nation's big size, with almost 2/3 of it being sea, makes it difficult for people to meet and interact with each other, thus hindering collaboration on educational activities. The islands stretch across the seas south of continental Southeast Asia spanning 1,888 kilometers (1,180 miles) north to south and 5,110 kilometers (3,194 miles) east to west. Indonesia straddles the equator and has a strategic location along major sea lanes from the Indian Ocean to the Pacific Ocean.

Indonesia, with its population of just under 230 million people, is the world's fourth most populous nation after China, India and the United States of America. The largest ethnic groups are: Javanese (45%), Sundanese (14%), Madurese (7.5%), coastal Malays (7.5%) and other (26%). The average annual population growth rate for the last decade was 1.6 %. Each ethnic group has its own distinct culture and language. This diversity is reflected in over 400 languages and dialects. The government chose a version of Malay as the official language and labeled it 'Bahasa Indonesia'. It has served as the language of government, of mass communication and of instruction at all educational levels.

Most of Indonesia's wealth is derived from oil and gas, mineral resources and plywood, followed by agricultural products such as coffee, rubber and palm oil. Although most of the population lives in rural areas, the government is seriously committed to developing economic potential in the industrial sector through the introduction of modern technology. With this goal in mind, starting in the 1970s the government planned investments at all levels of education with the intent of developing the required knowledge and skills. Reform in 1975 succeeded in improving the quality of national education, but due to the economic crisis in 1998, this progress has been interrupted. Recently, starting in 2000, one of the reform efforts following the crisis has been that the government started to shift the system from being centralized to decentralized. This entails that all 30 provinces and 357 districts have to take responsibility for all departments in their own regions, including education.

1.1.2 Education system in Indonesia

The national education system is defined in the National Education Law No. 2 of 1989, which is based on the *Pancasila* (five principles of the national ideology, that is: belief in one God, humanitarianism, national unity, democracy, and social justice) and the Constitution of 1945.

As in many countries, Indonesia's educational system is comprised of a formal school system following a 6-3-3 structure (see also Table 1.1). Pupils study at primary school, junior secondary and senior secondary school for six, three and three years respectively. The majority of schools are managed by the Ministry of National Education (MONE) and others are managed by the Ministry of Religion.

Table 1.1
Levels and types of Indonesian schools (MONE, 2000)

Age of Pupils (year)	4	5 - 6	7 - 12	13 - 15	16 - 18	19 - 22 +
Level	*Pre-school*		*Basic Education (Compulsory)*		*3-year senior secondary*	*Higher education*
Type	*Play group*	*Kinder garten*	*6- year primary school*	*3-year junior secondary*	*Academic, business, technical and home economic*	*Universities, Institutes, and Higher schools*

Pre-school education includes kindergarten at the formal school, play groups and day-care centers. Basic Education, a general education of nine years (primary school and junior secondary school), is a compulsory education that provides the learners with basic knowledge and skills. The current basic education curriculum was developed in 1994. The senior secondary schools give priority to expanding knowledge and further development of pupils' skills, preparing them to continue their studies at the higher levels of education or to enter the workforce.

Higher education has two types of courses: degree and non-degree. The degree programs emphasize academic enrichment, whereas the non-degree programs focus more on professional or technical work. The degree programs can be categorized in three levels: a four-year undergraduate level; a two-year master's level; and a three-and-a-half-year doctorate level. The non-degree programs offer the following courses: four-year polytechnic, diploma 1 (one-year diploma), diploma 2, diploma 3, and diploma 4. Secondary teacher education falls under the degree program (the four-year undergraduate level), whereas primary school teacher education is categorized into the non-degree program (diploma 2).

There are 30 public teacher education institutions, almost all of which are located in the capitals of the provinces. They are categorized in three types: a full educational university (10 universities, hereafter IKIP); a faculty of education as a part of a general university (19 FKIP or faculty of teacher training and education); and a higher school of teacher training (1 STKIP or higher school of teacher training and education).

The CASCADE-IMEI study has been conducted at the University of Indonesian Education (UPI, the former IKIP Bandung) in Bandung, the capital of West Java province (see also Figure 1.1).

1.1.3 Recent history of mathematics education in Indonesia

As mentioned by Moegiadi and Jiyono (1994), in the Indonesian 5th Five-year development plan (1990 to 1994), one of the most important goals of educational development is to improve the educational quality of all types of education at all levels and all subjects. This endeavor is conducted through various programs such as the improvement of teachers' quality through pre-service and in-service training programs, the improvement of the school curriculum and the provision of textbooks and other school facilities.

In mathematics education, the main issues were related to teacher improvement and mathematics curriculum reform. Regarding mathematics teachers, the initiatives had not only to do with the quality of teachers, but also with quantity. For instance, based on the research findings of MONE in 1999/2000 (MONE, 2000), only 37,099 mathematics teachers were employed at junior secondary schools, whereas ideally 43,130 were needed. Moreover, from an educational perspective the quality of the teachers was deemed relatively low. As junior secondary school teachers, they should ideally have earned at least a Bachelor's degree. Table 1.2 shows that only about 38% (S1 and S2) of mathematics teachers meet this criterion to teach mathematics in junior secondary schools.

Table 1.2
Educational background of teachers in Indonesia in the level of junior secondary school

Percentage	Education background
12.4%	D1 (one year diploma)
25.7%	D2 (two year diploma)
23.8%	D3 (three year diploma)
37.9%	S1 (bachelor's or undergraduate program)
0.2%	S2 (graduate or master's program)

Resource: MONE, 2000.

Regarding the issue of mathematics curriculum reform, the government has implemented four mathematics curriculum changes since the 1970s. These reforms are briefly outlined below:

Curriculum before 1975. This curriculum was implemented based on the mathematics strands such as Algebra, Geometry and Trigonometry. These strands were often taught using a mechanistic or traditional approach. According to Treffers (1991), this approach makes extensive use of a drill and practice approach, which treats pupils like a computer or machine.

Curriculum 1975. This curriculum was deeply influenced by modern mathematics or 'new math'. New math was also called a structuralistic approach as it focuses on the schema and the structure of mathematics that uses set theory as a core concept. This approach originated in the USA and Europe in the early 1970s. De Lange (2001) criticizes modern mathematics, calling it mathematician mathematics due to its content that covers many theoretical aspects and lacks real-life application.

Curriculum 1984. In this curriculum, the only change was in the structure of the content. For example, the subject of statistics that had previously been taught only in the senior secondary school was moved not only to junior secondary school but also to primary school. In this period, the teaching approach that was used by teachers was a combination of a mechanistic and a structuralistic approach.

Curriculum 1994. In this curriculum, most changes were made to the content in the primary schools. The concept of set theory was replaced with arithmetic, or the basic skills with which pupils learn how to count and manipulate numbers using a set of algorithms and procedures. The weakness of this curriculum was its overload; too many topics needed to be learned by pupils leading to much criticism and heated debates.

Curriculum 1994 revised. In 1999, the government reduced the 1994 curriculum regarding the number of mathematics topics. For instance, graph theory was removed from secondary mathematics.

Although the curriculum for mathematics education has been changed a number of times, some problems in all school levels still remain. For instance, 'local' mathematics textbooks were made by simply translating the English textbooks into Bahasa. These materials contain mainly sets of rules and algorithms as well as context free problems and they lack applications that are experientially real to the pupils. Also, teachers use the mechanistic approach in teaching mathematics, which puts pupils in a passive role, although this attitude is also partially caused by the pupils' culture. Mathematics is typically experienced by pupils as the most difficult subject in the schools, leaving most of them are afraid of, and with little love of the subject. Consequently, the learning outcomes (both for knowledge and attitude) of the pupils are low.

The main goals of the mathematics education curriculum (MONE, 2000) are to prepare pupils:

(1) to be good citizens in a dynamic society through practice, acting and thinking logically;
(2) to be able to use mathematics in their daily life.

These goals are not easily achieved. How can pupils practice, act and think logically in a dynamic society if they are taught using a mechanistic approach in which they do not have a chance to communicate, argue, or justify their positions. How do they hope to use mathematics in their daily lives when they are not challenged to solve real problems in the mathematics training? The next section addresses a number of current problems related to the learning outcomes of pupils in mathematics education in Indonesia's junior secondary schools.

1.1.4 Problems in mathematics education in Indonesia

As mentioned briefly in the previous section, the main problem of mathematics education in Indonesia–especially in the arena of secondary schools–are both low objective achievement of pupils in mathematics and their poor attitude toward mathematics. The problem of low objective achievement can be seen, for instance, in the average of mathematics scores on the national test. This test is conducted by the government annually and is taken by all of Indonesia's junior high school students from the previous year. From 1990 to 1997 the average score was always below 5.0 on a scale of 1 to 10, making it consistently the lowest scoring of all the subjects taught in school (Manan, 1998). Furthermore, findings from two diagnostic tests that were conducted by Somerset (1997) and Suryanto (1996) suggest that the average score in mathematics education for 16 different urban and rural junior secondary schools in several provinces in Indonesia was also lower than 5.0. The results of the tests indicated that most pupils lacked understanding of the basic skills that they were supposed to have learned in primary school and in everyday application problems. Finally, at the international level, based on the results of the Third International Mathematics and Science Study (TIMSS), the achievement of Indonesian pupils in mathematics was ranked 34th out of 38 participating countries (Mullis et al., 2000).

The problem with regard to the attitude toward mathematics was explicitly addressed by Marpaung (1995). He stated that most pupils in a number of primary schools in Jogyakarta were afraid of mathematics. He pointed out that mathematics teachers are less confident and do not stimulate any interaction between pupils during the lessons. Likewise, as informally discussed in various seminars, national newspapers or among mathematics teachers, many pupils - even adults with 12 years of mathematics instruction in schools - see mathematics as a *ghost* (in Indonesian language well known as *momok*) that make them scared. However, in some cases this was not due to the mathematics itself, but to the teachers. Teachers with inadequate understanding of the content and the pedagogy of mathematics make the already challenging subject that much harder for their pupils to learn. On top of that, pupils' poor attitude toward mathematics may also be contributed to by an overload of exercises and homework.

In an attempt to combat the low achievement and bad attitude toward mathematics, the Indonesian government has attempted to identify likely causes for these problems. Research cites various potential causes, including inaccurate learning materials, inadequate mechanistic teaching methods, and poor forms of assessment (Somerset, 1997; Suryanto, 1996). First, with regard to the learning materials, Somerset and Suryanto report that some contents in mathematics textbooks are inaccurate. However, many teachers, especially those whose own knowledge of mathematics is questionable, are not aware of these errors. These teachers present inaccurate mathematics to their students, leading to mistakes in answering related questions in subsequent testing. In addition, there is a scarcity of support materials from other resources, which could be used by teachers to supplement their textbooks and help them to overcome their problems of insecurity.

Second, with respect to the teaching methods, most mathematics teachers in Indonesia base their teaching on teacher-centered instead of student-centered learning (Soejadi, 2000). Teachers use most of the contact time for explaining and solving mathematics problems, while students remain passive and simply copy what their teacher writes on the black board. Moreover, Suryanto (1996) pointed out that although teachers frequently asked questions, most of these were low-demanding questions, requiring students to do no more than to carry out an operations of a mathematical term. High-demanding questions and checking on conceptual understanding were rarely seen. In this situation, students do not learn to understand and take ownership the concept by solving problems using their own strategies, but they only rewrite the strategy that is used by their teacher.

The third problem in the Indonesian context refers to assessment. Currently, the assessment activities in Indonesia are not integrated in the instructional process (formative evaluation), but are provided at the end of the lesson (summative evaluation) or as homework assignments. Often, due to a lack of time for teachers to evaluate students' worksheets, students do not get any feedback on the correctness or efficiency of their strategies. In addition, mathematics problems used in assessment activities focus merely on algorithms and procedures and they lack elements of practical applications (Suryanto, 1996). These abstract problems can be categorized to the lower level of thinking. However, according to de Lange (1995), the teaching and learning of mathematics students should be assessed not only by problems in low level thinking but also by problems in middle level (problem solving) and higher level thinking (mathematization).

In summary, it is clear that there are currently three problems in mathematics education that need to be solved, namely mathematics curriculum materials, teaching methods and the assessment approach. One promising approach toward the teaching and learning of mathematics that is thought to address these problems is realistic mathematics education (RME). In the next section, this point of view will be presented.

1.1.5 The potential of Realistic Mathematics Education

RME is a theory of teaching and learning mathematics that has been developed in the Netherlands since the early 1970s. This approach emphasizes increasing pupils' understanding and motivation in mathematics (de Lange, 1987; Freudenthal, 1991; Gravemeijer, 1994; Streefland, 1991).
As a theory, RME has its own philosophy and characteristics. It incorporates views on what mathematics is, how students learn mathematics, and how mathematics should be taught. The philosophy of RME is strongly influenced by Hans Freudenthal's concept of mathematics as a 'human activity' (Freudenthal, 1991). He felt that students should not be considered as passive recipients of ready-made mathematics, but rather that education should guide the students towards using

opportunities to reinvent mathematics by doing it themselves. Furthermore, RME is characterized by the use of contextual problems; the use of models; and the use of students' production, interaction, and intertwining among strands. This theory will be elaborated in *Chapter 2*.

As reported by de Lange (1996), RME has been adapted in various projects in different parts of the world such as USA, Latin America and South Africa. For example, in the USA, through a collaborative project between the Freudenthal Institute and the University of Wisconsin, RME has been adopted and redesigned in the *Mathematics in Context (MiC)* textbooks for grades 5-8. After the books had been used by students in several school districts from different states, preliminary research showed that student achievement had improved in district and state tests. For example, in 1995, the students in grades 5-9 students in the Ames, Iowa district with two years experience of MiC took the *Iowa Test of Basic Skills (ITBS)*. In this test, the percentile rankings of student scores improved as shown in Table 1.3.

Table 1.3
Student achievement results on ITBS

	1993 (Before MiC) National Percentile	**1996 (With MiC) National Percentile**
Computation		
Grade 6	62	81
Grade 7	60	72
Grade 8	59	79
Concepts		
Grade 6	79	93
Grade 7	81	90
Grade 8	84	90
Problem solving		
Grade 6	87	96
Grade 7	89	94
Grade 8	93	94

Source: http://www.ebmic.com.

In a follow-up study of student achievement, the *Iowa Tests of Educational Development* was administered to ninth-grade students. In this test, 25% scored in the top 1% of the nation, 47% scored in the top 10%, and 90% scored above the national median

(Romberg & de Lange, 1998a). Furthermore, in order to gain data on how MiC students perform on standardized tests vs. students not using the MiC program, a three-year MiC longitudinal study was conducted beginning in the fall of 1997 (Shafer, 1999). The results of this study will soon be reported on the MIC web site (www.ebmic.com).

However, these impressive results were achieved after having faced some obstacles. Clarke, Clarke and Sullivan (1996) mentioned that in the initial implementation of MIC textbooks, teachers experienced difficulties in teaching the book materials in the classrooms. Although each pupil had his/her own book, teachers were used to making their own teaching materials. So, in some cases they both used the textbooks and made their own materials by adapting the materials in the books. Hence, the project provided a professional development opportunity for teachers. Here teachers learned how to teach with the new materials while using a new approach, and how to redesign the materials based on their needs.

In the Netherlands, where RME was originally developed and has been in use for about 30 years, there are also positive results. For instance, the results of the Third International Mathematics and Science Study (TIMSS) showed that pupils in the Netherlands performed well in mathematics, achieving a rank of 6th out of 38 participating countries. In addition, the gap between the highest scoring and lowest scoring pupils was relatively small (Mullis et al., 2000). These results may be seen as indicators that RME has promise to improve the quality of mathematics education. In a more recent international comparative study on mathematical literacy (PISA= Programme for International Student Assessment), the Netherlands scored highest among all OECD countries, but was left out of many tables because of a low degree of participation. However, this low participation still resulted in reliable and representative data (OECD, 2001). Also here, these positive results were not achieved overnight.

1.1.6 Introducing RME in Indonesia

As seen in the previous sections, RME seems to be a promising approach for implementation in Indonesia, since it aims to – and has been shown to – both increase pupil's understanding of and motivation toward mathematics.

However, in order to carry out such an implementation, there are at least three issues that need consideration. First, RME curriculum materials are not easily designed and are not readily understood by teachers. RME curriculum materials differ from former materials in that they emphasize application problems with a loose structure and a re-definition of basic skills. For instance, the assessment materials have to focus on middle-level and high-level order thinking instead on the low-level only. Second, teachers need to be instructed in how to use RME materials in their classroom. According to de Lange (1991), the role of teachers in RME changes from teaching to 'un-teaching'. He pointed out that the teacher's role is one of organizing and facilitating the learning process. In doing so, the teacher faces several obstacles. Teachers and students will regularly be confronted with mathematical problems that have multiple correct answers, or one correct answer and different strategies.

Finally, the implementation of RME is not a short-term program or project, but needs many years to be institutionalized.

These issues are consistent with Fullan's (2001) suggestion that the innovation of teaching is a complex undertaking for teachers, usually involving a combination of changes in the following areas:

- new curriculum materials or changed use of existing materials;
- new knowledge and skills required by the teacher; and
- new values and attitudes concerning pupil learning and the new patterns of work in the classroom.

Therefore, in order to introduce RME in Indonesia, it is important to take into account the obstacles that were faced either by the MIC project or the Dutch experts. Related to Fullan's suggestions, the following questions arise:

- How to develop or adapt new curriculum materials for the new context?
- How can teachers be assisted in implementing these materials in the classroom?
- What advice can be given?
- What support can be offered?

The next section gives an overview of the PGSM project that aimed to introduce RME in Indonesia.

1.2 THE PGSM PROJECT

The PGSM project (secondary school teacher education project) was launched in 1997 as an extension of the PGSD project (primary school teacher education project), which was conducted from 1990 to 1996. The purpose of the PGSD project was to improve the primary school teacher education while the PGSM project aims to improve the quality of secondary education. Both projects were funded by the World Bank. The PGSM project covered almost all secondary school subjects including science, languages, mathematics education and physical education.

The variety of activities carried out by the PGSM project can be categorized into three broad interrelated components:

- pre-service and in-service training for both teacher educators (increasing the quality of teacher educators by completing a master's or a doctorate program) and secondary mathematics teachers (increasing the quality of school teachers by completing a four-year undergraduate program in teacher education);
- professional development for both teacher educators and school teachers by conducting collaborative action research; and
- providing infrastructure for teacher education such as laboratory equipment and teaching tools.

In the context of mathematics education, for instance, institutions for teacher education provided a special in-service program for mathematics teachers who want to increase their degree from diploma 3 to bachelor's degree. A one-year in-service program was held three days a week from Friday to Sunday, so teachers still had four days for doing their job in their schools. However, many teachers felt that the program was overly demanding since they had almost no free days for a whole year.

Furthermore, the project provided a number of scholarships for teacher educators who wanted to follow master's or doctorate programs. For instance, for the doctorate program in mathematics education, the project sent a number of lecturers to the Netherlands to learn about RME. The idea of adapting the RME approach to mathematics education in Indonesia was initially proposed by the PGSM project team in collaboration with the University of Twente and the Freudenthal Institute in the Netherlands. Finally, four studies about RME have been initiated. One of them is the CASCADE-IMEI study, which focuses on RME in the secondary school level in the context of pre-service teacher education. The other three studies focused on RME at:

- secondary school level in the context of in-service teacher education. In this study a professional development program was developed in order to introduce RME to a number of junior secondary school teachers in Jogyakarta (Hadi, in press);

- primary school level, in which a number of lessons in multiplication and division were developed and tested in several primary schools in Jogyakarta and Medan (Armanto, in press); and
- primary school level, in which a number of lessons in geometry were developed and tested in several primary schools in Surabaya and Padang (Fauzan, in press).

The next section explains how the CASCADE-IMEI study was initiated.

1.3 ORIGINS OF THE STUDY

As mentioned in the previous section, the CASCADE-IMEI study was initiated along with three other studies in order to support the initiative of the Indonesian government to introduce RME in Indonesia in an effort to improve the quality of mathematics education. This study has three roots that are explained in the following three sections:

- teacher education as a starting point for an innovation;
- the growth of internet technology, which seems to hold great promise as a platform for promising support tools for teacher education in a vast and geographically fragmented country such as Indonesia; and
- the CASCADE line of research which has developed three different computer support tools for curriculum developers as well as teachers.

1.3.1 Teacher education: A place to start an innovation

Teacher education institutions in Indonesia have as their main task to educate teachers for primary and secondary school. The government often uses institutions for teacher education to launch an innovation in education for the following three reasons. First, they are situated in the capital of provinces and become the government representation in introducing the innovation to other cities in that province. Second, teacher education institutions have many teacher educators who are experts in all school subjects. This makes it easier for the government to find partners to introduce the innovation in the schools. Finally, teacher education institutions, through their student teachers, will bring the innovation to the schools during teaching practice periods. In this study, it was decided to follow the same strategy when introducing RME as an innovative approach to the secondary schools.

1.3.2 Web support: A promising tool in Indonesia

According to Khan (1997), the world wide web is one of the most important environments of learning and teaching that can provide an opportunity to develop new learning experiences for students that were not possible previously. The web can provide equal access to students and teachers from all places around the world to the many learning resources available. Also, it provides tools for cheap and fast communication that can overcome distance barriers among users (for example in countries that have many islands such as Indonesia). On top of that, the web with its simple point-and-click navigation system is fairly easy to use by both new and experienced users.

As in many countries, the web is growing fast in big cities in Indonesia. According to a recent survey by an Indonesian newspaper, about a million people use the Internet on a daily basis, and it might grow to five times that by the end of 2002 (Kompas, 1999). Almost half of these users are university students or school students including pre-service teachers. The city where this study was conducted, Bandung, is Indonesia's leading city in Internet use. In this city, students commonly use internet cafes as an 'internet laboratory' due to lack of access on their campuses. Some universities in Indonesia have Internet access but at this moment it is only used for displaying the administration and management of the university instead of for teaching and learning purposes.

As the use of Internet is growing, it is increasingly being used as a platform for Electronic Performance Support Systems (EPSSs) (Khan, 1997). EPSSs are electronic systems (usually computer-based) that provide users with support such as tools, information, learning opportunities and communication tools in order to increase their performance (cf. Gery, 1991). Web-based EPSSs use the Internet as their delivery platform. The main functions of web-based EPSSs are: (1) they provide information and resources that can be accessed by Internet users from all over the world; and (2) they can include tools for communication and exchange of ideas using an e-mail or newsgroup (Khan, 1997). The increasing use of EPSSs is also a trend in curriculum development (cf. Nieveen, 1997; McKenney, 2001; Wang, 2001). Based on these trends, therefore, it was decided that the CASCADE-IMEI study would explore the use of the Internet in supporting pre-service students learning RME.

1.3.3 The CASCADE line of research

The CASCADE project was initiated in 1993 by the Department of Curriculum Faculty of Educational Science and Technology, University of Twente in the Netherlands. The first project aimed to learn about how EPSSs could contribute to curriculum development. Originally, it focused on supporting Dutch professional curriculum developers through the often-neglected process of formative evaluation (Nieveen, 1997). In 1996, two follow-up studies, CASCADE-SEA and CASCADE-MUCH, were launched to explore computer support in different contexts. The CASCADE-SEA (Science Education in Africa) study investigated support of teachers in creating exemplary science lesson materials for classroom use in southern Africa (McKenney, 2001). The CASCADE-MUCH study, examined computer support for instructional scenario development in the process of multimedia curriculum development in Shanghai, China (Wang, 2001).

The CASCADE-IMEI study, which was initiated in 1999, also followed the line of the previous CASCADE studies in the sense that it aimed at exploring how EPSSs can support mathematics student teachers in Indonesian teacher education in carrying out curriculum development and implementation activities in pre-service teacher education.

1.4 AIM AND RESEARCH APPROACH OF THE STUDY

1.4.1 Aim of the study

The CASCADE-IMEI study is based on some tenets that were explained in the previous sections. These underlying ideas can be summarized as follows:

- pupils in Indonesia have shown low achievement in and poor attitude toward mathematics;
- there are basically three current problems of mathematics education in the classroom that need to be solved, i.e. inaccuracies in curriculum materials, teaching methods that place low-level demands on pupils and inadequate assessment approaches;
- it is assumed that the quality of mathematics education can be improved by introducing RME as an innovation to the mathematics education in Indonesia;

- there are several issues that need consideration when implementing RME, especially that it is a complex task (requiring changes in teacher beliefs, teaching approach and use of materials) that needs a long-term program;
- student teachers could be used as change agents in the schools; and
- the Internet could serve as a platform for innovative support tools for improving teacher education in Indonesia.

Based on these ideas, the main aim of the CASCADE-IMEI study was to develop and evaluate a learning environment (LE) that can assist mathematics student teachers in UPI Bandung (Indonesia) with their learning of RME as a new instructional approach in mathematics.

1.4.2 Research approach

Focus of the development research

Educational development often occurs in dynamic situations and under uncertain circumstances, but with high ambitions. Research can be conducted to support curriculum designers or programmers of reform. Yet, according to van den Akker (1999), traditional research approaches do not always provide enough support to design and development efforts, as answers are often too narrow, too superficial and too late to be useful. More adequate information and more timely feedback are required for designers to make proper choices in such dynamic circumstances. Development research could provide a useful alternative research approach in complex situations where needs are diverse, problems ill defined and the outcomes of intervention are often unknown.

Van den Akker (1999) distinguishes two types of development research depending on its aims and on the timing of the research being carried out: formative research and reconstructive studies. *Formative research* includes research activities undertaken throughout the design and development process of a specific intervention, from exploratory studies through to formative and summative evaluation activities. The purpose of these research activities is to optimize the characteristics of the intervention and to test design principles. *Reconstructive studies* focus on research activities undertaken mostly following completion of the development process of several interventions. The purpose of these activities is the articulation and elaboration of the design principles.

Formative research is often categorized in three main activities or stages (van den Akker 1999, Nieveen, 1997):

1. preliminary stage or front-end analysis (including problem and context analysis) in order to analyze the initial situation;
2. prototyping stage with a focus on the cyclic process of the design and formative evaluation of prototypes; and
3. assessment stage or summative evaluation of the final product when it is implemented in practice.

Development research in the CASCADE-IMEI study

This study can be categorized as formative research as it aims at developing a prototypical learning environment and generating methodological instructions and guidelines for the development of such learning environments. Using that approach, the learning environment has been developed and evaluated during a period of approximately three years from 1999 to 2001. The following main research question was central to the study:

> *What role can the CASCADE-IMEI learning environment play in assisting Indonesian mathematics student teachers with their learning of the* RME *approach?*

The CASCADE-IMEI study was aimed at developing a high quality learning environment (LE). In this study, three quality criteria (validity, practicality and effectiveness) were used in the following ways:

- *Validity* implies that the LE and its components should be designed based on the state-of-the-art knowledge (*content validity*) and the components should be consistently linked to each other (*construct validity).* If the product meets these requirements, it is considered to be valid. For example, in the case of the exemplary lesson materials, all components of the intended curriculum (e.g. subject matter, skills, attitudes, pedagogy, assessment) should be connected in a consistent and logical way.
- *Practicality* means that the LE should meet the needs and contextual constraints of the users and experts. In this study, for instance, student teachers need to be able to use the web site in a practical way while they are following the RME course.

Moreover, for the exemplary lesson materials, if student teachers are able to use the materials to execute their lessons in a coherent manner, without too many problems, the materials are said to be practical.

- *Effectiveness* implies that the results of using the LE should be consistent with the intended aims of the study – that is to assist student teachers learning RME as a new approach in teaching and learning of mathematics education. In this study, the potential effects of the LE are evaluated from the perspective of teacher development, using the five effectiveness levels of professional development (Guskey, 2000):
  - Participants' satisfaction. Student teachers' satisfaction with the organization and components of the LE as well as their experience of using the LE. This level also refers to the practicality criteria of the LE.
  - Participants' learning. Change in student teacher's knowledge, skill levels and their attitudes or beliefs with regard to the content and pedagogical part of RME.
  - Organizational change. Changes that happen in teacher education in Bandung after the implementation of the LE.
  - Participants' use of new knowledge and skills. Student teacher's performance when they use their learning gains in teaching in a RME classroom.
  - Pupil's reactions and learning results. Changes in pupil's attitude toward mathematics as well as their learning outcomes in the form of understanding and attitude. Yet, in this study, the main focus was only to find the indications to the changes.

These quality criteria in the CASCADE line of research (Nieveen, 1997; 1999; van den Akker, 1999; McKenney, 2001; Wang, 2001) usually shift in emphasis during the prototyping development process from validity, to practicality to effectiveness.

By following the development research approach, this study progressed through three main stages: preliminary, prototyping and assessment. Figure 1.2 illustrates the three stages.

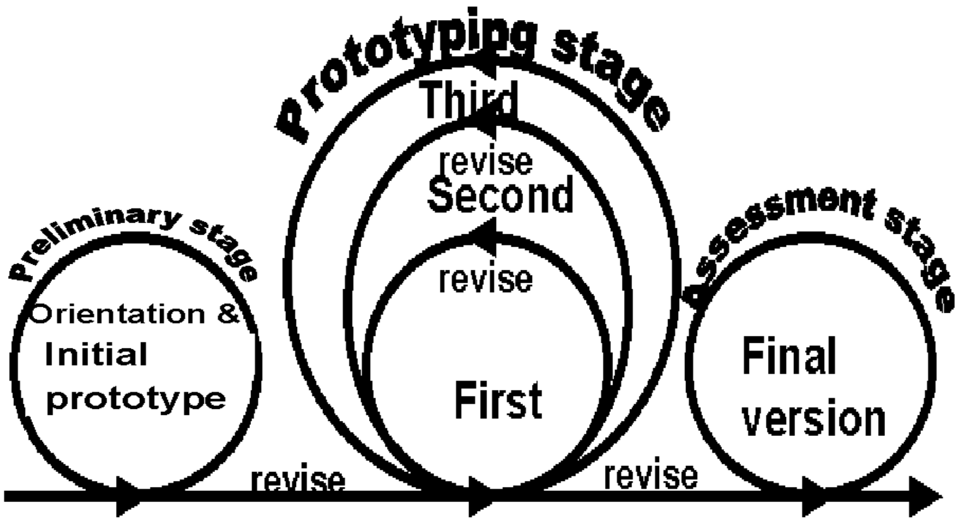


Figure 1.2
Flow of design, development and evaluation of the LE prototypes

Preliminary stage

Several preliminary investigation activities were conducted before the start of the actual development of the learning environment (LE). First, a literature review was performed on the theory of RME, the concepts of curriculum development and implementation, the concepts of (student) teachers' learning and web support. Second, an initial prototype of the LE was designed and evaluated.

Prototyping stage

This stage concentrated on finding valid and practical characteristics of the LE. However, in several cases, it also focused on the potential effects of LE. The development process of the LE was driven by a *prototyping approach*. In order to determine specifications and assess their adequacy, Nieveen (1997, 1999) suggested that significant characteristics of a prototyping approach include:

- *Extensive use of prototypes.* The CASCADE-IMEI study used an evolutionary prototyping approach, meaning that a prototype was continually refined based on reflections of developers on the prototype and formative evaluation results. This study used both paper-based and web-based prototypes. A paper-based version can make it easier for the developer to conduct the initial formative evaluation since all screens of the system are printed on paper and no elaborate programming is required. This prototype can focus more on the content and overall structure of the system or materials. This study used a paper-based version only for developing the course and RME exemplary curriculum materials. Next, a working prototype (or web-based version) helped in making the design considerations more concrete, since this prototype could actually be used by the target group in a more authentic setting. Finally, after the working prototype was tested and revised a number of times and all stakeholders were satisfied with the product, a final version was developed.

- *High degree of iteration.* This characteristic refers to the number of prototypes used during a prototyping process. Using the power of formative evaluation, suggestions for revision can be used to improve the quality of the prototypes. Also, the notion of 'think big, but start small' is important during the iteration process. By starting with a small part of the final product, it is easier to learn from failures and apply successes in developing the next parts. In this study, a total of five prototypes of the LE were developed and evaluated.
- *Participation of representatives of the target group.* This characteristic is very important in the sense that the real users give their comments and perceptions that are utilized in improving the practicality of the product. Nieveen (1997, 1999) indicates several positive effects from user involvement during the development process: more accurate information about the tasks which require support; more intensive discussions about the requirements of the materials; better opportunities to negotiate and justify design ideas; increased user commitment and ownership of the final product; and professional growth of the participants.

Assessment stage

In this stage, the potential effects of the final version of the LE were empirically assessed with student teachers in Bandung using the effectiveness levels suggested by Guskey (2000). This stage is thoroughly explained in Chapter 4.

1.5 PREVIEW OF THE DISSERTATION

This chapter has presented the background of the CASCADE-IMEI study, which has as its purpose the introduction of RME as an innovation in mathematics education by developing and evaluating a learning environment (LE) as a catalyst to such change. Using a development research approach, the LE has been mainly developed in the Netherlands and evaluated in Indonesia. The following chapters can be seen as findings from development research activities. *Chapter 2* presents the findings of the literature study on RME theory, current mathematics curriculum in Indonesia, teacher learning, LE, and web support which resulted in a framework and initial characteristics of the learning environment to be developed. *Chapter 3* describes the design and formative evaluation of the LE based on two stages of the study: preliminary and prototyping stages. This includes the design and development of prototypes, formative evaluation activities as well as revision decisions of all prototypes. *Chapter 4* reports on the findings of the assessment stage, in which the practicality and the potential effects of the LE in assisting student teachers learning RME were investigated. *Chapter 5* presents a summary of the research and discusses the main findings of the study based on the research questions. Finally, the book concludes with recommendations: for the Indonesian government; for the implementation of the LE in other Indonesian teacher education institutes; and for the future of the study and for follow-up research.

CHAPTER 2

PROBLEM ANALYSIS AND CONCEPTUAL FRAMEWORK

The previous chapter introduced the background of the CASCADE-IMEI study, that aimed to develop and evaluate a learning environment in order to assist student teachers in UPI Bandung learning RME as a new approach for mathematics education. This chapter presents the problem analysis and conceptual framework of the study. It reviews relevant literature and the connections to the Indonesian context. First, section 2.1 explains the concept of curriculum and its connection to the context of junior secondary mathematics in Indonesia. Section 2.2 discusses the concept of RME including its theoretical background, its materials, its teaching approach and its assessment. Section 2.3 presents the concept of curriculum implementation and its strategies. Section 2.4 describes the process of student teacher learning in pre-service mathematics teacher education in Indonesia, as well as the more general process of teacher learning. The chapter concludes by offering the framework of the learning environment to be developed (section 2.5).

2.1 THE CURRENT MATHEMATICS CURRICULUM IN INDONESIA

The purpose of this study was to assist student teachers in learning RME, which includes how to develop RME lesson plans and materials and how to implement these in the classroom practice. Hence, the concept of curriculum is important. The next sections elaborate on the concept of curriculum as relates it to the junior secondary school mathematics curriculum in Indonesia.

2.1.1 Concept of curriculum

The basic working definition of curriculum used here is that of curriculum as 'a plan for learning' (cf. Taba, 1968; van den Akker, 1998). The plan can be found at different levels of various educational settings. At the *micro level* (classroom), the curriculum refers to a plan for concrete instructional activities. At the *meso level* (school or institutional) it refers to a course or an educational program and at the *macro level* it is used to indicate a more general curricular framework for a district, province or nation.

For the discussion on curriculum development and implementation, it is helpful to use the representations of the curriculum according to the typology as proposed by Goodlad, et al. (1979) and adapted by van den Akker (1998). These include: *ideal curriculum,* the original assumptions and intentions of the designer; *formal curriculum,* the concrete curriculum documents, such as student materials and teacher guides; *perceived curriculum,* the curriculum as interpreted by teachers; *operational curriculum,* the actual instructional process as realized in the classroom (also referred to as curriculum-in-action or the enacted curriculum); *experiential curriculum,* the curriculum as it is experienced by the pupils; and *attained curriculum,* the learning outcomes of the pupils. In some studies the term *intended curriculum* is used, which refers to a combination of the ideal and formal curriculum while *implemented curriculum* refers to a combination of the perceived and the operational curriculum. This typology (cf. van den Akker, 1998; Ottevanger, 2001) has proven to be helpful in understanding the relationships and discrepancies between different representations of the curriculum in practice. This typology will be elaborated in the next section by taking mathematics curriculum at the junior secondary school level as an example.

Also, a curriculum can be characterized as being 'site specific' or 'generic' (cf. Marsh & Willis, 1995). In cases where the target group of a curriculum is small and homogenous and all persons involved (such as pupils, trainees or developers) are in relatively close proximity to each other and know each other quite well, one can speak of a site-specific curriculum. On the contrary, a generic curriculum is developed for a large and diverse target group and the physical distance between the participants is usually great. Finally, Marsh and Willis define curriculum development as a collective and intentional process or activity considered to be beneficial for curriculum change.

2.1.2 Analysis of the current mathematics curriculum in Indonesia

This study assists student teachers in learning to teach mathematics on the level of junior secondary school. Consequently, it is important to first discuss the current junior secondary mathematics curriculum in Indonesia's schools. The curriculum typology that was introduced in the former section was used as an analysis framework. The curriculum was taken from the Curriculum Implementation Guide (MONE, 1993) as a part of the national curriculum.

Ideal curriculum

The ideal curriculum contains the original assumptions and intentions of the designer, or goals for all topics to be learned by pupils in the school. According to MONE (1993), the goals of mathematics education curriculum in the junior secondary mathematics are that pupils:

- can use the concepts, identify symbols and facts and recognize the elements in the topics;
- can solve problems in the topics, and are able to apply the learned approaches in other subjects and everyday live;
- have the knowledge concerning geometry in one, two and three dimension; can use mathematical concepts to communicate ideas and data, and are able to interpret the meaning of statistics;
- have a critical attitude, are open, are consistent and appreciate mathematics; and
- start understanding mathematics deductively, which can give rise to a systematic way of thinking.

Formal curriculum

This type of curriculum represents the concrete curriculum materials, such as student materials and teacher guides, that are developed based on the ideal curriculum. The strands in junior secondary school include: arithmetic, algebra, geometry, trigonometry, probability and statistics. For each topic, information is provided on the depth and breadth of treatment, as well as its goals. Regions, schools or teachers who need materials other than the minimal materials are required to develop them themselves. In this guide, the term *materials* means the main content of curriculum or student materials (for all pupils) and enrichment materials (for high achieving pupils only). Use of the minimal materials is also suggested for the remedial teaching of the weaker pupils. However, as Somerset (1997) and Suryanto (1996) reported, the current materials lack quality and have been designed with a mechanistic approach in mind, i.e. one that stresses drill and practice. The books are more product-oriented then process-oriented. In addition, the lesson materials contain only learner materials; teacher guides are lacking. Therefore, the goals of the ideal curriculum (such as: pupils can use mathematical concepts to communicate ideas, pupils have a critical attitude, are open to and appreciative of mathematics) are far from achieved. The gap between the ideal curriculum and the formal curriculum of mathematics in junior secondary schools is broad, indeed.

Perceived curriculum

This type of curriculum relates to the curriculum as it interpreted by the teachers in the schools. In the national curriculum (MONE, 1993), it is presumed that teachers should design and develop lesson preparations in the form of a year-plan, quarterly plan and daily lesson plans. These plans are critical since not all learners have their own textbooks. However, due to a lack of quality materials and the lack accompanying instructor's guides, it becomes the teacher's responsibility to arrange all requirements in the lesson plan (Somerset, 1997; Suryanto, 1996). Hence, most teachers do not clearly understand what the intended means. Some teachers perceived that the goal of mathematics education is simply to prepare their pupils to answer the questions or mathematics tasks found in the textbooks or in the national exams.

Operational curriculum

This type of curriculum refers to the approach chosen by the teacher to make pupils active in the learning process. It relates to the use of teaching methods and assessment strategies. The curriculum guide (MONE, 1993) suggested that the role of teachers is to teach the pupils and to help them understand the mathematics tasks. Teachers are supposed to use teaching strategies that will inspire active involvement of their pupils. Yet, according to Marsigit (2000), teachers mostly use the common, traditional, expository teaching method (that they learned in teacher education). This method usually consists of the following steps:

- teacher starts the class by explaining a mathematics rule of a mathematics topic;
- teacher then presents an example on how to use the rule in solving a mathematical task from the textbook;
- teacher calls some pupils forward to solve some mathematical tasks from the textbook in the front of the class;
- the remaining tasks are assigned as homework; and
- teacher closes the lesson by giving summary.

In conducting the assessment, moreover, the curriculum explicitly suggests that teachers use mathematics tasks that invite *divergent* answers, such as open-ended problems that can be solved by more than one strategy. But in most cases, teachers were unable to follow this suggestion since the textbooks do not provide these kinds of examples. Hence, there is a discrepancy between the formal curriculum and the operational curriculum. Teachers need to be supplied with exemplary materials with open-ended problems, or need to learn to construct these materials themselves. Furthermore, the curriculum guide (MONE, 1993) suggested that the methods used for teaching mathematics should be adapted to the characteristics of the concepts, strands, topics and the cognitive development of the pupils. Nevertheless, as has been extensively discussed in the Indonesia's newspaper , most teachers focus almost exclusively on teaching how to solve the specific mathematics tasks most likely to be found in the national examination. Therefore, their approach doesn't even attempt to foster true understanding of the mathematics concepts.

Experiential curriculum

This type of curriculum refers to the way that curriculum materials and instructional processes influence pupils' learning of mathematics in the classroom. Suryanto (1996) reported that the mathematics curriculum materials in the junior secondary level are lacking practical applications. This problem is also found in the primary schools. Hence, because the concepts are not experientially real to them, pupils perceive mathematics as a very abstract and thus a difficult subject compared to others. Besides, since the instructional process most often in use does not move the pupils to activity, they remain passive (Marpaung, 1995).

Attained curriculum

The attained curriculum (or learning outcomes of the pupils in mathematics) mainly refers to students' achievements and attitudes. It is mentioned in the curriculum guide (MONE, 1993) that in order to determine the achievement of the pupils, teachers should evaluate the pupil both during and at the end of the instructional process. However, based on the reports of Somerset (1997) and Suryanto (1996), most teachers do not focus on the formative evaluation (during the instructional process), but focus only on the summative evaluation (at the end). Therefore, measurements of the learning outcomes of pupils place emphasis on the cognitive part of the learning outcome. Changes in attitudes are not taken into consideration as learning outcomes. Furthermore, the MONE curriculum (1993) suggests that teachers should provide enrichment materials for pupils who want to deepen their knowledge of mathematics and remedial teaching for those who have difficulty in learning mathematics. However, very few teachers have sufficient time to conduct these kinds of activities in addition to their normal teaching responsibilities. The number of hours spent by teachers on instructional time in Indonesian junior secondary schools (including mathematics) is categorized at the highest level in the world (Mullis et al., 2000) – that is ranked 3rd of 38 countries. Hence, the gap between weak and the smart pupils tends to remain or even grow.

Based on the analysis of the mathematics curriculum for the Indonesian junior secondary level, it can be concluded that there are large disconnects between the intended and the implemented curriculum, as well as between the implemented and the learned curriculum (experiential and attained curriculum). This also means that there is a gap between the ideal mathematics curriculum and the attained curriculum of the pupils. In order to reduce that gap it is important to focus on the intermediate stage of curriculum – the implemented curriculum (Ottevanger, 2001) – since this stage may have the greatest influence on closing the gap.

As stated in *Chapter 1*, there were three issues in secondary mathematics education in Indonesia, namely: quality of curriculum materials, teaching methods and assessment strategies. This means there is a gap between the intended curriculum and the implemented curriculum. This study intends to investigate how the gap between the intended and the implemented curriculum can be reduced by introducing RME.

2.2 UNDERSTANDING RME

This section explains the theoretical background of RME. First, the underlying philosophy and the five tenets of RME are given. Then, the concepts of RME curriculum materials and RME exemplary lesson materials are presented.

2.2.1 Philosophy and characteristics of RME

As a theory of teaching and learning in mathematics education, RME has its own philosophy and characteristics. It encompasses views on what mathematics is, how pupils learn mathematics, and how mathematics should be taught. This theory is strongly influenced by Hans Freudenthal's concept of 'mathematics as a human activity' (Freudenthal, 1991). According to Freudenthal, pupils should not be treated as passive recipients of ready-made mathematics, but rather that education should guide the pupils towards using opportunities to discover and reinvent mathematics by doing it themselves.

The characteristics of RME can historically be related to the levels that Van Hiele distinguished in learning mathematics (cf. de Lange, 1996): (1) pupils reach the first level of thinking as soon as they can manipulate the known characteristics of a pattern that is familiar to them; (2) as soon as they learn to manipulate the interrelatedness of the characteristics they will have reached the second level; (3) they will reach the third level of thinking when they start manipulating the intrinsic characteristics of relations. Traditional instruction is inclined to start at the second or third level, while realistic instruction starts from the first level. In order to start at the first level – the one that deals with phenomena that are familiar to the pupils – Freudenthal's *didactical phenomenology* that learning should start from a meaningful contextual problem, is used. Furthermore, by *guided reinvention through progressive mathematization*, pupils are guided didactically to progress efficiently from one level to another level of thinking through mathematization.

The combination of Van Hiele's three levels, Freudenthal's didactical phenomenology and Treffer's progressive mathematization (Treffers, 1991) result in the five characteristics (tenets) of RME (de Lange, 1987; Gravemeijer, 1994):

- the use of contexts in phenomenological exploration;
- the use of models or bridging by vertical instruments;
- the use of pupils' own creations and contributions;
- the interactive character of the teaching process or interactivity; and
- the intertwining of various mathematics strands or units.

These characteristics can be used as a study guideline not only in the process of adapting RME curriculum materials to the Indonesian context, but also in the process of pre-service training for student teachers in teacher education. Each of the following sub-sections briefly describes a single characteristic.

The use of contexts in phenomenological exploration

In RME, the starting point of mathematics instruction should be experientially real to the student, allowing them to become immediately engaged in the contextual situation. This means that instruction should not start with the formal system. According to Romberg (1998), an opportunity should be provided for students to progress from informal notions in a mathematical domain (for example, algebra) toward using formal reasoning and representations to model and solve non-routine problems. In line with this, Cobb (1994, pp. 23-24) stated: "This implies that students' initially informal mathematical activity should constitute a basis from which they can abstract and construct increasingly sophisticated mathematical components. At the same time, the starting point situations should continue to function as paradigm cases that involves rich imagery and thus anchor students' increasingly abstract mathematical activity".

The phenomena by which mathematics concepts appear in reality should be the source of concept formation. The process of extracting the appropriate mathematical concept from a concrete situation is described by de Lange (1987) as *conceptual mathematization*. This process forces pupils to: explore the situation; find and identify the relevant mathematical elements; schematize and visualize in order to discover patterns; and develop a model resulting in a mathematical concept. By a process of reflecting and generalizing, the pupils will develop a more complete concept. It is then expected that the pupils will subsequently apply mathematical concepts to other aspects of their daily life, and by so doing, reinforce and strengthen the concept. This process is called *applied mathematization* (see Figure 2.1).

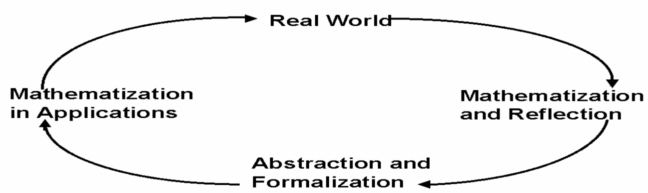


Figure 2.1
Conceptual and applied mathematization (de Lange, 1987)

The use of models or bridging by vertical instruments

The term *model* refers to situational models and mathematical models that are developed by the pupils themselves. First, the model is a *model of* a situation that is familiar to the pupils. By a process of generalizing and formalizing, the model eventually becomes an entity on its own. It then becomes possible to use this entity as a *model for* mathematical reasoning. Four levels of models in learning and teaching RME are described below (see also Figure 2.2):

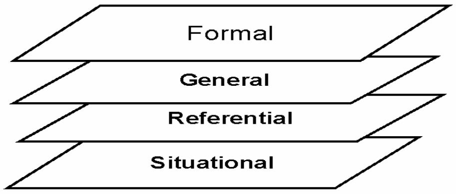


Figure 2.2
Levels of models in RME (Gravemeijer, 1994)

- the *situational* level, where domain-specific, situational knowledge and strategies are used within the context of the situation;
- *referential* level or the level 'model of', where models and strategies refer to the situation described in the problem;
- *general* level or the level 'model for', where a mathematical focus on strategies dominates over the reference to the context; and
- *formal* level of mathematics, where one works with conventional procedures and notations.

As an example from Gravemeijer (1994), in the first level, long division is associated with real-life activities such sharing sweets among children. Here, the pupils bring in their situational knowledge and intuitive strategies and apply them in the situation. The second level is entered when the same division of sweets is presented as a written task and the division is modeled with paper and pencil. Then, the focus is shifted towards strategies from a mathematical point of view. Now, the pupil is just dealing with the numbers, without thinking of the situation. Finally, the fourth level would be composed of the standard written algorithm for long division. This example shows how *self-developed (or emergent) models* of the pupils serve to bridge the gap between informal and formal knowledge (Gravemeijer, 1994).

The use of pupils own creations and contributions

Pupils should be asked to create concrete things. By making 'free production', pupils are forced to reflect on the their learning process. According to Streefland

(1991), pupils show greater initiative when they are encouraged to construct and produce their own solutions. In addition, free productions can form an essential part of assessment. For example, pupils may be asked to write an essay, to do an experiment, to collect data and draw conclusions, to design exercises that can be used in a test, or to design a test for other pupils in the classroom.

The interactive character of the teaching process or interactivity

Interaction between pupils and between pupils and teachers is an essential part in RME instructional processes. Explicit negotiation, intervention, discussion, cooperation and evaluation are essential elements in a constructive learning process in which the students' informal methods are used as a vehicle to attain the formal ones. In this interactive instruction, pupils are engaged in explaining, justifying, agreeing and disagreeing, questioning alternatives and reflecting. For instance, pupils are encouraged to discuss their strategies and to verify their own thinking rather than focusing on whether they have the right answer. Such activities can enable pupils to depend less on the teacher to tell them whether they are right or wrong. Hence, the pupils find opportunities to develop confidence in using mathematics.

The intertwining of various learning strands or units

In RME, the integration of mathematical strands or units is essential. It is often called the holistic approach, which incorporates applications, and implies that learning strands should not be dealt with as separate and distinct entities. Instead, an intertwining of learning strands is exploited in solving real life problems. One of the reasons that student have such difficulty applying mathematics is that it is taught 'vertically'– that is, with the various subjects being taught separately, neglecting the cross-connections. In practical applications, one usually needs more than algebra alone or geometry alone.

The five characteristics or tenets of RME are used as a guideline in designing curriculum materials.

2.2.2 Designing RME curriculum materials

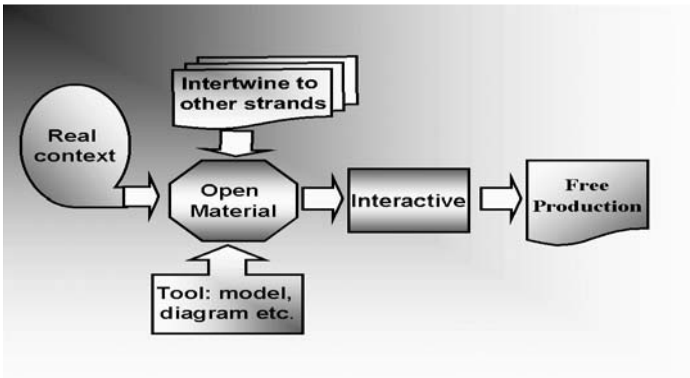
In order to design or redesign curriculum materials based on the realistic approach, they should represent the five characteristics of RME. Streefland (1991) developed realistic mathematics lesson materials (fractions in elementary school) using three levels of construction: the classroom level, the course level and the theoretical level.

The classroom level

At this level, instructional activities are designed based on all the characteristics of RME. Open material is introduced into the learning situation and opportunity is provided for carrying out free production. Then, characteristics of RME are applied to the lesson by:

- situating the intended material *in reality* which serves as *source* and as *area of application*, starting from meaningful contexts having the potential to produce mathematical material;
- *intertwining* with other strands or units such as fractions and proportions;
- producing *tools* in the form of symbols, diagrams and situation or context models during the learning process through collaborative effort;
- learning through construction is carried out by arranging student activities, so they can *interact* with each other, discuss, negotiate, and collaborate; and
- encouraging pupils to follow this kind of constructional activity by giving them an assignment that leads to *free productions*.

In summary, Figure 2.3 shows how all the characteristics of RME are pictured in a model for designing RME curriculum materials.



Source: (adapted from Streefland, 1991).
Figure 2.3
A model for designing RME curriculum materials

Course level

This level is also called the level of the instructional sequence. The materials constructed at the classroom level are now used according to their mathematical and didactical essence in order to shape the general outline of the course. At this level, after the materials from the classroom levels were tried out and revised, they are expanded to other contents and contexts in order to develop the instructional sequence of that topic. This means the measures taken to achieve contributions to the learning process at the local level must be continued at the general level.

Theoretical level

All activities that took place in both preceding levels, such as design and development, didactical reflection, and trying out in the classroom, form the source of theoretical production – the generative material for this level. Here, a theory in the form of a local theory for a specific area of learning is constructed, revised and tested again during additional cyclic developments.

The CASCADE-IMEI study focused on the classroom level, in which the exemplary lesson materials for some mathematics topics from the available realistic mathematics books were adapted to the Indonesian culture. The process of adaptation of these materials will be elaborated in Section 2.5.4.

2.2.3 RME exemplary lesson materials

RME exemplary lesson materials refer to learner materials and teacher guides. They can be used as a learning trajectory for teachers in the RME classrooms. They usually consist of the following main components: content materials, learner and teacher activities, and assessment.

Content materials

RME materials are associated with real-life activities where domain-specific, situational knowledge and strategies are used within the context of a genuine situation. A variety of contextual problems are integrated in the curriculum right from the start. But, the sequence of the contextual problems has to guide pupils to the mastery of a mathematical concept. Furthermore, the difficulty level of the contextual problems should be appropriate for the goals of the particular mathematics topic. De Lange (1995) characterized three levels of goals in mathematics education: lower level, middle level, and higher-order level. These three levels of thinking skill are seen as similar to the three 'competency classes' that are used by the PISA 2000 study to assess mathematical literacy. The three competency classes consist of (OECD, 2001):

1. reproduction, simple computation, and definitions; this requires students to do and compute of the type most familiar in conventional mathematics assessment;
2. connections and integration for problem solving; these are to be made between the different tools of the first competency class and the basic concepts to solve straightforward problems; and
3. mathematical thinking, generalization and insight; this requires students to engage in analysis, to identify the mathematical elements in a situation and to pose their own problems.

In the traditional program, the goals were classified as lower level goals that are based on formula skills, simple algorithms and definitions. In RME, goals also include 'middle' and 'higher' level goals. At the middle level, connections are made between the different tools of the lower level and the underlying concepts. It may not be clear in which strand the operations take place, but simple problems have to be solved without unique strategies. Moreover, the new goals also emphasize reasoning skills, communication and the development of a critical attitude. These are called 'higher order' thinking skills. In general, RME developers need to find contextual problems that allow for a wide variety of solution procedures – preferably those which, considered together, already indicate a possible learning process through a process of progressive mathematization.

Activities: The role of the teacher and pupils.

The role of the RME teacher in the classroom are (de Lange, 1996; Gravemeijer, 1994): a facilitator, an organizer, a guide and an evaluator. Generally, the roles of RME teachers can be seen from the following common teaching-learning processes:
1. Facilitate pupils with a contextual problem that relates to the topic as the starting point.
2. During an interaction activity, give the pupils a hint, for instance by drawing a table on the board, guiding the pupils individually or in a small group in case they need help.
3. Let the pupils find their own solution. This means that pupils are free to make discoveries at their own level, to build on their own experiential knowledge, and perform shortcuts at their own pace.
4. Organize and stimulate the pupils to compare their solutions in a class discussion. Ask the pupils to communicate, argue and justify their solutions. The

discussion refers to the interpretation of the situation sketched in the contextual problem and also to focus on the adequacy and the efficiency of various solution procedures.
5. Give other contextual problems.

The role of pupils in RME classroom is mostly that they work individually or in a group, they are active and should be more or less independent, they can not turn to the teacher for validation of their answers or for directions or for a standard solution procedure, and they are asked to produce free creations or contributions.

Assessment

In RME, the assessment functions not only in the margin of instruction, but it is also an integral part of the instructional process (de Lange, 1987; Van den Heuvel-Panhuizen, 1996). Ideally, during assessment activities, pupils can show their abilities to solve problems using different strategies. Moreover, through interactive discussions during the learning process, they can learn different strategies developed by other pupils. The strategies used by pupils can be good feedback for the teachers in order to improve the next lesson. In addition, pupils learn to use various strategies for solving problems during the exams.

De Lange (1987) formulated the following five guiding principles of assessment in RME:

1. The primary purpose of testing is to improve learning and teaching. This means that assessment should take place during the teaching-learning process in addition to at the end of a unit or course.
2. Methods of assessment should enable the pupils to demonstrate what they know rather than what they do not know. Assessment can be conducted by using problems that have multiple solutions and can be approached using multiple strategies.
3. Assessment should operationalize all of the goals of mathematics education: lower, middle and higher order thinking level.
4. The quality of mathematics assessment is not determined by its accessibility to objective scoring. For that reason, the use of objective tests and mechanical tests should be eschewed in favor of assessments in which we can see whether pupils truly understand the mathematical concepts involved.
5. The assessment tools should be practical, fit into the usual school practice.

Assessment can be conducted in the classroom using strategies both during the interaction process (formative), and products of their solutions (summative). In RME, both the process and product are considered important. Hence, these two assessment strategies should be applied in tandem when developing assessment materials.

In summary, the characteristics of RME curriculum materials, described above, are assumed to be better aligned with the intended Indonesian mathematics curriculum as compared with the current mathematics education – especially in junior secondary education. Hence, introducing RME in mathematics education in Indonesia might reduce the gap between the intended and the implemented curriculum, or even between the intended and the learned curriculum.

2.3 CURRICULUM IMPLEMENTATION

As a mentioned in Chapter 1, in order to introduce RME in Indonesia, some good implementation strategies are needed. This section presents the strategies for implementing the new curriculum.

2.3.1 Concept of curriculum implementation

Curriculum implementation can be defined as the translation of the intended curriculum into the operational curriculum, i.e. the classroom practice. Implementation is often presented as the second phase in a three-phase model of change: initiation, implementation and continuation (or institutionalization) (Fullan, 2001). *Initiation* is the process that leads up to and includes a decision to adopt or proceed with a change. In developing countries such as Indonesia, change programs are often initiated centrally, driven by political factors and by external agencies – especially if these agencies also provide funding for such programs. *Implementation* or *initial use* is the process that involves the first experiences of attempting to put an idea or reform into practice. *Continuation or institutionalization* refers to whether the change gets built in as an ongoing part of the system or the normal practice of an institution or a school, or disappears, such as by way of an explicit decision to discontinue the change or through attrition. A continuation requires successful implementation and needs to be planned for and given ample attention during the implementation phase.

2.3.2 Strategies in curriculum implementation

Three strategies are often used when implementing an innovation in schools, that is: treating teachers as learners, using exemplary curriculum materials and learning by designing. Each of these strategies is briefly discussed below.

Treating teachers as learners

The teacher has a key role in the implementation of a curriculum innovation in the classroom (van den Akker, 1998). Putting a new curriculum into practice requires teachers to learn new roles. According to Fullan (2001), this requires a change in their beliefs, teaching approach and use of materials. Therefore, curriculum reform can be seen as a learning process for teachers. They are required to use new or revised materials and to make use of new teaching methods. In addition, in many cases curriculum reform will involve a change in teachers' beliefs about student learning. Professional development during the implementation of curriculum reform is therefore important.

Comiti and Ball (1996) suggested that pre-service teacher education must recognize student teachers as learners. They must have a chance to experience new approaches and to master new content in order to learn some important aspects of that approach. Also, they should be able to reflect with colleagues and others on what happens in the classroom. Peer collaboration can play an important role in this process (Thijs, 1999).

Initial use of exemplary lesson materials

Exemplary lesson materials can contribute to the additional support for teachers during an implementation process. Such materials are useful for teachers if they contain many so-called *procedural specifications,* which are very clear and specific directions for use, including instructional and technical guidelines. These directions for use should focus particularly on essential, yet vulnerable elements of the curriculum innovation (van den Akker, 1998). From an implementation perspective, exemplary lesson materials can be seen as materials for teachers that serve as a catalyst for curriculum implementation (van den Akker, 1998; Ottevanger, 2001).

Furthermore, Ball and Cohen (1996) state that exemplary curriculum materials can better contribute to professional practice when they are created with closer

attention to the process of *curriculum enactment*. A curriculum enactment is constructed jointly by teachers, students and materials in particular contexts, even if it seems to be only a partial reconstruction of supplied materials. Materials could be designed to place teachers in the center of curriculum construction and make teachers' learning central to efforts to improve education, without requiring heroic assumptions about each teacher's capacity as an original designer of curriculum.
As teachers enact curriculum in and with their classes, they work across five domains:

- teachers are influenced by the trajectory of their learning of the content, what they think about their students, about what students bring to instruction, and students' likely ideas about the content;
- teachers work with their own understanding of the material, which shapes their interpretations of what the central ideas are, and how to respond to students' ideas;
- teachers fashion the materials for students, choose tasks or models, and navigate instructional resources such as textbooks in order to design instruction;
- teachers must manage the classroom interaction in such a was as to increase the intellectual and social environment of the class; and
- teachers are influenced by their views of the broader community and contexts in which they work.

Functions of exemplary lesson materials were differentiated by van den Akker (1998): helping to create an image regarding the lesson organization; providing teachers with aids to realize an effective lesson in accordance with the initial intentions of the designer(s); and stimulating reflection on the teachers' roles and stimulation of any possible adaptations of the teachers' attitudes towards the innovation. These functions should be represented both in the learner materials and in the teacher guide.

Learning by designing

After being treated as learners and having gained experience with the use of exemplary lesson materials, teachers may be involved in redesigning curriculum materials that they can use in their teaching practice. Wiggins and McTighe (1998) pointed out that in order to make learners fully understand what they are learning, they should be asked not only to explain and interpret, but also to apply their knowledge and skills by using and adapting what they know into different contexts. Before teachers teach a mathematics topic in the classroom, they have to consider the learning goal, the learning activities and the thinking and learning in which the pupils might be engaged. All of these aspects are brought together in a lesson plan. Simon (1995) refers to this plan as being a 'hypothetical learning trajectory'. Simon calls the learning trajectory hypothetical because the actual learning trajectory is still not known before the real instructional activities are carried out. Then, after the plan has been used in the classroom, it can be revised for use in the next subsequent lesson. This strategy shows similarities to one of the tenets of the RME: that learners need to be invited to reflect on what they have learned, by for example, designing exercises or mathematical problems that can be used in a test of for other pupils in the classroom.

Based on this line of reasoning, Gravemeijer and Cobb (2001) suggest lending support to teachers by creating a resource of exemplary lesson materials as a starting point, so they can redesign these materials to suit the specific needs of their situation. Moreover, Seegers and Gravemeijer (1997) suggest that the support for teachers in implementing the RME curriculum covers not only the content of the instruction (sequences of materials) but also the development of micro-didactic knowledge or the nature of instructional practice that deals with the character of the teaching/learning process. They argue that it is only on this micro-didactic level that beliefs may play an important role.

In this study, these strategies are used and integrated in the process of supporting student teachers in learning how to teach with a RME approach in the context of pre-service teacher education.

2.4 TEACHER LEARNING IN PRE-SERVICE EDUCATION

This section describes processes and problems of pre-service mathematics teachers learning to teach for the first time according to a new approach. First, an elaboration on the concept of learning to teach is given. Then, the current practice in pre-service education in Indonesia is presented.

2.4.1 Pre-service mathematics teachers learning to teach

In this context, learning means *learning to teach* while using new teaching methods in the classroom. According to Borko and Putnam (1996), learning to teach is a complex process. Novice teachers must learn multiple sets of knowledge, skills and attitudes in order to be well prepared to enter the teaching profession. They must learn enough classroom management skills to maintain order in a classroom, and to keep students motivated and productively engaged. They must learn about the subject matter that they will have to teach, as well as about their pupils and how they learn, and so on. Moreover, Arends (1994) pointed out that learning to teach can be seen as a process in which development progresses rather systematically through stages. An opportunity for growth can fail to yield fruit unless appropriate experiences occur.

Basically, new teachers have three types of concerns when in the process of learning to teach (Arends, 1994; Borko & Putnam, 1996). First, *personal factors* refer to the concern about their own personal survival when new teachers have their first classroom experiences. They worry about their interpersonal adequacy and whether or not their pupils and their supervisor respect and like them. Also, they worry about the adequacy of their content knowledge, pedagogical knowledge and beliefs required for teaching for understanding in ways that are currently advocated in the educational community. Secondly, beginning teachers have concerns about the *teaching situation* in the schools. Those aspects can include: too many students, inappropriate teaching materials, teaching method and assessment strategies. Finally, beginning teachers have concerns about their *pupils*. In this stage, they reach for higher-level issues and start asking questions about the social and emotional needs of pupils, being fair, and the match between the teaching strategies and materials.

2.4.2 Mathematics pre-service teacher education in Indonesia

The current Indonesian pre-service teacher education uses the curriculum from 1996. In the department of mathematics education, courses are categorized into four types (see also Table 2.1):

Table 2.1
Courses categories in Indonesian teacher education

Year/Course	**Foundation**	**Content**	**Method**	**Teaching practice**
First	✓	✓		
Second		✓	✓	
Third		✓	✓	
Fourth				✓

(1) foundation of education studies or general education including theory of education, management of education as well as guidance and counseling; (2) subject matter studies or content mathematics courses such as Geometry, Calculus, Algebra, Statistics and Computation mathematics; (3) professional studies or method courses such as teaching approaches, development of teaching preparation, seminars in mathematics education, secondary education curricula and assessments; and (4) teaching practice as well as research or a final project in mathematics education. These categories are consistent with Ben-Peretz's (1994) conclusion about teacher education curricula in the world, that most of them are categorized in four types: foundation of education studies, subject matter studies, method courses and teaching practice.

Practice in laboratory schools plays an important role in pre-service mathematics teacher education. It is usually conducted in one of two ways, either in the method courses or in teaching practice. In the method courses, student teachers perform both as curriculum developers and as teachers. They have to prepare the instructional activities along the traditional stages of curriculum development, that is: defining objectives, selecting content and learning experiences, choosing appropriate methods and classroom organization, gathering or developing the necessary materials, and making decisions about formative and summative evaluation. Then, they perform as teachers, trying out the materials using the new teaching methods in classroom practice. At the end of the course, they have to make a report and present it in front of their colleagues and teacher educators.

Similar activities are carried out in the final year, when they are doing practice teaching. In this time, student teachers also perform both as curriculum developers and as teachers, during which they have to develop their curriculum materials, implement them in the classroom and reflect on their experiences. These kinds of curriculum development activities (preparing lessons and accompanying materials, carrying out those plans and reflecting on what occurred) can increase the professional growth of student teachers (cf. McKenney, 2001).

Yet, the issue remains that pre-service mathematics teachers in Indonesia do not receive adequate preparation for their teaching practice. This could be caused by some obstacles that are often discussed among teacher educators. First, student teachers do not have enough resources for learning to teach, such as method books, lesson examples or electronic tools (e.g. video). Second, they have only limited time allotted for learning how to teach, since they also have to follow other courses that do not deal with teaching mathematics. Finally, they do not get a good teaching model from the method courses. Teacher educators often focus on the theoretical part but less on practical aspects. It is also mentioned by Borko and Putnam that teacher educators place greater emphasis on facts and procedures than on understanding the disciplines they need for teaching.

In conclusion, it is clearly understood that learning to teach using a new approach is not an easy task for student teachers. They have to master a set of skills related to the content to be taught, how pupils learn and how to teach. Besides, they have to learn how to develop their instructional activities and to teach using a new teaching method in the classroom practice. Therefore, the current approaches used in Indonesian teacher education could be improved upon in order to address these complexities in a better way.

2.5 FRAMEWORK FOR THE LEARNING ENVIRONMENT

This section summarizes the results of the problem analysis and literature study from all earlier sections, culminating in the conceptual framework of the study that is illustrated in the Figure 2.4.

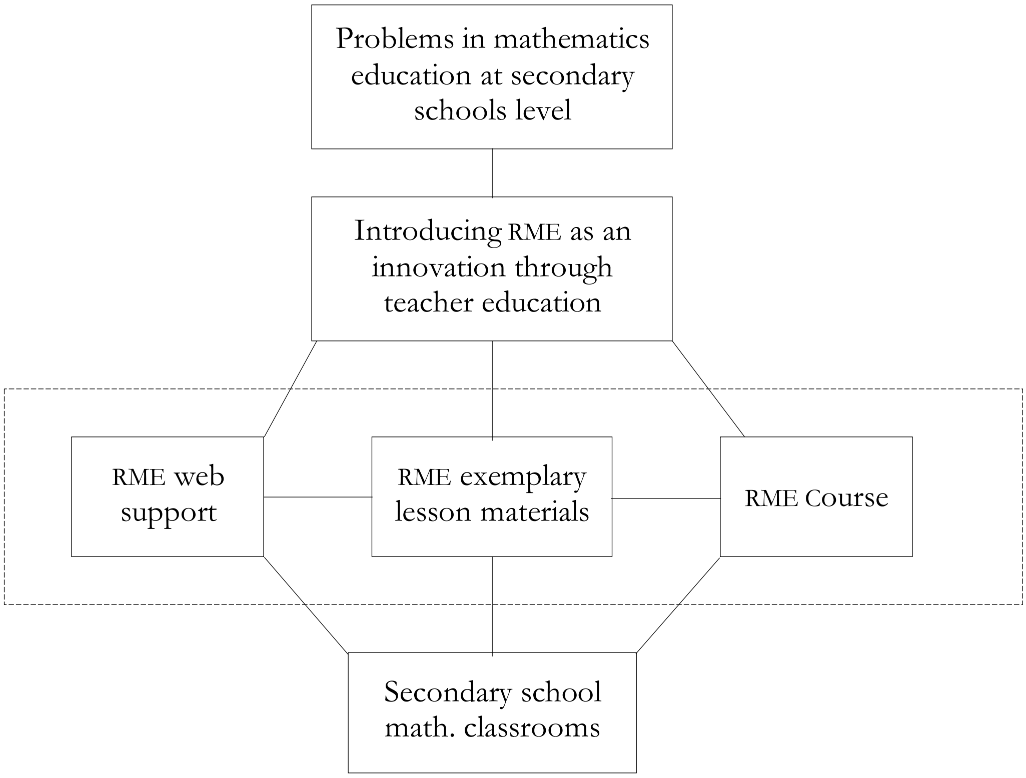


Figure 2.4
Conceptual framework of the CASCADE-IMEI study

From top to bottom, the framwork reads as follows. First, the literature study revealed, there are problems in the secondary mathematics education in Indonesia that are related to the pupils' understanding and attitude towards mathematics. These problems are assumed to be (at least partly) caused by the gap between the intended curriculum and both the implemented curriculum and the learned curriculum.

Second, this study takes as a starting point that the gap can be reduced by introducing RME in the secondary schools by mathematics student teachers. However, introducing RME as an innovation in teacher education in Indonesia is a complex process that involves changes in use of materials, teaching methods and beliefs. As a new approach in Indonesia, there are no books, papers or other materials related to RME. Third, it would seem unlikely that these obstacles could be overcome by a short pre-service course. Hence, it is assumed in this study that a learning environment is needed in which student teachers can learn not only the theory of RME, but also the skills relating to how to use that knowledge in redesigning their own materials, and to teach using these materials in the classroom. The dashed line in the Figure 2.4 shows the main structure of the LE, being composed of three main components: the web support, the exemplary lesson materials and the RME course.

Finally, after student teachers learn RME in the learning environment, they may introduce the new approach in secondary school classrooms leading to better understanding of and attitude towards mathematics.

Sections 2.5.1 through 2.5.4 describe the concept of the learning environment and the three main components of the learning environment in more detail.

2.5.1 Learning environment

In general, a learning environment (LE) is a place where learning occurs. Wilson (1996) defines a 'constructivist' learning environment as a place where learners may work together and support each other as they use a variety of tools and information resources in their pursuit of learning goals and problem solving activities. He states that at a minimum, an LE contains: the learner and a setting or a space in which the learner acts using tools and devices, collecting and interpreting information, interacting with others, etc.
Moreover, Perkins (1991) makes a distinction between 'minimalist' and 'rich' LEs:

- 'Minimalist' or 'traditional' LEs include *information banks* or sources of information (e.g. textbooks, videotapes), *symbol pads* or surfaces for the construction and manipulation of symbols and texts (e.g. drawing programs, word processors, databases); *task managers*-elements of the environment that set tasks, provide guidance, feedback and changes in direction (such as teacher, student, and computer-based instruction programs).
- 'Rich' or 'constructivist' LEs contain more: *construction kits* or areas for presenting, observing and manipulating less natural phenomena (e.g. simulation programs and games); and *phenomenaria,* or areas for presenting, observing and manipulating natural phenomena (e.g. teaching simulation, teaching practice); as well as place more control of the environment in the hands of the learners themselves. Students in constructivist LEs are typically engaged in multiple activities in pursuit of multiple goals, with the teacher serving the role of guide and

facilitator. An example of a contructivist or rich LE is called a REAL (rich learning environment for active learning) (Grabinger, 1996). A REAL is one attempt to bring together thoughts, ideas and theories in a way that will help teachers at all levels to develop classroom environments that foster higher-level thinking skills – especially reflection, problem solving, flexible thinking and creativity.

Finally, Wilson (1996) categorized LEs into three types:

- *Computer-based LE* such as computer microworlds. In these microworlds, students 'enter' a self-contained computer-based environment to learn. These microworlds may be supported by a larger classroom environment, but may also stand alone.
- *Classroom-based LE*. In many settings, the classroom is thought of as the primary learning environment. Various technologies may function as tools to support classroom learning activities. An example of a classroom-based environment is Grabinger's (1996) Rich Environments for Active Learning (REALs).
- *Virtual LE*s that make use of the Internet. Some computer-based learning environments are relatively open systems, allowing interactions and encounters with other participants, resources and representations. In a virtual environment, students interact primarily with other networked participants, and with widely disseminated information tools. Open, virtual environments have tremendous potential for learning, but they carry their own set of design challenges and concerns.

The last two types of LE are used in this study, that is the RME course (classroom-based LE) and the web support (virtual LE).

2.5.2 Classroom-based learning environment (RME course)

As described in section 2.3.1 and 2.3.2, learning to teach using a new approach is not an easy task. It requires learning the approach not only theoretically, but also practically. The learners need an environment in which they can practice how to prepare teaching materials, how to use the materials, how to manage the classroom, how to deal with pupils, etc. Hence, it is important to provide such a classroom-based environment (e.g. RME course) that could assist student teachers in their learning.

In so doing, Borko and Putnam (1996) summarized their analysis results of facilitating teachers' learning to teach into five features that can contribute to successful learning opportunities for new teachers. These are:

1. addressing teachers' pre-existing knowledge and beliefs about teaching, learning, learners and subject matter;
2. providing teachers with sustained opportunities to deepen and expand their knowledge of subject matter;
3. treating teachers as learners in a manner consistent with the program's vision of how teachers should treat students as learners;
4. grounding teachers' learning and reflection in classroom practice; and
5. offering ample time and support for reflection, collaboration, and continued learning.

Points 3 and 4 are similar to the second strategy of the curriculum implementation (see also section 2.3.2). All points could be provided by a classroom-based learning environment (either in teacher education or school classroom).

In addition to these features, Comiti and Ball (1996), who organized their research about preparing teachers on three teacher education institutions in Germany, France, and the USA, suggest three ways of helping teachers to teach mathematics in pre-service teacher education:

1. help student teachers to learn all mathematics approaches and their views of how mathematics is taught and learned;
2. help student teachers to learn about pupils' mathematical thinking, and how to teach mathematics while taking into account the pupils' ability; constructing learning situations that give meaning to mathematical subjects; and
3. coach student teachers in developing their capacity to learn, in thinking about their actions and thereby transforming them, in thinking about what they wanted to do and what they actually did, thinking about their practice, and becoming able to search for and use resources.

The first two points are related to the first implementation strategy (see also section 2.3.2), i.e. that student teachers should have the learners role so they could learn both the materials and experience how to teach with those materials. In addition, the third point is similar to the second implementation strategy or the use of exemplary lesson materials.

In the context of RME, Goffree and Oonk (1999) reported that training for developing RME teachers in the Netherlands should be based on the theory of RME itself. This is in line with previous recommendations to treat student teachers as learners. During the time in which the student teachers learn RME, their learning process in the course should be analogous with mathematics learning of pupils in the classroom. The training has some main steps:

1. Use of real contexts. Give student teachers concrete situations and familiar contexts as a starting point of the training (the first characteristics of RME) so they are directly engaged and come up with their own informal solutions, which are affected by their earlier experiences with learning mathematics and teaching mathematics.
2. Mathematizing and didactizing. Guide student teachers by using sequences of problems into the process of both mathematizing and didactizing.
3. Reflection. Ask student teachers to carry out mathematical activities appropriate for pupils' ability levels, and then reflect on and discuss the results in small groups with their peers. These reflective discussions create a foundation for learning how to work with pupils. Reflections on childrens' learning process combined with the student teachers' own experiences in learning mathematics contribute to the creation of an educational basis for teaching mathematics to pupils. During this process, student teachers work with pupils and study their learning process while continually referring back to their own learning process.

During the training, student teachers not only learn how to mathematize but also how to didactize. While the former is related to the materials, the latter is related to the teaching/learning process, which Gravemeijer (1997) calls micro-didactic knowledge.

Finally, regarding the structure of the mathematics education course for student teachers, the suggestions given by Selter (1997, 2001) can be used. He suggests including four important sessions in teacher education, including sessions on:

1. understanding the new approach by providing a theoretical overview and by actually doing mathematics (the mathematical component);
2. designing instructional materials (the didactical component);
3. managing the new situation in the classroom during teaching practice (the practical component); and
4. understanding the ways that pupils learn mathematics in the school classrooms (the assessment or psychological component).

These four components are used in the RME course or the classroom-based learning environment. The course is mainly supported by another environment – that is a virtual environment or web support. The next section elaborates the web support and its development guidelines.

2.5.3 Virtual learning environment (web support)

It is assumed in this study that a web-based support tool can play a valuable role in improving the performance of student teachers in learning and teaching RME, and that such a tool can be used by mathematics student teachers in the long term.
Web-based support tools are strongly related to the domain of electronic performance support systems (EPSSs). As briefly discussed in the section 1.3.2, an EPSS is an electronic system that provides performance support such as information, advice, learning opportunities and tools to its users (Gery, 1991; Nieveen, 1997; Stevens & Stevens, 1995). The purpose of an EPSS is to support the performance of a job or task. In this study, the system aims to support the performance of mathematics student teachers learning and teaching using the RME approach.

In order to achieve this goal, the EPSSs include components which should be ideally available on demand at any time, any place, and regardless of the situation. An EPSS typically includes some or all of the following five components (Gery, 1991; Raybould, 1995):

1. Tools – referring to external applications that can help users carry out tasks, such as calculator, forms, templates, etc.
2. Information – referring to electronic access to reference information, which remains the same for various users.
3. Learning/training opportunities – referring to embedded programs such as interactive tutorials and multimedia (e.g. video clips) used to improve learners' or teachers' knowledge and skills.
4. Advice – referring to heuristic and dynamic support materials, which are provided based on users' specific needs or questions.
5. Communication aids – referring to support for sharing knowledge with others or for using the mailing list in which they can communicate with each other.

A web-based EPSS is an EPSS that uses the Internet as its delivery platform. These EPSSs provide: (1) information and resources that can be accessed by users from all over the world and (2) tools for communication and exchange of ideas using e-mail facilities and newsgroups (Khan, 1997).

Generally, developing a system on the web offers distinct advantages. First, a large amount of resources are readily available. There are vast amounts of information online that can be repackaged and linked to the system's users. Second, the web provides a system that can be reached by a large population. In addition, it offers the ability to easily update and add information without huge investments in time and resources (unlike republishing and distributing printed materials). Moreover, the web with its graphics and hyperlinks is fairly intuitive to use. Ease of use is important since many target users are not proficient web users or even computer users. Finally, the web offers communication capabilities such as e-mail and mailing lists. Web browsers often contain a built in set of tools that can be used for communication.

These advantages seem to match the needs of student teachers in Indonesia, which is a big country with a large and dispersed population. This means that developing web support for mathematics student teachers in Indonesian teacher education may provide an added value to the future of mathematics education in Indonesia. Hence, it is seen as worthwhile for the CASCADE-IMEI study to design and develop a web support system in addition to the RME course, in order to help mathematics student teachers in Indonesian teacher education in learning RME as a new approach in mathematics education.

Based on the five common components of an EPSS and studies of Kirkley and Duffy (1997), Khan (1997), Nieveen (1997), and Winnips (2001), several tentative guidelines for the support of the web site were formulated (see Table 2.2).

Table 2.2
Guidelines for support offered via the web

EPSS Components	**Support offer by the LE**
Tools	support users in performing their tasks in learning RME. For instance, tools can support student teachers in learning how to redesign RME lesson materials in order to meet their immediate teaching needs.
Information	▪ provides general information about RME that is needed by users. ▪ includes web addresses (URLs) that consist of information that strongly relates to the job of mathematics student teachers.
Training	provides opportunities for the users to learn how to teach RME in the classroom.
Advice	provides facilities in such a way that student teachers can learn how to use the web site, how to deal with new concepts by asking questions directly to the developer, or by looking up a new RME term in a glossary.
Communication	provides users with some tools for communication and discussion.

The interface of the web site should be designed to accommodate users so they can easily access the support components on the web; to be user-friendly; and to easily navigate around the web. Table 2.3 summarizes the guidelines for the user interface of the web site (Khan, 1997; Winnips, 2001). They are categorized into four parts: general, content, navigation and lay out.

Table 2.3
Guidelines for the user interface of the web site

General	▪ The web-based LE should be: ▪ *flexible,* by the fact that one of the advantages of the web site is that the content can be constantly updated; ▪ *simple* in the use of colors, text and navigation; and ▪ *consistent* when using the graphics and text.
Content	▪ The content of a site should be appropriate for its intended users. Appropriate relates not only to the material itself, but also to the way in which it is expressed. ▪ The web page should be designed for transmission of information in both directions.
Navigation	▪ Place navigational buttons on the same location on the screen throughout a program, so that the user can always find them in the same place. ▪ Don't let the user get lost in the information; a web page should contain no more than two to three screens worth of information. ▪ Make sure the users have a good overview of the structure of a site, so that they can easily find their way to what they want. ▪ Keep the users oriented by using the logo on each page . ▪ Menus lose their value if they don't carry at least four or five links; text or list-based menu pages can easily carry a dozen links without overwhelming the user or forcing users to scroll through long lists.
Layout	▪ Choose background and text so that there is enough contrast. ▪ Be consistent in the style of graphics used in a product. ▪ Set as few heading styles and subtitles as are necessary to organize the content, then use the chosen styles consistently. ▪ Use space effectively. ▪ Page design in HTML should emphasize the power of hypermedia links to take full advantage of this medium. ▪ The page should look attractive and inviting; making a structured pattern can help to accomplish this.

All of these general guidelines have been and will be used in the design and development of the web support.

2.5.4 RME exemplary lesson materials

Ball and Cohen (1996) pointed out that curriculum materials are of paramount importance to (student) teachers. In everyday teaching practice, curriculum materials are the essential substance of lessons and units, i.e. of what teachers and pupils actually do. Moreover, curriculum materials are agents of instructional improvement. The design and dissemination of curriculum materials is one of the oldest strategies for attempting to influence classroom instruction, either for conventional teaching or as a means to shape what pupils learn. Also, curriculum materials and teachers' guides could support teachers' learning.

RME exemplary lesson materials can be seen as the main materials of the learning environment. The materials may be adapted either from RME books that were developed by Freudenthal Institute experts or from 'Mathematics in Context' (MIC) books (mathematics books for student grade 5-8 in the USA). This series of books was developed during a collaborative project between the Freudenthal Institute and University of Wisconsin-Madison. Therefore, it is assumed that the materials are valid from RME theoretical point of view. However, some special alterations are needed before these materials are suitable for the Indonesian context, such as: examples, curriculum level and the number of problems.

The MIC curriculum materials consist of two main parts: student materials and a teacher guide. Basically, the student materials have the same content as the teacher guide except for the following main components, which are only found in the teacher guide (Romberg & de Lange, 1998a):

- logistical preparation of lesson such as topic and time;
- explanation of learner activities, goals and concepts addressed in the lesson;
- materials or media that are needed in the lesson such as student activity sheets, student assessment materials, etc.;
- learning trajectory about context used and learning activities;
- learning trajectory about assessment activities;
- alternative solutions of each problem and sample student work;
- explanation of how to execute the lesson for each problem such as grouping, homework and assignments; and
- hints and comments about problems.

In general, the RME exemplary lesson materials may be adapted based on the following guidelines concerning the content, support and organization of the materials (Gravemeijer, 1994; 1997; Romberg & de Lange, 1998a; van den Akker, 1998):

- The *content* of the RME exemplary lesson materials should be adapted based on the junior secondary mathematics curriculum in Indonesia. The process of adapting materials should be guided by the characteristics of RME.
- The *support* part of the curriculum materials should consist of procedural specifications or essential characteristics on how to use them. For example, it should consist of concrete suggestions on the role of the teacher during the realization of the lesson. Also, the support should include information on the logistics of lesson preparation, such as what teachers should do before, during and after the lesson.
- The *organization* of the exemplary materials should help student teachers in putting them to use in the classroom. Preferably, the materials consist of student materials, teacher materials and assessment aids on various topics, parallel with the curriculum being used in schools.

Based on these guidelines, all prototypes of the lesson materials have been adapted and developed. These design guidelines should be taken into account when assisting student teachers to use the materials, to develop lesson materials by adapting the available materials and to implement those materials in classroom practice.

The next chapter discusses how the LE has been designed and developed using a development research approach.

CHAPTER 3
DESIGN AND EVALUATION OF THE LEARNING ENVIRONMENT

The process of the design and evaluation of five successive versions of the learning environment (LE) is explained in this chapter. Section 3.1 introduces the design process and evaluation approach of the LE and a general overview of all LE prototypes. Sections 3.2 and 3.3 present the design and evaluation of the initial prototype of the LE in the preliminary stage of the CASCADE-IMEI study. This prototype focused on the online component of the LE. Sections 3.3 through 3.9 describe the design and evaluation of three subsequent prototypes of the LE that focused on online and offline support. Each section starts with the description of the prototype including its content, support and interface. Then, the formative evaluation activities, along with the revision decisions for the next prototype, are described. Finally, the chapter concludes with a description of the final version of the LE (section 3.10), including a 'guided tour' of the web site.

3.1 DESIGN PROCESS AND EVALUATION APPROACH

This section will briefly introduce the design process of the five prototypes of the learning environment, together with the formative evaluation approach. At the end of the section, the general overview of all prototypes is presented.

3.1.1 Design process of the LE

As mentioned in section 1.4.2 of Chapter 1, the design process of the learning environment was driven by the prototyping approach. Using this approach, the LE proceeded through two stages with five prototyping cycles. Each prototype focused on the three main features (content, support and interface) of the three main components of the LE (RME course, web site, and exemplary lesson materials). At the end of each prototyping cycle, formative evaluation activities were conducted and revision decisions were made based on the comments and suggestions. During the revision of each prototype, revision decisions and new design ideas were integrated.

The preliminary stage of the CASCADE-IMEI study resulted in the initial prototype of the LE. This prototype focused only on the content, support and interface of the web site. At the end of this stage, a small-scale formative evaluation activity was carried out at the University of Twente. More detailed information regarding the initial prototype and its accompanying evaluation can be found in Sections 3.2 and 3.3.

The prototyping stage resulted in the four prototypes of the LE that are referred to as the first, second, third and final version. All prototypes focused on the content, support and interface of the web site, course and exemplary lesson materials. At the end of each prototyping cycle, a formative evaluation was carried out either in the Netherlands (both at the University of Twente and the Freudenthal Institute) or in Indonesia (at the UPI Bandung). The evaluation approach used in the Netherlands consisted mainly of expert appraisal, whereas cooperative evaluations and tryouts were used in Indonesia. More detailed information regarding the prototyping stage (first, second and third prototypes) can be found in Section 3.4 through section 3.9. The final version of the LE can be found in Section 3.10.

3.1.2 Formative evaluation approaches

During the prototyping stage, attention was paid to the validity and practicality of the content, support and interface of the LE. Formative evaluation of each prototype was prepared and conducted using three main approaches: *expert appraisal, cooperative evaluation,* and *try-out* (Nieveen, 1997; Tessmer, 1993).

Expert appraisal. Various experts were invited to judge the validity and in some cases the practicality of the LE during expert appraisals. Two experts in the field of RME were asked to review the validity and practicality of the content and support of the prototype both in the first and second prototype. In addition, two experts in the field of computer supported curriculum development, an expert in the field of teacher training, and an expert on web-site development were asked to review the user interface of the web-based prototype. Their comments were interpreted and used as grounds for the revision decisions.

Cooperative evaluation. The cooperative evaluation approach reflects the important role of the users during the development process. It encourages users to work with the prototype. Cooperative evaluation was chosen to gain insight into the practicality of the prototypes of the web site. Nieveen (1997) explains that by using this method, users (one-by-one) work through a set of tasks with the system. The task must be representative of the work that the product will support. The tasks are selected by the designer of the prototype because free use of the prototype is often not possible with a partial product. While the users work with the prototype, they are encouraged to think aloud (explain to designer what they are doing) and to ask questions about aspects that are not clear. On the other hand, the designer of the prototype may also ask the users questions and look for unexpected behavior and comments from the user. Because this evaluation method is focused on prototypical products, users may encounter some problems during their task performance, for instance because of technical errors or software glitches. If this happens, the designer of the product will assist the user in order to prevent any major delays. This type of evaluation provides an indication that revision decisions may be required.

Try-out. A try-out is a situated evaluation, where instruction is evaluated in the same environment in which it will be used when it is finished. It the CASCADE-IMEI LE study, this method was used to gain insight in the following three areas: to confirm the revisions made in previous formative evaluations; to generate final revision suggestions; and to investigate the potential effects of the instruction.

All of these evaluation approaches were used in the formative evaluation of the prototypes, as is illustrated in Table 3.1.

Table 3.1

Focus of the formative evaluation of the learning environment

	Prototype version, research location, and number of participants							
	Initial	**First LE**		**Second LE**		**Third LE**		**Final**
	Neth	*Neth*	*Indo*	*Neth*	*Indo*	*Neth*	*Indo*	*Indo*
Quality aspect	*U = 2* *E = 2*	*E= 2*	*U=12*	*E=4*	*U=4*	*E = 0*	*U=8*	*U =10*
Validity	EA	EA		EA				
Practicality	CE		CE		CE		CE/TO	TO
Effectiveness			TO		TO		TO	TO

Note: CE = Cooperative evaluation, EA = Expert appraisal, TO = Try-out, U= Users, E= Experts, Neth = Netherlands, Indo = Indonesia.

3.1.3 Overview of the prototypes of the LE

This section provides an overview of all prototypes of the LE that are explained in the next sections. For each prototype, the overview includes the content, support and interface of the web site; the activities and support in the course; and the RME lesson materials.

Web site

Throughout the prototyping stage, the *content* of the web site expanded. The initial web site only provided the theoretical background of RME. All pages were written in English. In the first prototype of the web site, two examples of RME lessons and the assessment materials were included. In the second prototype, examples of students' productions or students' work were added. Also, some pages of the web site were translated into the Indonesian language. In the final prototype of the web site, all web pages are available in two languages: English and Indonesian.

The kind of *support* offered by the web site evolved from one prototype to the next. Table 3.2 illustrates the general characteristics of the support of the web site in each prototype of the LE.

Table 3.2
Overview of support of the web site of each LE prototype

Support offered by the web site		**Initial**	**First**	**Second**	**Third**	**Final**
Task	Number of topics of mathematics lesson materials	–	2	4	5	5
	Examples of student's production	–	–	√	√	√
Tutor	Tutorial in text	√	√	√	√	√
	Video clips on teaching and learning RME	–	–	–	–	√
Tool	Lesson builder	√	√	√	√	√
	Java applet simulation and mathematical game	–	√*	√	√	√
	Links to other related sites	√	√	√	√	√
	RME papers	–	–	√	√	√
Help	On-line Help	√	√	√	√	√
	Glossary	√	√	√	√	√
	FAQ	√	√	√	√	√
	Map	√	√	√	√	√
Talk	Feedback form by e-mail	–	√	√	√	√
	Bulletin board	–	–	√	√	√
	Mailing list	–	√	√	√	√
Test	Problem of the month	–	–	–	√	√

Note: – = Support is not available; √ = Support is available; √* = Links to other web sites are available.

The *interface* of the web site also changed from the initial to the final version of the prototype. A general overview of the changes can be found in the Table 3.3.

Table 3.3
Overview of user interface of the web site of each LE prototype

User interface	Initial	First	Second	Third	Final
Main menu	with text explanations on the right screen	no text explanations	=	=	=
	no sub menu	with sub menu	=	=	=
Template	not complete for all parts of a lesson format	complete	=	=	=
	in two pages	in one page	=	=	=
Screen area	menu and navigation areas are on the both left and right of the screen; the rest used for the content area.	sub menus are on the right screen	=	sub menu are moved to the left	=
	front page and the main menu are in the same page	=	=	The new front page added	=
Color	many colors were used	colors were reduced	=	=	=
Text	much text was used	amount of text was reduced	=	=	=
Images	for menu options & logo	flags for language choice	figures for lessons	text are added to the figures	=
Navigation	clickable only in main menu	also in sub menus	=	=	=
	Buttons	including text	=	=	=
Help Location (map)	√	√	√	√	√
Help Screen	√	√	√	√	√
Logo	only tangram	=	photos added	=	=
	not clickable	clickable	=	=	=
Buttons	use for main menu, home, back and forward	=	=	=	=

Note: √ = Available; '=' = Similar.

RME course

Regarding the RME course, the *activities* of the course were divided into the following sections: theoretical background, doing mathematics, didactics, peer teaching, teaching practice in the school, reflection by either group discussion or by seminar. All of these activities were included in each prototype of the RME course (of the LE), except for the seminar that was only given in the third and final version of the LE.

Moreover, the *support* that was mainly provided by the course included theoretical resources, RME exemplary lesson materials, advice/coaching, the web site, and video display. All of these were provided in each prototype of the RME course (or the LE), except for the video display, which was only used in the final version of the LE.

Exemplary lesson materials

RME exemplary lesson materials were used for the first time in the first prototype of the LE. Two topics were given: *linear equation system* and *matrices*. Based on the solutions of the student teachers in the course and pupils in the schools, these materials were revised. These revised versions of the materials were used in the next try-out along with the newly developed materials. In the second prototype, two additional new topics were added: *symmetry* and *side seeing,* and in the third prototype the topic *statistics* was added. Thus, the final version of the LE incorporated five mathematics topics.

3.2 DESCRIPTION OF THE INITIAL PROTOTYPE OF THE LE

The initial prototype of the LE focused on the web support. This section briefly describes the content, support and user interface of the web support in the initial prototype.

Content. In the initial prototype, the content covered the background of RME theory, the characteristics of RME, information on how to design lesson materials, how to teach using the RME approach and how to assess pupils (see Chapter 2 for more information on these topics).

Support. Based on the guidelines in Chapter 2, the support elements of the web site was designed. Table 3.4 offers a description of the support provided by the initial prototype of the LE.

Table 3.4
All support components that were offered in the initial prototype

LE components	Description
Tools *(Tool)*	This support element provides tools such as search engine, forms and templates. A lesson template for designing the lesson plan was designed based on the lesson plan format that is used in Indonesian schools. Using this template, a student teacher can type, edit, preview, print and save the lesson plan. The components of the template are customized from the lesson plan standard for mathematics teachers in the secondary school in Indonesia.
Information *(Info)*	This part of the initial prototype consists of general information about RME including the background theory and book references. The prototype also provides links to some web pages that deal with RME, mathematics education and teacher education.
Training *(Tutor)*	This part of the web provides opportunities for the users to learn how to teach RME in the classroom. It consists of information about how to teach, how to manage a classroom and how to evaluate pupils.
Advice *(Help)*	The help option consists of three facilities: user's guide, glossary of new terms and frequently asked questions.
Communication *(Talk)*	This support provides users with some tools for communication and discussion, such as e-mail and a mailing list. Communication among users is extremely important for student teachers in learning a new approach such as RME. They can enhance their understanding about RME through discussions with other users and the developer. For instance, by using e-mail and a mailing list, users can freely communicate to each other or share ideas through the list.

Figure 3.1 illustrates all support components that were included. It can also be seen as the structure of the initial prototype.

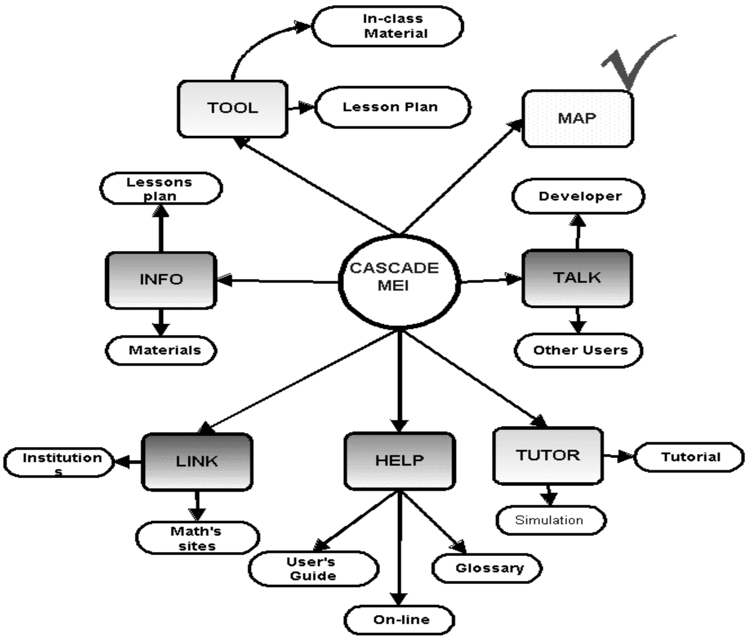


Figure 3.1
Structure and support of the initial LE prototype

User interface. The user interface was designed based on the guidelines presented in Chapter 2. Figure 3.2 shows the main menu of the initial web site of the LE.

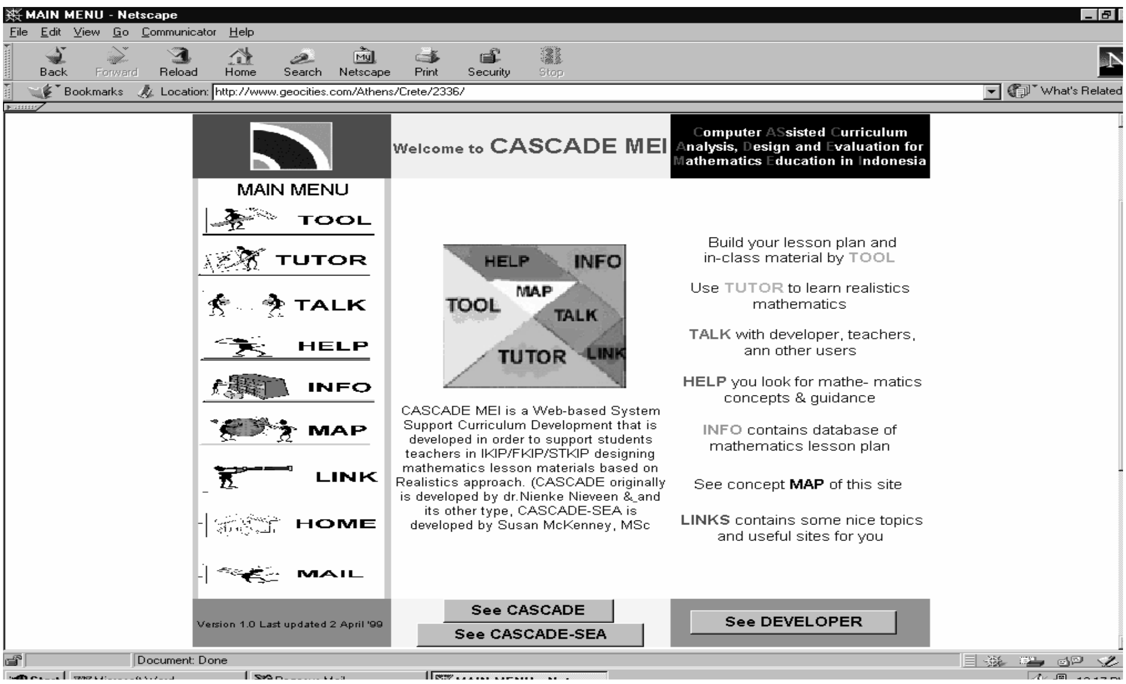


Figure 3.2
Main menu of the initial web site prototype

The left side of the menu provides access to the menu options. Explanations are given in the middle and on the right side. In addition to the main menu, a counter was used for counting the number of users who accessed and used the web site. Finally, in the initial LE, the navigation included titles, heading, buttons, backtracking, sneak preview (description of the link), index, menu, links, map and a search engine.

3.3 FORMATIVE EVALUATION OF THE INITIAL PROTOTYPE

In order to improve the validity and practicality of the initial LE, a formative evaluation was carried out consisting of an expert appraisal and cooperative evaluation.

3.3.1 Expert appraisal of the initial prototype

The expert appraisal is important in order to see whether the web site is designed based on the state-of-the-art knowledge, and whether its components are consistent. In addition, the perception of experts was gathered concerning the practicality of the system. Table 3.5 provides an overview of the number of experts, focus, method and procedure of the evaluation.

Table 3.5
Overview of the expert appraisal of the initial prototype

Number of Experts	2 experts on computer supported curriculum development
When	March 1999
Focus	Validity and practicality of the content, support and user interface of the web site
Method	Walk through
Procedure	The experts were provided with a paper-based printout of the system that contained all web pages. They evaluated all pages, walked through all screens and reviewed the content, support and user interface of the system. The role of developer was to record all their comments and suggestions.

In general, both experts agreed that the web site held potential to support student teachers in learning and teaching a new approach. In addition, both of them gave suggestions in order to improve the validity and practicality of subsequent prototypes of the web support. Table 3.6 presents the general suggestions of the computer support experts and related decisions of the developer that were integrated into the next version of the prototype.

Table 3.6
Suggestions from the experts to the initial prototype of the LE and revision decisions

Suggestions	Decisions
Emphasize the concept of the realistic approach into all parts of the web site: content, support and user interface. For instance, try to support the users by providing a tutorial about how to teach RME so they can learn it whenever and wherever they need.	It was decided to fill the Tutor part of the web site with information not only about the background of RME, but also with a guide on how to deal with materials, teaching method and assessment strategy in RME. This can be used as a guide for learning and teaching using the RME approach.
Provide usable links about mathematics in general and those that are related to the RME. Those links could make the web site rich in terms of content.	It was decided to add a number of links to mathematics web sites that related to lesson materials, teaching methods, assessment, Java applets simulation programs, mathematical games and organizations.
Add some options to the lesson builder that help student teachers to complete each of the lesson plan components.	It was decided to make local links between the lesson builder page and other pages, such as a glossary and exemplary lesson materials.
Reduce the number of colors used in the menu so the web will look transparent.	It was decided to reduce the number of text colors that did not match with the background.

3.3.2 Cooperative evaluation of the initial prototype

This evaluation focused on the practicality of the key components of the prototype (content, support and user interface) from a user point of view. Table 3.7 summarizes the design of the cooperative evaluation.

Table 3.7
Overview of the cooperative evaluation activities of the initial prototype

Number of participants	2 Master of Science program students from Zimbabwe and Jamaica. Both are web developers and one of them is a mathematics teacher
When	March 1999
Focus	Practicality of the support and interface of the web site
Method	Walk through
Procedure	The developer gave a brief introduction about the web site before the participants continued by themselves. The role of the developer was to record all their comments and questions as well as to answer their questions.

Generally speaking, the participants agreed that the web site is interesting, especially its structure, which consists of a number of support elements, as well as its colorful interface. However, they also had some valuable comments. All comments were used for making the decisions that were integrated in the next version of the prototype. Both comments and decisions are summarized in Table 3.8.

Table 3.8
Comments from the users of the initial prototype of the LE and resulting revision decisions

Comments	**Decisions**
Give several examples of lesson plans in the Info part. Due to time limitations, users usually only look for available lesson materials instead of making new materials with assistance of the web site.	It was decided to add a number of RME exemplary lesson materials in the web site.
Put all options in the lesson template in one page only (if possible) in order to make it easier to use.	It was decided to make local links between the lesson builder page and other pages, such as a glossary and exemplary lesson materials.
Clarify some texts on the web site. Some texts were not clear because of the colors used.	It was decided to use black for all text and white for the background so the texts are clear to read.

3.3.3 Overall conclusion for the initial prototype

From the results of the small-scale formative evaluations, it can be concluded that the initial prototype of the learning environment (LE) was valid but it was not practical. Suggestions and comments from either experts or users to the initial prototype were integrated into the subsequent prototype (see Tables 3.6 and 3.8). In addition, some changes were made in light of the fact that the next prototype of the LE would be tried-out in Indonesia. For instance, it was decided to use both English and Indonesian language in the web site. The most important decision made was to continue working on the practicality of the support by extending the LE with a face-to-face course and exemplary lesson materials on RME.

3.4 DESCRIPTION OF THE FIRST PROTOTYPE OF THE LE

Unlike the initial prototype, the first prototype consisted of both the face-to-face RME course (offline) and the web site (online). Figure 3.3 illustrates the structure of the first prototype.

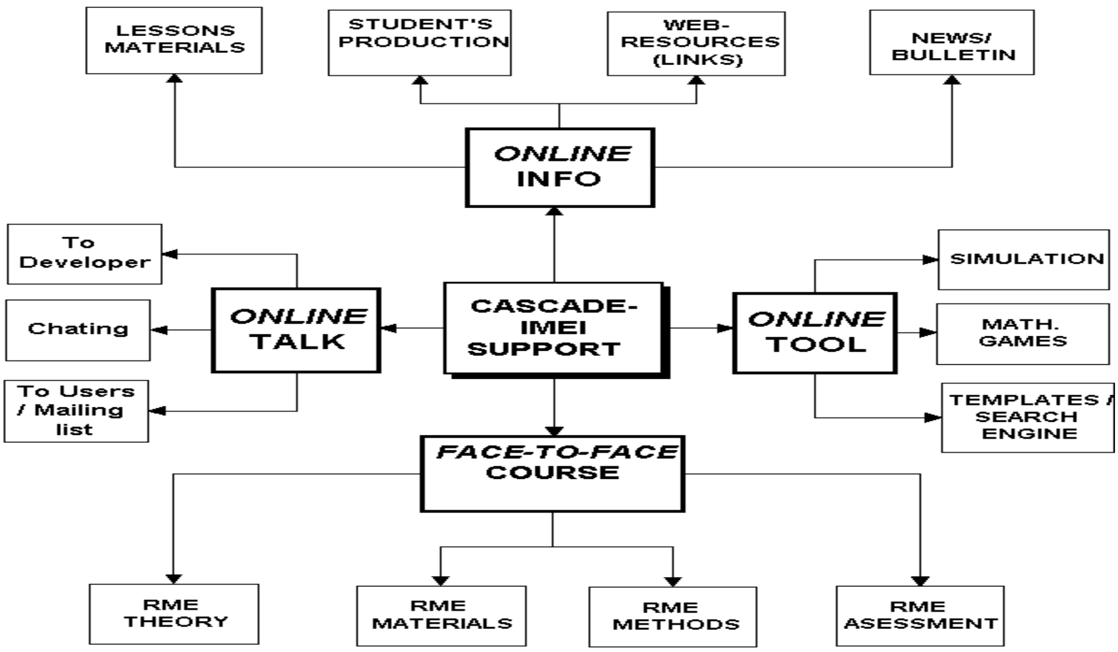


Figure 3.3
Structure of the first prototype of LE

Web site. The main components of the web site were similar to the previous prototype, except for the following features:

1. exemplary RME lesson materials (student materials, teachers' guide and assessment materials) were available in the online info;
2. some web pages had an Indonesian version ('Bahasa Indonesia'), so Indonesian student teachers could use it without facing language problems;
3. a number of links were added to the simulation and game programs about visualization in some topics of mathematics education; and
4. the lesson template was revised by putting all parts together into one page and by adding several options (such as preview and printing options) to the template.

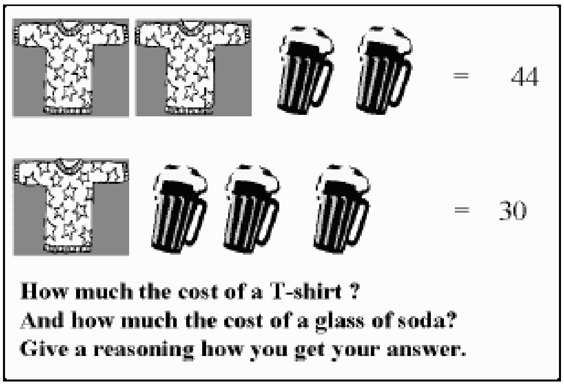
RME course. This course was developed in order to assist student teachers in learning what RME is, how to implement RME in the classroom and how to work with the web site. Therefore, the entire course consisted of two components. The first component covered the RME approach that was integrated into the existing 'Research on Mathematics Education' course. The entire course took 11 weeks. Table 3.9 shows the organization of the course. Sessions 3 and 7 deal with the web site activities.

Table 3.9
Design of the first prototype of the RME course

Session	Course Component	Time (min.)	Content, activities and goals
1	Overview of RME theory	100	Discussion about the background and characteristics of RME using some examples of contextual problems. This activity aims at making participants familiar with RME.
2	Doing mathematics	200 (2 meetings of 100 minutes)	Student teachers are treated as learners while the developer performs as a RME teacher. RME exemplary lesson materials are used in this activity. The goal is that the participants learn how to teach using the RME approach.
3	Introduction to the Internet and the web site	120	The selected participants learn how to access the internet, apply and use e-mail, and use the CASCADE-IMEI web site.
4	Designing contextual problems	200 (2 meetings of 100 minutes)	The selected participants learn how to design a lesson, which consists of a sequence of contextual problems by adapting the available RME materials. The focus of this activity is to use at least the first tenet of RME: the use of context.
5	Practical part (Peer teaching and teaching practice)	2 weeks	The selected participants learn how to teach using the peer teaching approach. Each of them performs as a RME teacher while their fellow students assume the role of learners. At the end a focus group, discussion is conducted. In addition, 10 pre-service teachers conducted teaching practice in the first-year student teacher in UPI Bandung and 2 in-service teachers in the two secondary schools.
6	Reflection	100	At the end a focus group, discussion is conducted. The 12 student teachers reflect on their experiences after following the LE activities.
7	Self study	120	The 12 student teachers used the web on their own in order to support their job in the course and used the communication tools for discussion and collaboration.

RME exemplary lesson materials. The first prototype used exemplary lesson materials on two mathematics topics: linear equation system and matrices. These two topics were chosen for three reasons. First, these topics were taught in the secondary schools at the time when student teachers did their teaching practice. Second, RME materials were available for these topics. Finally, connecting these topics both to other strands and to real-life applications was expected to be relatively easy.

An example of the lesson material for linear equation system, called 'finding price', was taken from the module or book *Get the most out of it* (Romberg & de Lange, 1998b). This book was designed for grade 8 at the junior secondary level. This topic matches with the current curriculum of grade 8 in junior secondary school in Indonesia, and it makes use of a common context (shopping and price on the market). Figure 3.4 shows an example of an assessment problem that is taken from the 'finding price' lesson. It is called the 'T-shirt and soda' problem.



Note: Originally from Romberg & de Lange, 1998b).
Figure 3.4
'T-shirt and soda' assessment problem

Another example of a mathematics topic that was used is a matrix, which can be found in Figure 3.5. This contextual problem was adapted from *Mathematics insight and meaning* (de Lange, 1987). It is called Cihampelas, a name of the biggest jeans and t-shirt market in Bandung.

Cihampelas

Cihampelas is a famous market in Bandung. Here, in a number of stores, people can buy various jeans and t-shirts. One of the stores is Toko Rambo. In this store, 36 trousers Wrangler with different sizes and types are available with the following specifications:

28" (long 28 inches)= 6 ; 30" = 12; 32" = 12; 34" = 6

Other types of jeans is also available with size and quantities as follows:

Levis: 6, 12, 12, and 6; Cardinal : 3, 7, 6 and 3

Esperite: 6, 6, 6 and 3; Darwin : 3, 6, 6 and 3

Problems:

1. All this information can be written down well-ordered in matrix-form.
   Write the matrix.
2. How many trousers fit with your sizes? Explain!

Figure 3.5
The Cihampelas problem

This topic is taught in the high school. As student teachers will also teach at the high school level, it is important to give an example of a lesson in that level. The entire lesson of both topics can be seen in appendix A.

3.5 FORMATIVE EVALUATION OF THE FIRST PROTOTYPE

In order to find indications for the validity and practicality of the entire LE, an expert appraisal, a cooperative evaluation and a try-out were conducted.

3.5.1 Expert appraisal of the first prototype

An expert appraisal was conducted in order to find out whether the first prototype of the LE was designed based on the state-of-the-art knowledge on RME, and whether its components were consistent with each other. In addition, the perception of experts regarding the practicality of the system was gathered. The expert appraisal focused on the validity of the first prototype from the RME perspective.

Table 3.10 provides an overview of the number of experts, focus, method and procedure of the evaluation.

Table 3.10
Overview of the expert appraisal of the first prototype

Number of Experts	2 Experts on realistic mathematics education (RME)
When	April 2000
Focus	Validity and practicality of the LE (web site, course and lesson materials) from a RME perspective.
Method	Discussion and walk through
Procedure	The evaluation was conducted at the Freudenthal Institute, Utrecht, the Netherlands. First, the developer gave an overview of the LE, including the web site, the course and the lesson materials. Then, it was continued with an open discussion. Both experts gave comments on the RME course and the materials and asked questions on aspects that needed clarification. During the discussion, the developer wrote down their comments and suggestions. Finally, they walked through the web site on the computer screen. While they were browsing the web site, they made comments on each page. The developer also wrote these down.

In general, both RME experts agreed that the LE is new in the context of mathematics education, especially in Indonesia. Table 3.11 presents the general suggestions of the RME experts and related decisions of the developer. All decisions were integrated into the second version of the prototype.

Table 3.11
Suggestions from the RME experts to the first prototype of the LE and decisions to be made

Suggestions	Decisions
Provide the web site with such information not only about RME but also on mathematics education in general. For instance, try to use the web for supporting or making an organization of mathematics teachers as an initial stage of 'future national mathematics teacher organization in Indonesia' such as the one (NCTM) in the USA.	▪ It was decided to include as many teachers and student teachers as possible in the mailing list so they could discuss and collaborate. This can be seen as an initial stage of organizing mathematics teachers. ▪ It was decided to add a publication page that provides several papers or reports about RME. This seemed to be very important for the users not only for learning the background of RME in Indonesian language but also as an initial stage of an online magazine or journal of mathematics education.
Add a measurement tool to identify users who return to the web site. This may provide insight into the usage and usefulness of the web site.	It was decided to provide a counter and a form in the front page of the web site for counting the number of users who visit the web and for recording the number of times that a user comes back to the web site.
One of the experts suggested to include several short video clips on the web site concerning how to teach RME. This may provide users with real examples of activities on how to teach in RME classrooms.	It was considered to use several short video clips on how to teach RME. However, based on the budget and time limitation, for the moment it was decided to replace this by a 'slide-show' of the activities.
Develop several Java applet simulation programs and games in Indonesian language on the web site. Because Java applet is a part of Java web programming language that is dedicated to the mathematics and scientific subject matters, these applets may be a strong part of a mathematics web site.	It was decided to develop several Java applets programs and mathematical games in Indonesian language.

3.5.2 Cooperative evaluation of the first prototype

The cooperative evaluation was conducted in order to find the practicality of the content, support and user interface of the web site according to the student teachers. Table 3.12 summarizes the design of the cooperative evaluation.

Table 3.12
Overview of the cooperative evaluation activities of the first prototype of the web site

Number of participants	12 mathematics student teachers of the working group
When	November 1999
Focus	Practicality of the content support and interface of the web site
Method	Walk through
Procedure	Student teachers were asked to access the web site of CASCADE-IMEI, and to send comments to the developer by e-mail. Further, they were asked to communicate their experiences and problems in the course to the developer and other participants using e-mail.

Generally speaking, the web site was perceived to be a practical tool for supporting the RME course. The content, support and interface matched with student teachers' needs and seemed to be useful for them. Also, they found that the sample lessons in the Info part of the web were helpful and flexible, so they could use and adapt them to their own lesson materials.

Moreover, they suggested some revisions to several parts of the web site that were summarized in Table 3.13 along with the decisions made by the developer.
All decisions were integrated in the next version of the prototype.

Table 3.13
Comments from the users of the first prototype of the web site and resulting revision decisions

Comments	Decisions
Add new RME lesson materials on several topics and examples of students' productions to the web site. Examples may make it easier for student teachers to redesign materials.	It was decided to add two topics that would also be used in the course. Several students' productions would be added to the web as a part of the revised lesson, so the users could see the real examples of one of the RME tenets (use of students' production).
Add more theoretical information about RME to the web so student teachers can use these as resources when writing their reports or final projects.	It was decided to add a web page that provides scientific papers about RME.
Use Indonesian language on some parts that are still in English and Dutch (For instance, the Java applet simulation programs and games).	It was decided to continue improving the Indonesian part of the web site although it takes much time for translation. Also, some Java applet programs would be developed in Indonesian.
Add lesson materials and activities of student teachers to the web, so other users can learn from these experiences.	It was decided to put some examples of student teachers' lessons online, but not all of them due to the limitation of the web space. Also, some pictures would be put on a slide-show, so the users could gain insight into the RME teaching and learning activities.

3.5.3 Try-out of the first prototype

In this try-out, the main focus was on how the LE can support student teachers – both pre- and in-service teachers– in learning and teaching using the RME approach.

Research questions. The try-out focused on the practicality issue, to confirm the revisions made in the initial prototype, and to investigate the potential effects of the LE. It was guided by the following five evaluation questions (Guskey, 2000):

- What are the perceptions of student teachers with regard to the LE?
- What knowledge and skills did the student teachers learn after they followed the LE?
- What effects may the CASCADE-IMEI LE have had on the organization at the department of mathematics education in UPI Bandung?

- To what extent do student teachers apply their RME's knowledge and skills in their teaching practice?
- What is the reaction of pupils after they experienced the RME teaching?

Instruments. In this try-out, a number of instruments were used for collecting data (the URLs of all web pages of the instruments can be found in appendix C). Table 3.14 summarizes the instruments that were used.

Table 3.14
Overview of formative questions and instruments in the first try-out

			Instruments					
	Potential effects	*Sub-questions*	*Entry questionnaire*	*Test*	*End questionnaire*	*Lesson analysis*	*Interview*	*Observational note*
Focus		Level 1			X			
		Level 2		X		X		
		Level 3					X	
		Level 4						X
		Level 5			X			
	Characteristics of participants		X					

The entry questionnaire was used for gaining the background information of the participants such as name, age, teaching background, method courses they had already followed and the reason why they were interested in the LE program. The test was used in order to gauge the knowledge of student teachers, which would be used to determine who would become the main participants of the LE. The test as a part of the exemplary lesson materials was also used as an assessment tool. The end questionnaire was given at the end of the course for gaining data about participants' degree of satisfaction with the RME course. This instrument was also used for collecting data about pupils' reaction to the instructional process during teaching practice in the schools. Lesson analysis was used for analyzing to what extent the student teachers were able to embed the characteristics of RME into their lesson materials. For instance: Do they use meaningful real-life contexts related to the concept of the mathematics topic? Do their mathematics problems invite pupils to discuss their solutions? Furthermore, the observational note was used for observing student teachers in their teaching practice. Finally, interviews were used for collecting data on the support and permission from the Dean and the Head of department of mathematics.

Participants. Participants of the RME course were mainly third year student teachers at the department of mathematics education in UPI Bandung. All of them were registered as participants of the Seminar on mathematics education course – one of the method courses. The RME course was implemented in two classes: class A was followed by 55 third-year mathematics student teachers of UPI Bandung (15 men and 40 women) and class B was followed by 29 (9 men and 20 women) in-service student teachers. After the 'doing mathematics' session was over, a working group with a small number of student teachers was formed. For practical reasons, the LE program was continued only with this group. In order to select the members of the working group, two indicators were used: their mathematics test results (use of the RME-test) and motivation to work with the developer (use of the informal interview). As a result, 12 participants (10 pre-service and 2 in-service teachers) were chosen as the working group members. None of them had prior knowledge about RME. In addition, all students had at least some experience in using computers under the Windows operating system. They mainly use the computer for word processing. Only seven participants had experience in using the computer for Internet purposes. While all in-service students are teachers in their schools, none of the pre-service students had teaching experience.

Situation, activities and procedures. The try-out was conducted at the department of mathematics education in UPI Bandung from October 1999 until December 2000. Also, two selected schools participated in the teaching practice activities. For the Internet session, the activities were conducted in the Internet cafe nearby the UPI campus. The entire try-out took 11 weeks; 2 weeks dealt with the web site activities and the rest covered the course activities. All activities and instruments are summarized in Table 3.15.

Table 3.15
Main activities in the LE and instruments that were used in the first try-out

No.	LE activities	Instruments
1	Overview of RME theory and doing mathematics	- entry questionnaire - RME-test
2	Introduction to the Internet, e-mail facilities and the web site	- e-mails journal
3	Designing lesson materials or contextual problems	- lesson analysis
4	Peer teaching in teacher education	- observational note, pictures
5	Teaching practice in the schools	- observational note, pictures - pupils' solutions
6	Reflection in a group discussions	- end questionnaire

First, participants were invited to complete the entry questionnaire in order to determine their various backgrounds. Then, the course started by presenting the overview of RME theory. During the 'doing mathematics' session, the participants worked on a number of RME problems in two topics (*linear equation system, matrices)*. In this instance, they were treated as learners while the researcher assumed the role of a teacher. Some examples of RME problems were given and discussed in small groups, in order to give an idea of each characteristic of RME. After solving the problems, they were guided in discussing the various strategies in order to identify efficient and adequate strategies. In several cases they were invited to present their answers in front of the class. Next, the RME test was given to all student teachers in order to help select the main group of the LE. This selected group followed the rest of the program.

Regarding the web site, several activities were carried out. The first task was to build familiarity with the Internet. All student teachers got some technical training. They were trained how to access the Internet and were guided in making a personal e-mail using a free-email utility in Yahoo. In order to get e-mail experience, they were invited to send some personal background information to the researcher, as well as to other participants. Here, they learned how to compose a new e-mail message, to send it and to access e-mail received from others. Finally, they were taught how to use the attachment facility.

In addition, as a part of the course, all student teachers learned how to develop lesson materials based on the available materials. Student teachers were invited to redesign sequences of mathematics problems in a topic with a new context. Then, they learned how to teach using these materials in the peer teaching session. Here, each student teacher performed as a teacher while other student teachers performed as pupils. At the end, they reflected and discussed their observations. Finally, they were asked to conduct the teaching practice in the classroom. In this try-out, however, only two teachers had the opportunity to teach their materials in the classroom (Mr. D, and Mr. S). Both of them were in-service teachers who had their own classroom in their schools. While the rest (10 pre-service teachers) could not get the permission from the schools because the schools had only a limited time left before the fasting month holiday in December. Hence, they only conducted their teaching practice in the first-year student teachers class.

Finally, at the end of the teaching practice, student teachers were asked to discuss their experiences in a group discussion in front of their fellow students and the developer. At the end of the whole course, an end-questionnaire was also given to the student teachers. It was used for collecting data of participants' perceptions about the whole LE.

Result 1: Participants' satisfaction

At the end of the course, the perception of the student teachers concerning the course process was gathered by an end-questionnaire. The first column of Table 3.16 (TE) shows the results.

Table 3.16

The results of final questionnaire of 29 student teachers in teacher education (TE), 36 senior high school students (SMUN) and 24 junior high school students (SMPN) after they followed the RME instructional process

Items	**E**			**SMUN**			**SMPN**		
Reactions overall	+	+/–	–	+	+/–	–	+	+/–	–
Learning process of RME is interesting	27	2	0	32	1	3	24	0	0
RME materials are interesting	28	1	0	32	2	2	23	0	1
Interaction helps me to understand the materials	29	0	0	36	0	0	23	0	1
The role of teacher is helpful to me	28	0	1	35	0	1	24	0	0
The assessment materials challenge me	26	0	3	33	3	0	24	0	0
RME materials motivate me to learn	28	1	0	33	1	2	24	0	0
Learning other strategies is new to me	28	1	0	36	0	0	24	0	0

Note for reactions: '+': yes, '+/-': neutral, and '-': no.

In general, the results in the first column of Table 3.16 illustrate that the student teachers are very interested in the RME teaching approach. These positive reactions from student teachers are a necessary prerequisite to higher-level evaluation results. The items refer to the characteristics of RME. For instance, from the results on the second item 'RME materials are interesting', it may be concluded that the materials are interesting due to one possible reason that they used a real and meaningful context (the first characteristic of RME). Further, the participants found 'a nuance of democracy' in learning mathematics through the interactivity and the chance to learn other strategies during the discussion (the fourth characteristic of RME).

Result 2: Participants' learning

Student teachers' learning was indicated by two criteria: their knowledge of mathematics, as measured by the test, and their skills in redesigning lesson materials. First, at the end of the 'doing mathematics' session, the student teachers were given a test with only one assessment problem (the T-shirt and soda). Before starting, student teachers were asked not to use the 'old strategy' of linear algebra. All of them could solve the problem but some of them could not find a new strategy. Figure 3.6a and 3.6b show two types of solutions: formal (Syukur's) and 'informal' (Eulis').

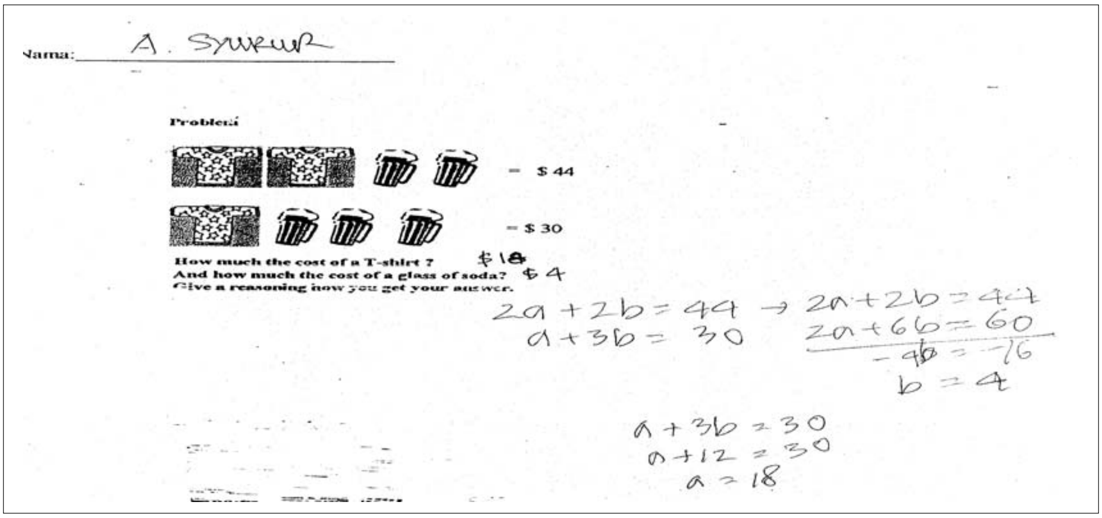


Figure 3.6a
Syukur's strategy in solving 'T-shirt and soda ' problem

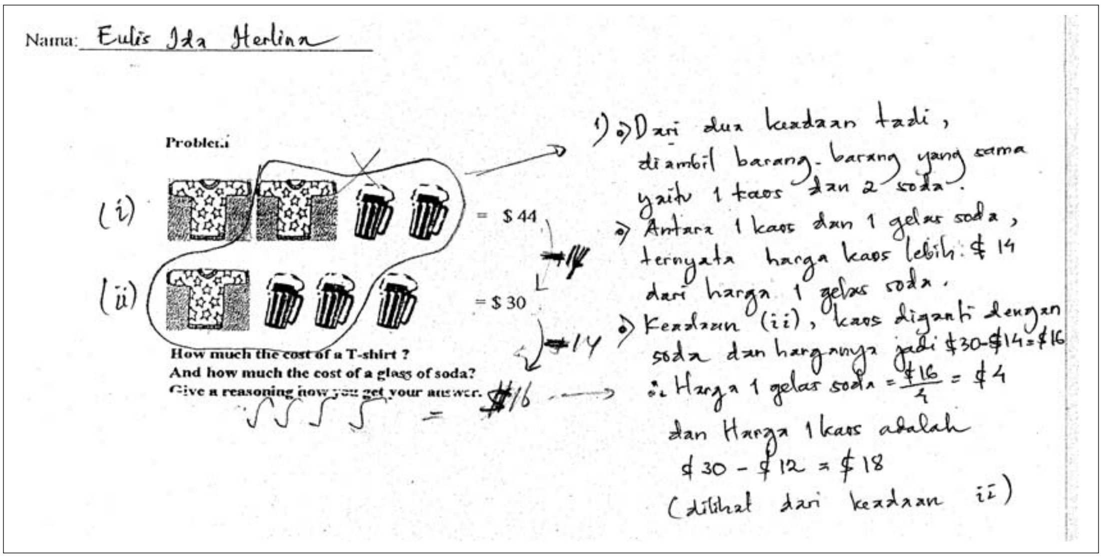


Figure 3.6b
Eulis' strategy in solving 'T-shirt and soda ' problem

The Syukur's is the example of the 'old strategy' of linear algebra while the solution of Eulis is similar to the 'counting on strategy' (de Lange, 1996). She starts by taking away a T-shirt and two cups from each picture, which shows that a T-shirt is $14 more expensive than a cup of soda. Then, she substitutes the T-shirt in the second picture with a cup and subtracts the price 30 with 14. Finally, from the 'third picture' where four cups equal to 16, she gets the price of a cup (4). Eulis' solution shows that she had learned how to solve the mathematics problem with an informal approach. That is called student's creation, one of the RME tenets. In general, in doing the mathematics session, all student teachers have learned the RME materials, and how to provide answers for those materials.

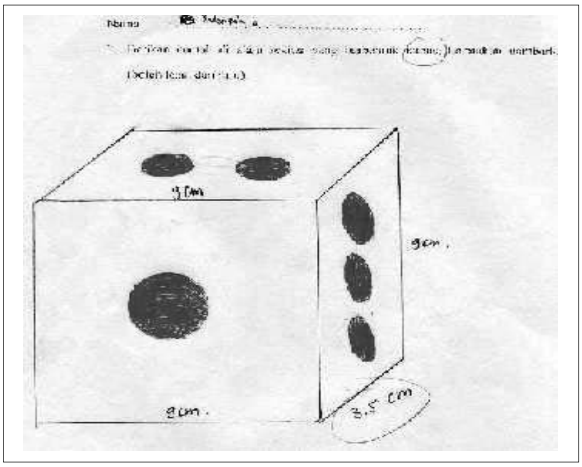
Furthermore, the skills of student teachers in learning how to develop lessons based on the RME tenets were evaluated using the lesson analysis method. Table 3.17 shows that lessons were designed by student teachers on various topics, at different levels, and implemented at a number of locations.

Table 3.17

Topics school mathematics, which were designed and implemented by student teachers

Topics	By student	Level	Location implementation
Social Arithmetic	Pre-service	1 SLTP	UPI Bandung
Linear equation system	Pre-service	2 SLTP	UPI Bandung .
Statistics	Pre-service	2 SLTP	UPI Bandung
Logarithm	Pre-service	3 SLTP	UPI Bandung .
Matrices	Pre-service	1 SMU	UPI Bandung
Cube	In-service	1 SMP	SMPN 2 Bandung
General graph	In-service	2 SMU	SMUN 1 Cimahi, Bandung

For example, two lessons based on the RME tenets that were developed by Mr. D. (the cube) and Mr. S. (the general graph) were evaluated in actual teaching practice (the rest of the lessons can be found in the Appendix B). Figure 3.7a illustrates an example of a problem that was taken from the Cube lesson and the pupil solution to that problem.



The problem was: *Draw an example of a cube that you are familiar with. Give the size of your cube.*

On the left, there is an example of the solution of a pupil who took a dice as the example. That is very good. However, when giving the sizes he used the 'real' size of the picture.

Figure 3.7a
An example of pupil's solution to the one of the cube problem

Figure 3.7b presents an example of problem from the General graph lesson. The problem was: *Complete the graph by adding the dash-line to the following cards*:

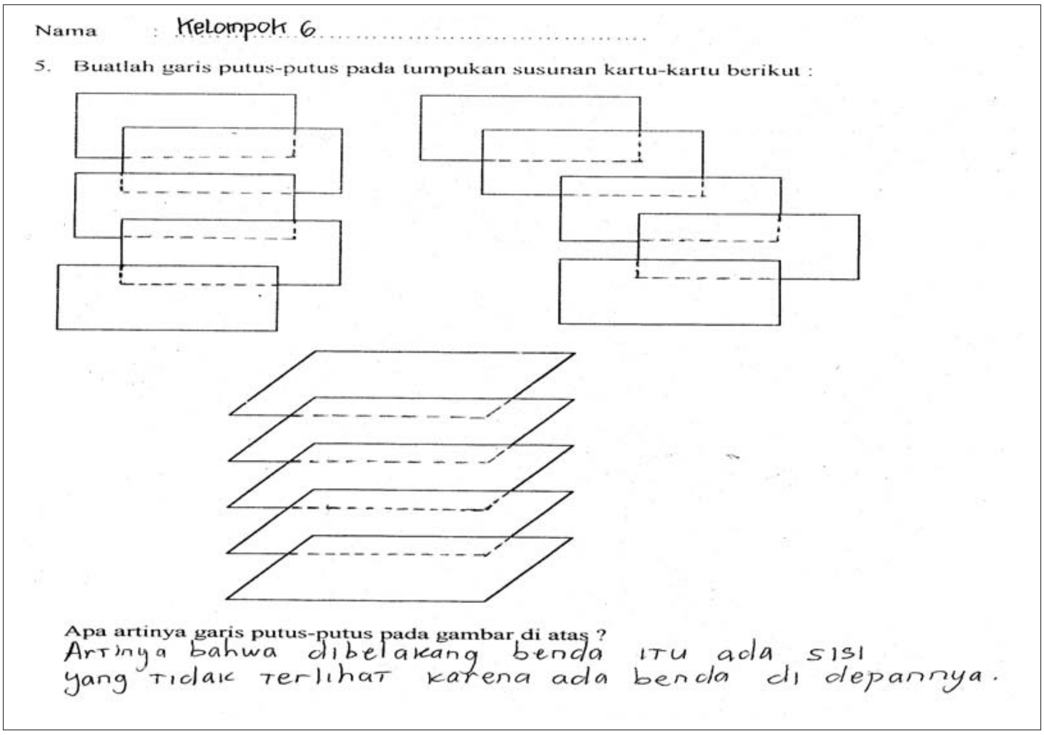


Figure 3.7b
An example of pupil's solution to the one of the general graph problem

Here, pupils were asked to complete a picture by drawing a dashed-line (so the dashed line is the pupil's work) and to explain what the line means. This figure shows the solution of one pupil. He wrote '*the meaning of the dashed-line is that in the back side of the figure there is a side that was not known because is covered by the other figure*'.

Both problems demonstrate the use of context (the cube and the dash-line). These problems were also invited pupils to come up with different answers.

In general, all lesson materials developed by the student teachers were good in the sense that they had started to embed the RME tenets into their lessons. Based on the analysis, the student teachers mostly used the first tenet, or the use of context. However, they also applied the interactivity tenet when they used their materials in their teaching practice.

Result 3: Organization support and effect

As a result of an interview with the Dean of the faculty of the mathematics and science, UPI Bandung in October 1999 (the starting time of the fieldwork), she agreed to the use of the LE and gave permission to conduct the research for three years. At the same time, the interview was also conducted with the Head of the Department of mathematics education in UPI Bandung. He also agreed, and gave permission to the developer to conduct the research in his department, using some courses, facilities and the student teachers. In addition to gaining permission, a seminar was held for teacher educators in order to give them a general overview of the research, RME and the LE. About 20 mathematics teacher educators attended the seminar. Many questions and comments were given. On top of that, they were very enthusiastic about the LE. As a result, an RME team with 6 teacher educators as members was formed. In the Department of mathematics, this team has responsibility for the RME as a new approach in UPI Bandung.

Result 4: Participants' use of new knowledge and skills

This part of the results focuses on the student teachers' use of RME knowledge and skills in the classroom. In this case, the teaching skills of Mr. D. and Mr. S. were observed by the developer. The instrument used was an observational note. The observer used the main indicators: Do the student teachers use the approach that the developer used in the RME course? An overall impression was that they were able to teach using an RME approach. They used their knowledge from teacher education, such as how to start the lesson, make groups of students, guide group and class discussions and close the lesson. However, they also had some problems, such as how to motivate the students to get involved in the discussion and how to conclude the lesson.

Result 5: Pupils' reactions

Reactions of the pupils to the instructional process based on the RME approach were gathered by an end questionnaire that was similar to the one that was given to the student teachers. The results have been summarized and combined in the last two columns of Table 3.16. Based on the results, it may be concluded that not only student teachers but also pupils in the schools were satisfied with the instructional process based on the RME approach (Zulkardi, Nieveen, van den Akker & de Lange, 2002b; 2000c).

Conclusions of try-out of the first prototype

Based on the findings of the try-out, it can be concluded that:

- Student teachers (both pre-service and in-service) were satisfied with the RME course program as a part of the LE. They learned not only about the theoretical background of RME, but also were directly involved in 'doing mathematics'. Here, they were treated as learners.
- All student teachers learned and had good experience with designing lesson materials based on the realistic approach. All of them have designed their own lesson materials and have tried to use the RME tenets. Although all of them focused on the use of the context, they felt that the most difficult part of designing RME lessons was to find a real-life context that matches with the mathematics concept.
- In teaching practice, all student teachers (both pre-service and in-service student teachers) encountered problems in acting as a facilitator and a guide. In contrast to the in-service teachers, pre-service teachers had problems in communication skills and most of them had low voice volume.
- The RME materials and teaching/learning process were identified as an interesting part of the course not only by student teachers but also by pupils in the secondary schools. The idea that a question can have more than one right answer was new to both student teachers and pupils. In the group work discussion, teachers acted as facilitators or moderators and pupils learned how to work in a group. In this way, the least motivated students and pupils also got involved.

On the balance, it can be concluded that the first prototype of the LE was seemly practical in supporting student teachers in Indonesia learning RME as a new approach. However, the practicality of the support and materials could be improved.

Based on the suggestions and comments from both experts and target users, as well as on findings from the try-out, the first prototype of the LE was revised.

3.6 DESCRIPTION OF THE SECOND PROTOTYPE OF THE LE

This section reports on the results of the design and formative evaluation of the second prototype of the LE. In this prototype, the structure of the LE remained the same as the first prototype. However, there were some differences in some parts of the web site, in the learning and teaching activities of the course and the number of topics of lesson materials. These changes were based on the results of the formative evaluation of the first prototype.

Web site. Figure 3.8 shows the front page of the second prototype of the web site. The main components of the web site remained similar to the previous prototype, except for the following items:

1. The logo was updated by integrating pictures taken during the fieldwork that illustrate the activities in the LE.
2. Several web pages were added, such as a web page about the fieldwork activities including pictures, a web page that consists of several papers about RME, and a page that consists of Java applet simulations and mathematics games.
3. Two new lessons were added into the Info part including some examples of pupil solutions.

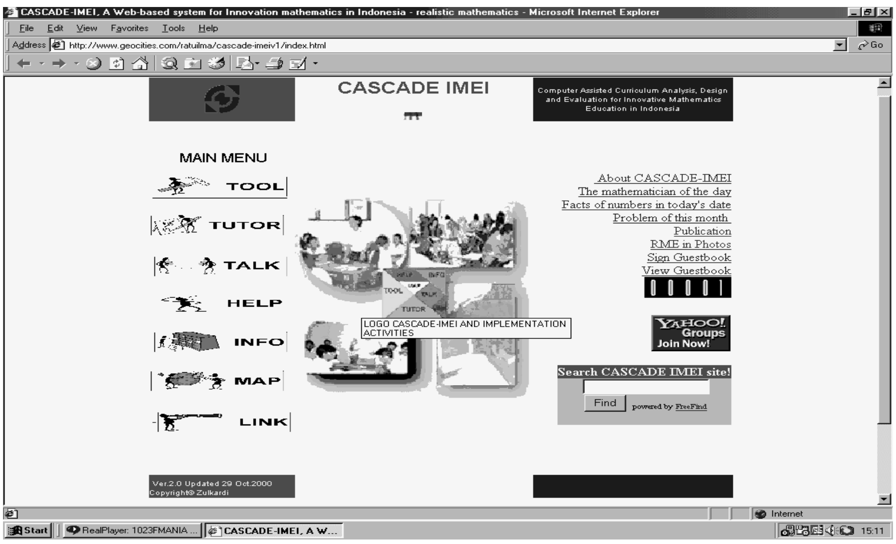


Figure 3.8
The front page of the second prototype of the web site

RME course. In this prototype, the course remained similar to that found in the previous prototype, except for the development lesson activity. Instead of the developing lesson activity, the student teachers (all of whom were in-service teachers) would be invited to adapt and use all materials that were adapted by the developer from the MIC book on the Geometry strand. For this reason, it was decided to add additional materials to the web site. The additional topics were: symmetry and side seeing. The materials were adapted to current mathematics in the school.
RME exemplary lesson materials. Materials related to the topic symmetry and side seeing were provided in response to the request of the participants that they would like to have them available in their class during that period. Of course, these materials needed to match with the current curriculum in the schools.

3.7 FORMATIVE EVALUATION OF THE SECOND PROTOTYPE

In order to find indications for the validity and practicality of the second prototype of the LE (course, web site and exemplary lesson materials), an expert appraisal, a cooperative evaluation and a try-out were conducted.

3.7.1 Expert appraisal of the second prototype

The aim of this evaluation is to gather information from experts about the validity and practicality of the second prototype of the CASCADE-IMEI web site. The developer used the results of this activity in order to improve the next prototype of the web site. Table 3.18 provides an overview of the number of experts, focus, method and procedure of the evaluation.

Table 3.18
Overview of the expert appraisal of the second prototype

Number of Experts	4 Experts on web site design, realistic mathematics education and curriculum development
When	April 2000
Focus	Validity and practicality of the content, support, user interface of the web
Method	Walk through
Procedure	The evaluation was conducted at the University of Twente, the Netherlands. Every expert was invited to use the computer to walk trough the web site. A questionnaire (see appendix C for the instruments), which contains a list of questions that are related to their expertise, was also given in advance in order to give them a chance to answer the questions. During a one-hour session, they were asked to comment about the web site while the developer wrote their comments down as well as answered their questions on aspects that needed clarification.

This evaluation is important in order to see whether the web site is designed based on the state-of-the-art knowledge and whether its components are consistent. In addition, the perception of experts regarding the practicality of the system was gathered.

In general, the experts agreed that the web site is valid and seemingly practical. To add more practicality to the web site, they gave suggestions for revision that have been summarized in Table 3.19. This table also presents the decisions made by the developer that were to be integrated in the next prototype of the LE.

Table 3.19

Suggestions from the experts to the second prototype of the LE and revision decisions

Suggestions	**Decisions**
Add a front page in which users can choose the language (either English or Indonesian). This seems to be more practical for the users rather than using a small flag that is integrated in the main menu.	It was decided to add a new front page that has a choice whether the user want to go to the English or Indonesian version.
Reorder the navigation buttons based on the goals of the web site. For instance, the button INFO will be in the first priority. The next priorities are TUTOR, TOOL, TALK, HELP, and LINK. Hence, users could be automatically guided by the options.	It was decided to change the order based on this suggestion.
Move all sub menus on the right to the left side of the main menu page. Just leave the white spaces on the right area in order to make the web site simple and clear.	It was decided to put all sub menus to the left (a level below the main menu.)
Add descriptions on each external link so the user can get an idea of the linking page before they move to that page and a new window for external links so the user can still see the previous page.	It was decided to follow this suggestion.
Add new window for the external links as well as add internal links to the some long pages.	It was decided to follow this suggestion.
Make the support such as Java applets, lessons and student productions useful for student teachers in Indonesia. Provide explanation on the goals of the applets and add ideas for the teachers on how the programs and games work mathematically, in order to make it easy for the users to use the applets.	Explanations on each Java applet simulation program and mathematics game were added to the next prototype of the web site.
Give users more tools to choose from, forms for feedback, explanations, available links for what's related to it in order to make the web site it more practical.	It was decided to add some new tools such as Problem of the month, which consists of assessment problems. It includes a form so the user could fill in her/his solution and send it to the developer Also, a printing facility in the lesson builder was added.

To be continued

Table 3.19 *(Continued)*

Suggestions	**Decisions**
Add more words to the glossary and more questions to the FAQ (frequently asked questions), because these two support components are helpful for users who are not so clear about the content or RME.	It was decided to add more difficult words in the glossary and important questions along with their answers in the FAQ
Add more explanation – especially for new users, for example, by adding texts to indicate the lessons instead of figures alone in order to make the support elements more clear.	It was decided to add text that explains the meaning of the buttons or figures
Add links from each page to all pages so users could directly click on a page that they want to see.	It was decided to follow this suggestion.
It was suggested to add a link in the bottom of each page so the users can directly navigate to other pages without returning to the main menu page first	

3.7.2 Cooperative evaluation of the second prototype

The aim of this cooperative evaluation was to gain feedback on how valid and practical the current web site is to mathematics student teachers. The research question to be investigated in this evaluation is similar to the cooperative evaluation in the first prototype (see also section 3.5.2). Table 3.20 summarizes the design of the cooperative evaluation.

Table 3.20
Overview of the cooperative evaluation activities of the second prototype of the web site

Participants	4 mathematics student teachers of the working group
When	June 2000
Focus	Practicality of the support and interface of the web site
Method	Walk through
Procedure	Two groups (two users per group) worked at computers in the Internet café. In each group, one user was asked to use the web while his partner was asked to write down the problems and comments. The evaluation was focused on the user interface of the web site, the language and the support given by the web site –especially the lesson part. Here the researcher acted as observer and interviewer and wrote down problems and comments. The practicality of the web site included: the user interface of the web site is easy to use, the users do not get lost or have navigation problems, and the support is helpful and relevant, was easy to use and easy to understand.

On the whole, the in-service teachers enjoyed using the web site and agreed that the whole web site is rather practical. However, they also had valuable comments. All comments were used for making the decisions that were embedded in the next version of the prototype. Both comments and decisions are summarized in Table 3.21.

Table 3.21
Comments from the users on the second prototype of the LE and decisions made

Comments	**Decisions**
Reduce some redundant buttons in the sub menus. This helps to make the sub menu page fit in one page.	It was decided to change the sub menus as well suggested by the users.
Add more lesson and assessment materials on new topics to the web site. This may help them be adapted to their own lessons.	It was decided to add one more lesson and a number of assessment problems in the 'Problem of the month' page.
Include more papers in Indonesian language rather than in English.	It was decided to translate some English papers into Indonesian and if possible to add papers in the Indonesian language.

3.7.3 Try-out of the second prototype

In this try-out, the focus was on how the LE could offer support for in-service teachers in learning to teach RME to their pupils in their schools.

Research questions. Four research questions that guided the try-out were:

- What are the perceptions of student teachers with regard to the LE?
- What knowledge and skills did the student teachers learn after they followed the LE?
- To what extent do student teachers apply their RME's knowledge and skills in their teaching practice?
- What are the learning outcomes of the pupils in term of solutions that students create in response to the lesson materials?

Instruments. The instruments that were used in this try-out were: an interview, an observational note, a logbook and two topics of ready-made lesson materials. The developer used the informal interview during the group discussion in order to learn about the perceptions of the in-service teachers. The logbook and lesson materials were used in the course. In-service teachers also used these materials in their teaching practice. The developer, using the observational note, observed their teaching skills. The pupils' solutions to the RME materials were used to answer the fourth research question.

Participants. Four in-service student teachers participated in the RME course. They were selected after the previous try-out. All of them were mathematics teachers who had been teaching mathematics in the junior and high schools for more than five years. Now they were following the in-service program at UPI Bandung for one year in order to earn their undergraduate degree.

Situation, activities and procedures. Two locations were used for conducting the try-out: the department of mathematics UPI Bandung for conducting the course and preparing the materials, and four secondary schools for implementing those materials. The activities of the course remained the same as in the previous course, except that this time around, students did not have to design their own lesson materials; instead, they used the available materials. The schools that participated were secondary schools where the four student teachers work. After all student teachers implemented the curriculum materials, a reflection meeting was conducted in the department of mathematics. In this meeting, they discussed their experiences and the pupils' productions from the classrooms.

Result 1: Participants' satisfaction

From the reflection meeting it was found that the four in-service teachers were satisfied with the course –especially because its materials matched with their need for teaching materials in the teaching practice. Also, they felt that the course materials were useful for them, either for teaching materials in the school or for their final project. With the procedural specifications on each topic, the materials seemed clear and helpful to the in-service teachers. The components of the course were perceived to be relevant to their job as teachers, as well as to student teachers in teacher education. On top of that, the way the course was conducted served as a model for the in-service teachers in how to teach mathematics using the realistic approach.

Result 2: Participants' learning

First, using the two sets of materials: symmetry and side seeing, the four participants assumed the role of learners. They were put in two groups and discussed the materials. Also, they solved all problems and in some cases they explained the materials.. If they had problems, they asked the developer guidance. At the end, after they had solved and discussed all problems, they were ready to use the materials in the classrooms. From these activities, in-service teachers not only learned about the materials but also how to teach the materials. They agreed that as a result of the activities, they had gained a better understanding of the subject matter of the two topics of the lessons. Also, they gained fruitful experiences by experiencing the materials from the vantage point of learners.

Result 3: Participants' use of new knowledge and skills

Finally, regarding to teachers' skills in teaching RME, it was found that the in-service teachers could teach using RME materials. They displayed proficiency in opening the lesson, introducing the context; managing the discussions, and closing the lesson. However, two in-service teachers still had a problem with managing time.

Result 4: Pupils' reaction and products

All pupils reported enjoying the RME lesson that was taught by the in-service teachers. Based on the observations, several pupils wanted to communicate their solutions in the front of the class. In some cases, they argued and justified their solutions. Moreover, based on the analysis of their solutions in their worksheets, it can be shown that they were able to solve the RME lesson materials. Figure 3.9 shows two examples of pupils' solutions to a symmetry problem. First, problem 11: *Give an example of when people use a translation.* At the beginning, a pupil used the example of a person who pushed a car. Another pupil used a drawing of a mathematical figure with the concept of tessellation, and a drawing of person in association with the concept of reflection.

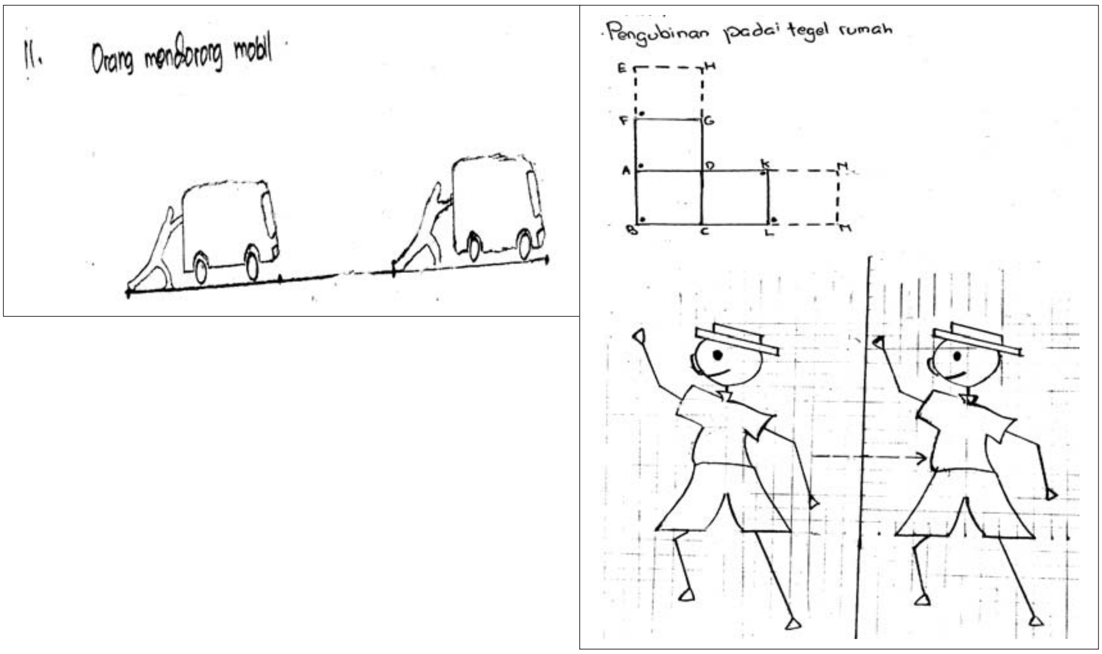


Figure 3.9
Examples of pupils' solutions

The interesting part was that two pupils started to use the context of people and the car - the real-life examples in an hour-long classroom assessment. However, the rest of the pupils were still using the mathematical figures. Although they were able to produce their creations, it appeared to be difficult for them to find a daily life example. Based on this, therefore, the problem was revised to make the goal of the assessment more explicit. The new form was: *Give an example of people who use a translation in daily life.*

Similarly, in problem 14 pupils were asked to design or create a free design that uses the ideas of symmetry like a batik –a well known print design on clothing from Java Island that usually uses the concepts of translation, reflection and rotation.

Figure 3.10 shows two examples of pupils' solutions. In one solution, the pupil used three different batik motifs using three different transformation concepts. In another solution, the three transformation concepts were integrated in one figure (the original figure (*asli)*, reflection (*refleksi)*, translation (*translasi*), and rotation (*rotasi*)).

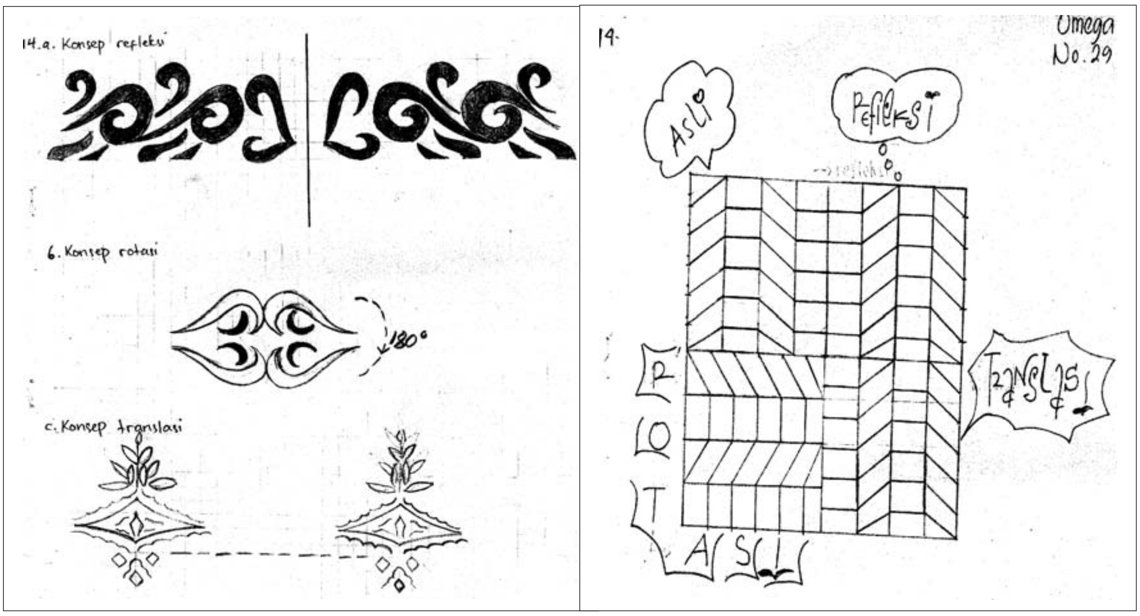


Figure 3.10
Examples of pupils' solutions

Problem 14 was categorized as a good and an easy problem. From 23 pupils, only one pupil had no solution, while 22 of them had good designs. Hence, the problem was not changed for future use. All assignments used can be found on the web pages with the URLs in appendix B.

Conclusions of try-out of the second prototype

Based on the findings of the try-out, several conclusions were generated as follows.

- In-service student teachers were satisfied with the RME course as a part of the LE. They perceived that the course as interesting –especially when they were treated as learners.
- They learned not only about the theoretical background of RME, but also were directly involved in 'doing mathematics'. Being treated as learners, in-service teachers not only learned the materials by solving all problems in the lesson materials, but also learned how to teach using the idea of interactivity, one of the tenets of RME.

- In general, all of the in-service teachers performed well in teaching practice; they were able to use the knowledge and skills they learned from the RME course. However, two in-service teachers got a problem in managing time.
- The RME materials and teaching/learning process were evaluated as an interesting part of the course, not only by student teachers but also by pupils in the secondary schools. Moreover, the pupils' solutions show that they were able to solve of all realistic problems that were adapted from the MIC textbooks. They were also able to follow the instructional process in terms of active participation in the discussions, communicating and defending their solutions.

3.8 DESCRIPTION OF THE THIRD PROTOTYPE OF THE LE

In this prototype, the evaluation was still focused on the validity and practicality of the learning environment.

Web site. Figure 3.11 shows the front page of the third prototype of the web site.

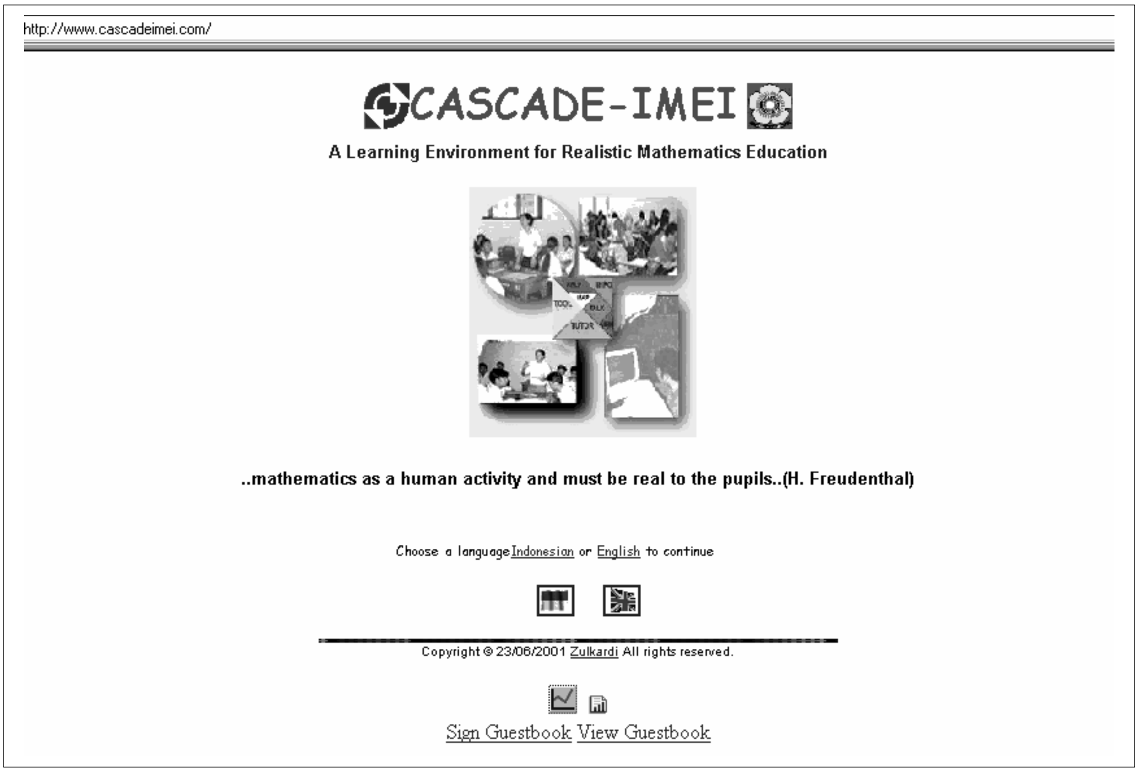


Figure 3.11
Front page of the third prototype of the web site

The main components of the web site were the same as to the previous prototype, except for the following new parts:

1. the front page was changed to a more clear and simple page;
2. a number of Java applet programs were added; and
3. new information (papers, lessons, and student productions) was added.

RME course. In this prototype, the organization of the RME course remained the same compared to the former prototype, except for the feedback activity and lesson development. In the feedback activities, the participants not only discussed their experiences in a group discussion but also presented their experiences in a seminar. This seminar was actually the final evaluation for the course (Seminar in mathematics education) that student teachers followed concurrently with the LE. Therefore, during the seminar they would discuss their experiences not only with their colleagues and the developer, but also with their supervisors (teacher educators). In addition, as pre-service student teachers, the participants were guided in redesigning lesson materials based on the realistic approach.

RME exemplary materials. The exemplary lesson materials were the accumulation of the lesson materials from previous prototypes along with the addition of a new topic (statistics). Hence, a total of five topics were used in the course: linear equation system, matrices, symmetry, cubes, and statistics.

3.9 FORMATIVE EVALUATION OF THE THIRD PROTOTYPE

In order to find indications for the practicality of the entire LE, a cooperative evaluation and a try-out were held.

3.9.1 Cooperative evaluation of the third prototype

The aim of this cooperative evaluation was to gain feedback on the practicality of the current web site in the eyes of the new working group of mathematics student teachers. Table 3.22 summarizes the design of the cooperative evaluation.

Table 3.22
Overview of the cooperative evaluation activities of the third prototype of the web site

Participants	8 mathematics student teachers (pre-service)
When	October 2001
Focus	Practicality of the web site
Method	Walk through
Procedure	Eight student teachers were asked to think aloud while using the web site. All of their comments were recorded in the observational notes. At the end they were also asked to fill out the end questionnaire.

Based on the data from the observational notes and the questionnaire, the third prototype of the web site can be judged as being practical for student teachers. The following are the overall results of the formative evaluation of the web site: the web site is easy to use; support components such as info, tutor, talk, and tool are helpful; the user interface is easy to understand; it is easy to navigate through the web site; and the content is consistent with the school curriculum.

In addition, student teachers gave their suggestions to make the web support even more practical. All comments were used for making the decisions that were embedded in the final version of the web site. Both comments and decisions are summarized in Table 3.23.

Table 3.23
Comments from the users of the third prototype of the web site and resulting revision decisions

Comments	**Decisions**
Add several short video clips in the TUTOR part of the web site so other student teachers and teachers who do not have chances to follow the course can learn from these video clips.	It was decided to add several video clips on the web site.
Include lessons, assessment materials and pictures of the student teachers on the web site so other users can use and learn from their experiences	It was decided to follow this suggestion if time and space would allow.

3.9.2 Try-out of the third prototype

In this try-out, the main focus was on the how the LE could support pre-service students in learning and teaching using the RME the approach.

Research questions. The third try-out was based on the following questions:

- To what degree are participants satisfied with the CASCADE-IMEI LE?
- What knowledge and skills did the student teachers learn by following the LE?
- To what extent do student teachers apply their RME's knowledge and skills in their teaching practice?
- What are the reactions of pupils after they followed the RME lesson?

Instruments. The instruments that were used in this try-out were: entry and end-questionnaires, lesson analysis, e-mails journal, log book, observational journal and interviews. The functions of these instruments were similar to the previous try-outs. For example, the lesson analysis was used for analyzing the lesson materials that were developed by the student teachers. The observational note was used for the teaching practice in the schools.

Participants. The participants in the program were eight fourth-year pre-service student teachers, seven females and one male, at the department of mathematics UPI Bandung. They were selected in a manner similar to that used in the first try-out. As a result, student teachers were selected with experience in using the computer under the Windows operating system, mostly for word processing and programming. They did not have experience in using Internet and e-mail facilities. Furthermore, they had some initial experience in developing lesson plans, but did not have any teaching experience in practice.

Situation, activities and procedures. The course was implemented in UPI Bandung. The activities were conducted within a time frame of seven blocks of two-hours for training, and two blocks of two hours for self-study and the seminar. After doing the mathematics session, all student teachers learned how to redesign lesson materials. Then they taught their lesson materials in a peer teaching simulation. Here, they gained input and feedback from their peers as well as from the researcher. Then, they used the materials in the teaching practice in the school classroom. The researcher observed their lessons and made notes.

Result 1: Participants' satisfaction

The participants' perceptions of the LE program were evaluated using the end-questionnaire. Table 3.24 presents the participants' perceptions of the LE (see also Zulkardi, Nieveen, van den Akker & de Lange, 2002a).

Table 3.24
Participant's (n=8) perceptions to the overall LE

Overall perceptions to the LE	Mean	S.d.
Helpful for me as a math. student teacher	4.9	0.35
Rich with new information	4.6	0.52
Interesting	4.6	0.52
Educational	4.1	0.35
Consistent with the needs	4.0	0.53

Note: 5 = highly positive, 1 = highly negative.

Based on the data, it can be concluded that participants' satisfaction with the LE has been adequately achieved for these student teachers. They agreed that the LE is helpful for them as student teachers, is rich with information that they need, and is interesting and educative. From this can be concluded that the LE is practical for these student teachers.

Result 2: Participants' understanding of RME

The potential effects of the LE on student teachers' understanding of RME were evaluated based on two kinds of results. First, student teachers' understanding of RME theory was assessed. All of the participants were able to describe the philosophy of RME, its principles and its characteristics. It was important for them to gain this understanding before they dealt with the materials and how to use them in the classroom. Second, the student teachers understood how to redesign lesson materials based on the available RME materials. All of them were able to develop their own lesson materials (although they mentioned in the questionnaire that redesigning teaching preparation plans or lessons based on the RME tenets is difficult). However, they were not successful in embedding all characteristics of RME into their lesson. The results were similar to all previous try-outs; student teachers were only able to incorporate one or two RME tenets (the use of context and the integrating with other mathematical strands) in their lessons.

Result 3: Participants' use of new knowledge and skills

The researcher observed the teaching skills of the student teachers both during peer teaching and in the real classroom. An overall impression was that they were able to teach adequately using realistic materials. They used their knowledge from teacher education, such as how to start the lesson, make groups of student, guide a group and class discussion and close the lesson. However, some of student teachers still encountered difficulties in motivating the pupils get involved and in justifying and arguing their solutions, or in critiquing other problems. Also, some of student teachers still had problems in concluding the lesson based on the pupils' conclusion in the end of the discussion. Although these critical moments have been discussed during the course, this remained a problem.

Result 4: Pupils' reactions

All pupils more or less enjoyed the RME instructional process that was taught by the student teachers. Based on the observations, almost all pupils thought that the materials were interesting, they were satisfied with working in collaboration with one another in the group discussion, and they liked that they could learn an adequate and efficient strategy from their fellow students. Finally, pupils could communicate and justify their solutions in front of the class. All of these findings relating to the pupils' reactions were quite similar to the previous try-outs.

Conclusions of try-out of the third prototype

Based on the results, it can be concluded that:

- The LE program was perceived as an interesting program by student teachers in teacher education. They are satisfied with the LE.
- The LE can promote student teachers' understanding in learning what RME is, and how to develop an RME lesson. However, in the development part they still have some difficulties in finding appropriate real-life problems that are matched with the topics. Nevertheless, based on the examples of RME materials, the web site and in collaboration with the researcher, they were able to develop their own lessons. Of course, they have to do a number of cycles of an evaluation and redesign in order to improve their lessons.
- All student teachers performed well in teaching, both in the peer teaching and in the schools. Still, they had problems both in the closing the lesson and in the managing the time.

- The RME materials and teaching/learning process were experienced as interesting by the pupils in the secondary schools.

On the whole, the findings in this try-out were not so very different from the first and second try-outs. These results show that the LE was sufficiently valid and practical to be used in the assessment stage or more formal stage of research. The following suggestions are based on the results of this formative evaluation round. Based on the finding that the theory session is the easiest session, it is suggested that this session could be integrated into the 'doing mathematics' session. Also, student teachers suggested adding a video session in the RME course in order to help student teachers get a realistic image of how to implement the RME materials in the classroom.

3.10 FINAL VERSION OF THE LE

The final version of the LE is actually the fourth prototype of the LE. Results from the first 3 prototypes indicated that this prototype would also be sufficiently valid and practical for Indonesian student teachers in learning to teach according to the RME philosophy. The main structure of the final version of the LE prototype can be seen in the Figure 3.12.

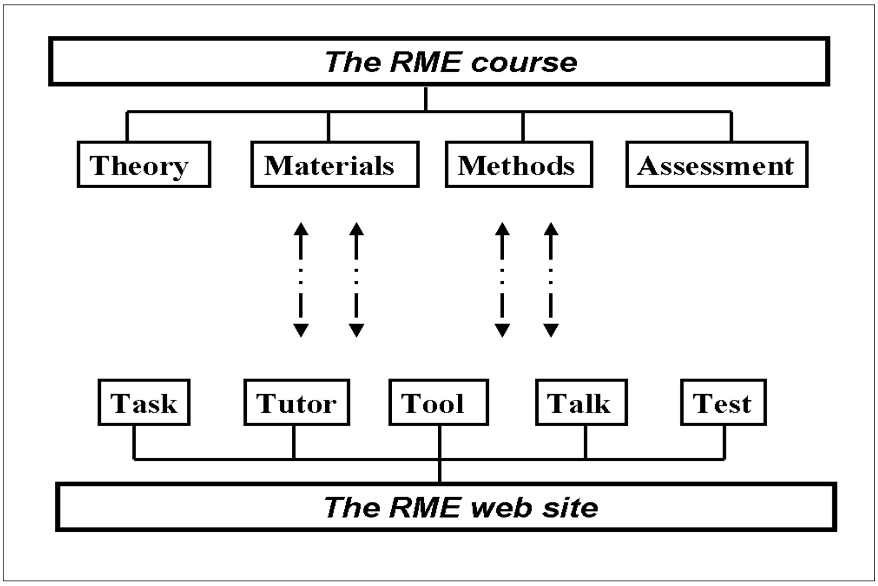


Figure 3.12
Structure and components the final version of CASCADE-IMEI LE

The next sections provide descriptions of the three main components of the LE: the web site, the course and the exemplary lesson materials. For the web site, a guided tour with the main screens of the web site is presented.

3.10.1 Web site: A guided tour

This guided tour shows several main pages of the web site (http://projects.edte.utwente.nl/cascade/imei/). Figure 3.13 illustrates what a user types in the address field of a web browser to access the web site.

Figure 3.13
Starting the web site

This action loads the front page of the final prototype of the web site, as shown by Figure 3.14.

Figure 3.14
Front page of the final version of the web site

In this page, users may choose which language they want to use by clicking the mouse either on the text (Indonesian or English) or on the one of the flag images. This selection brings the user into the main menu of the web site for the chosen language (see also Figure 3.15). In the left area of the web page, menu options are displayed in the form of buttons with icons and text.

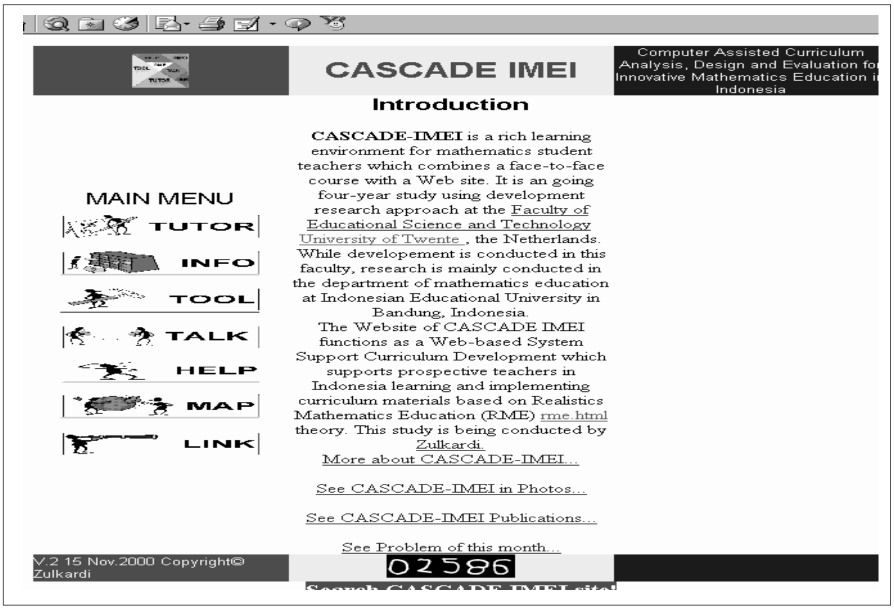


Figure 3.15
Main menu of the web site

An introduction to the web site is given in the middle of the web page. In addition to the options of the main menu, the introduction also provides several click-able options such as an introduction to RME (by clicking rme.html- see also Figure 3.16), a collection of try-out pictures (Figure 3.17), and a publication page (Figure 3.18).

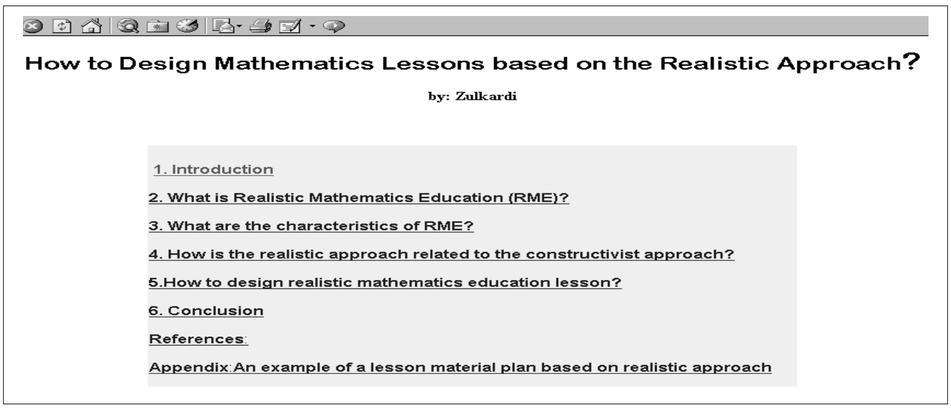


Figure 3.16
Introduction to RME

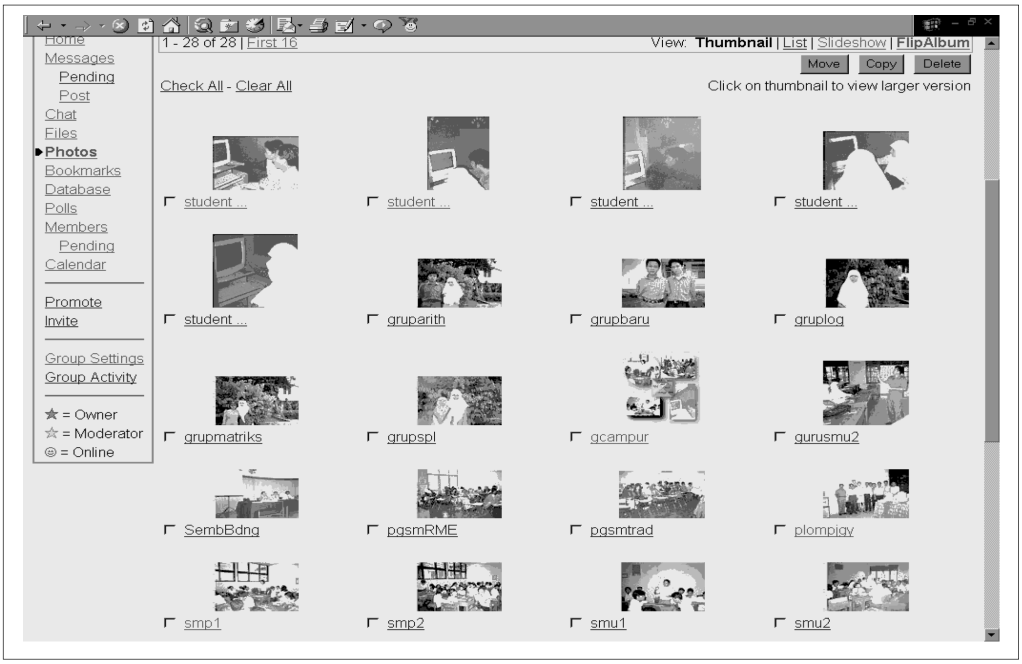


Figure 3.17
Collection of pictures that show the activities of the study


Publications:

01. Zulkardi, Nieveen, N.M, van den Akker J.J.H, de Lange, J. (2002). Implementing a "European" approach to mathematics education in Indonesia. Paper presented and published in the Jhon Willey&Son Proceeding of Second International Conference of Teaching Mathematics, in Crete, Greece, July 1-6, 2002. [Online]. Available at: http://www.math.uoc.gr/~ictm2/Proceedings/pap81.pdf
02. Zulkardi (2002). Developing a 'rich' learning environment on RME for student teachers in Indonesia. Paper presented in the IAMS-1 seminar at the Faculty of Mathematics at the University of Twente, 23-24 June 2002 and will be published in the special edition of International journal of Indonesian Mathematics Society (MIHMI) January 2003.
03. Zulkardi, Nieveen, N.M, van den Akker J.J.H, de Lange, J. (2002). Designing, evaluating and implementing an innovative learning environment for supporting mathematics education reform in Indonesia: the CASCADE-IMEI study. In P. Valero & O. Skovsmose (2002) (Eds.). *Proceedings of the 3rd International Mathematics Education and Society Conference. Copenhagen: Centre for Research in Learning Mathematics, pp. 1-5.* [Online]. Available at: *http://www.congress-consult.com/mes3/Projects/Zulkardi.doc*
04. Zulkardi and Nieveen, N.M. (2001). CASCADE-IMEI: Web site support for student teachers learning Realistic Mathematics Education (RME) in Indonesia. In Manfred, H (2001) (Eds.). *Proceedings of the 5th International Conference on Teaching Mathematics using Technology.* University of Klagenfurt, Austria, 6-9 August 2001.
05. Zulkardi (2001). *Lingkungan belajar RME dan perannya dalam menghasilkan guru RME di Indonesia.* Paper dipresentasikan di seminar nasional PMRI di Universitas Sanata Dharma Jogyakarta, 14-15 November 2001
06. Zulkardi (2001). *RME dan aplikasinya terhadap aljabar linear sekolah menengah.* Paper dipresentasikan di seminar nasional aljabar di Universitas Pahriyangan, September Bandung
07. Zulkardi (2001). *RME and its application to statistics in secondary education.* Paper dipresentasikan di seminar nasional statistik di Institut teknologi Surabaya, Surabaya 20 Oktober 2001
08. Zulkardi (2001). Learning RME through internet. In Sugiman (2001) (Eds.). *Prosiding seminar national pendidikan matematika.* Univeristas Negeri Jogyakarta, 20 April 2001
09. Zulkardi, Nieveen, N.M (2001). Learning environment for realistic mathematics education in Indonesia. Paper submitted to the PME25 in Utrecht, the Netherlands July 2001.
10. Zulkardi (2000). CASCADE-IMEI, an ongoing study in the field of mathematics reform in Indonesia using web and RME *Prosiding seminar national pendidikan matematika.* FMIPA Universitas Gajah Mada, Jogyakarta, 27 July 2000
11. Zulkardi (2000). RME theory meets Web technology. In MIHMI (2000) (Eds.). *Proceedings of 10th National Conference of Mathematics.* Bandung Institute Technology, Bandung 12-17 May 2000.
12. Zulkardi (1999). *Computer assisted curriculum analysis, design and evaluation for mathematics education in Indonesia.* Master's thesis. Enschede: University of Twente.
13. Zulkardi. (1999). How to design lesson based on the realistic approach. Available on line at [http://www.geocities.com/ratuilma/rme.html]

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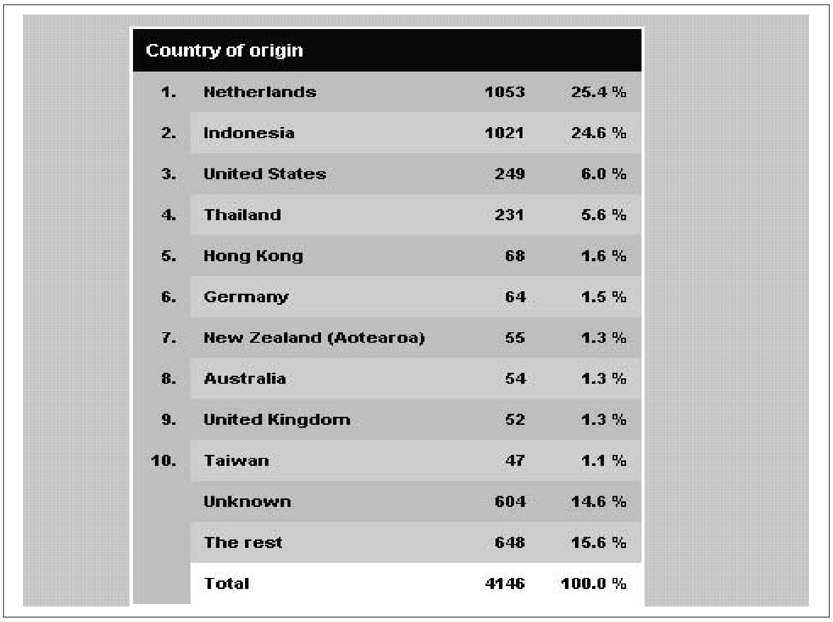
Figure 3.18
The publication page



Country of origin			
1.	Netherlands	1053	25.4 %
2.	Indonesia	1021	24.6 %
3.	United States	249	6.0 %
4.	Thailand	231	5.6 %
5.	Hong Kong	68	1.6 %
6.	Germany	64	1.5 %
7.	New Zealand (Aotearoa)	55	1.3 %
8.	Australia	54	1.3 %
9.	United Kingdom	52	1.3 %
10.	Taiwan	47	1.1 %
	Unknown	604	14.6 %
	The rest	648	15.6 %
	Total	4146	100.0 %

In some cases, the user may also see the statistics of the users who visited the web site by clicking the images on the bottom of the page. Here, the user can see the statistic page as shown in the Figure 3.19.

Figure 3.19
Statistic page of the web site

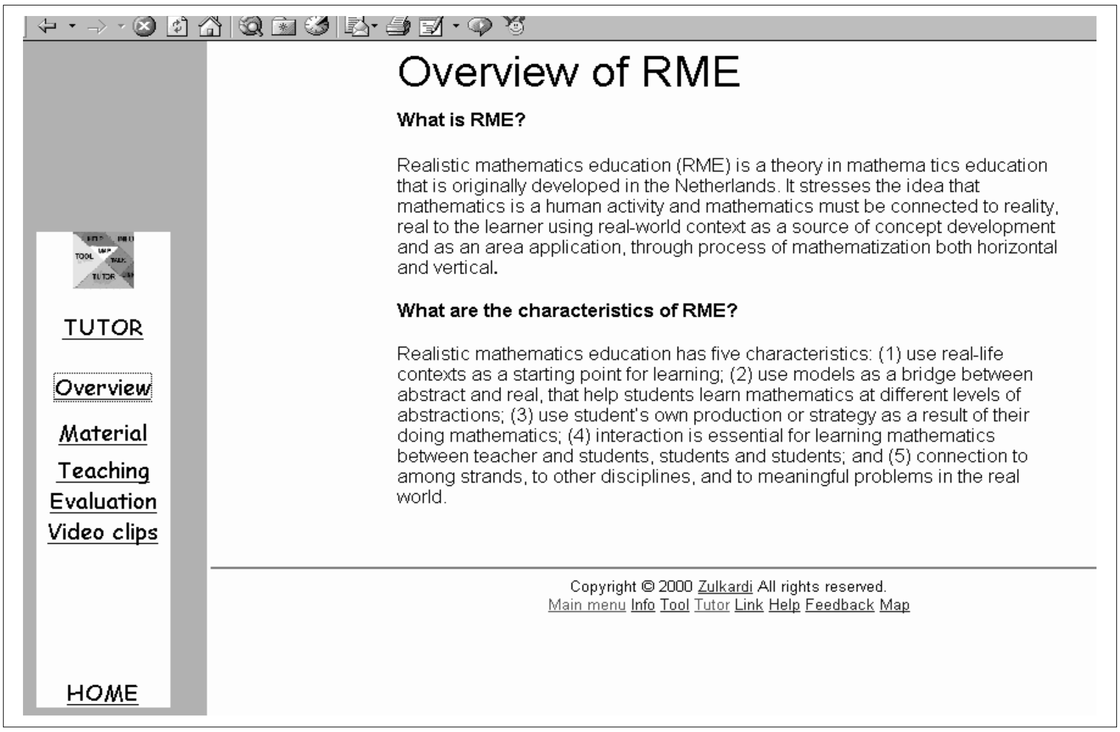


Figure 3.20
Tutor page of the web site

The 'Tutor' section consists of five options about RME. One of the options is an overview of RME that is shown in Figure 3.20. Others were pages that related to the RME materials, teaching method, evaluation and video clips.
Figure 3.21 shows the page that consists of ten video clips about RME. These clips give examples of how to teach RME such as opening the lesson, grouping, managing the discussion, and concluding the lessons. One of the video clips shows an RME expert stating the main goals of RME.

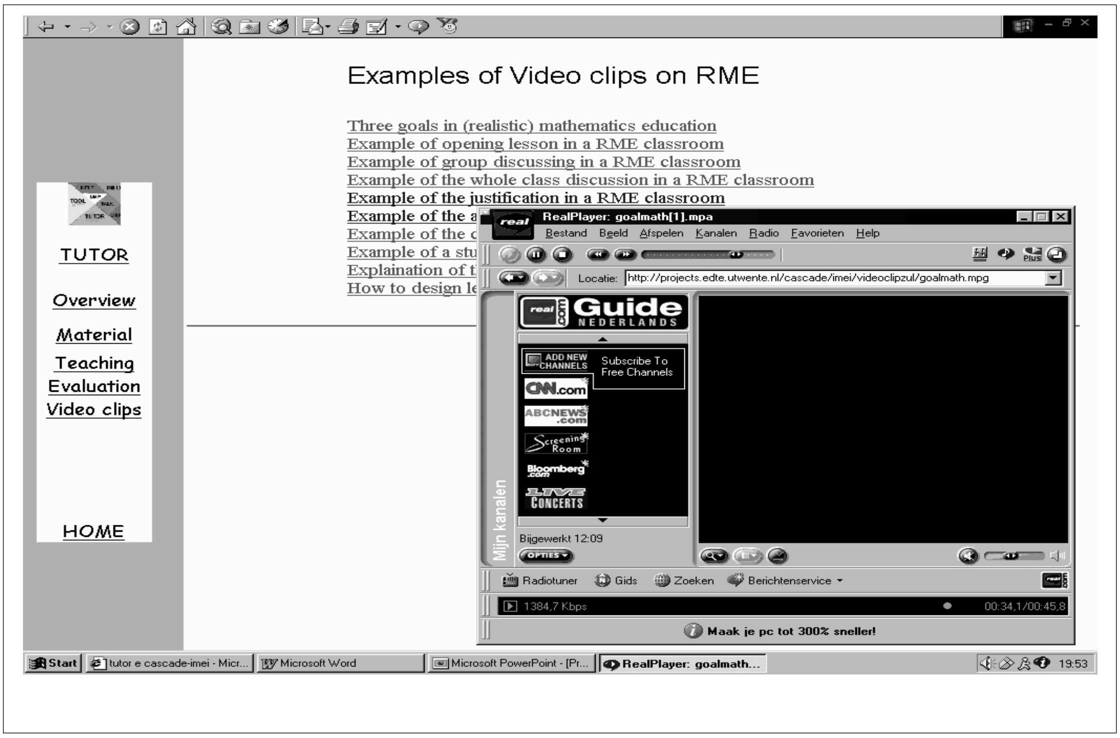


Figure 3.21
The video clips page

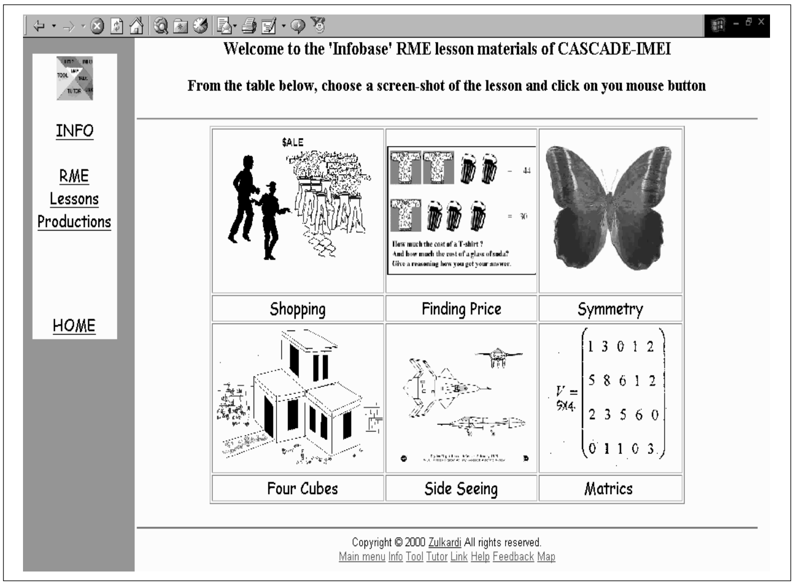


Figure 3.22
Info page of the web site

The online task or info consists of exemplary lesson materials on several mathematics topics. The materials are student materials, a teacher guide, assessment materials and students' productions from the RME classrooms.

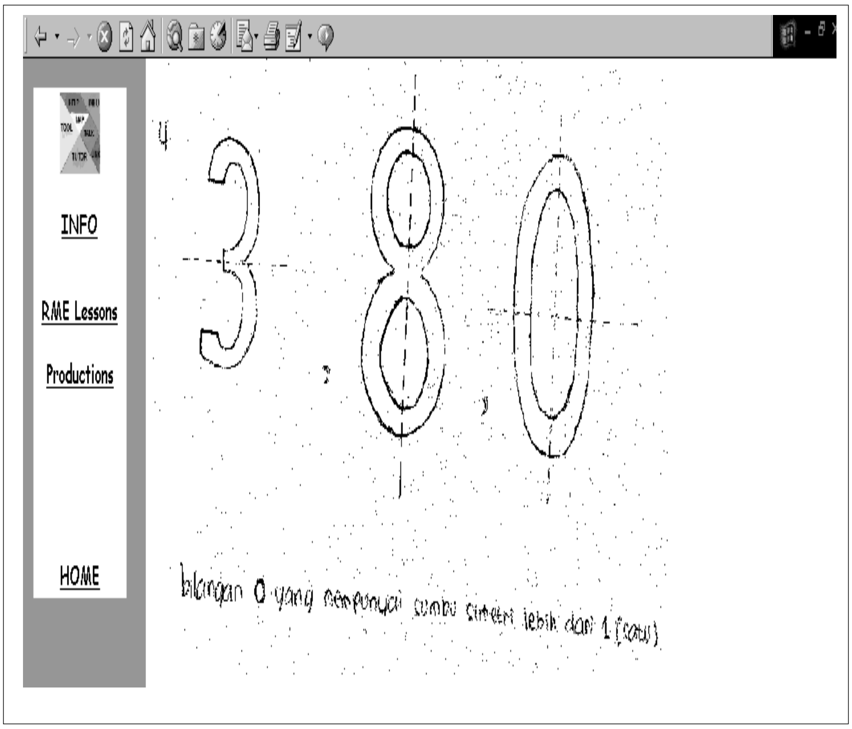


Figure 3.23
An example of pupil's solution to a symmetry problem

Figure 3.20 gives an example of the product or solution created by a pupil to a symmetry problem. He demonstrated all possible line symmetries using the Arabic numbers.
He argued that 0 has more than one plane of symmetry.

Figure 3.21 shows the Tool page of the web site. It consists of three options: Java applet simulation programs, Java scripts mathematical games (see also Figure 3.24) and the lesson builder (see also Figure 3.25). In this page, snapshots of twelve programs are displayed. All of them can be clicked on. By clicking the mouse on the each snapshot, a user can start the simulation.

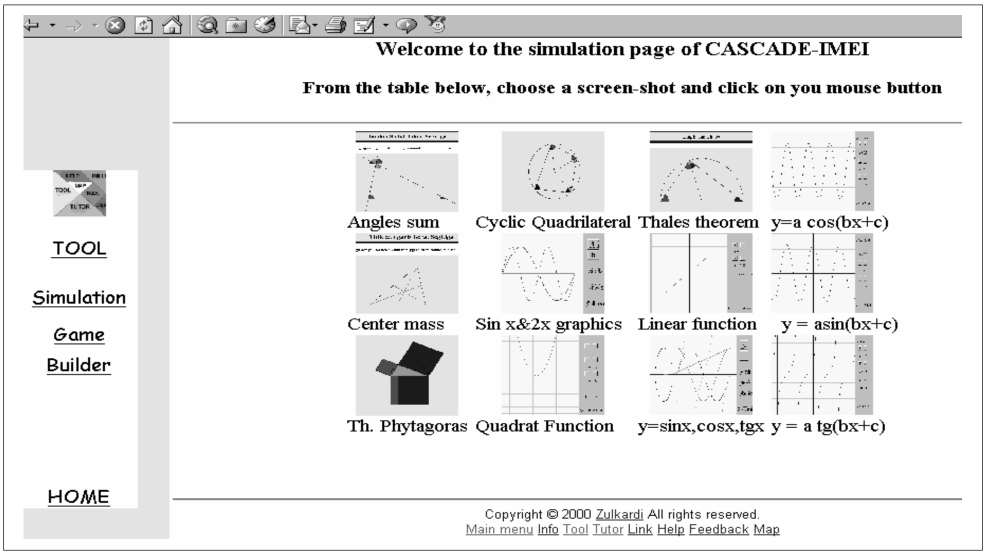


Figure 3.24
The Tool page: Java applet simulation programs

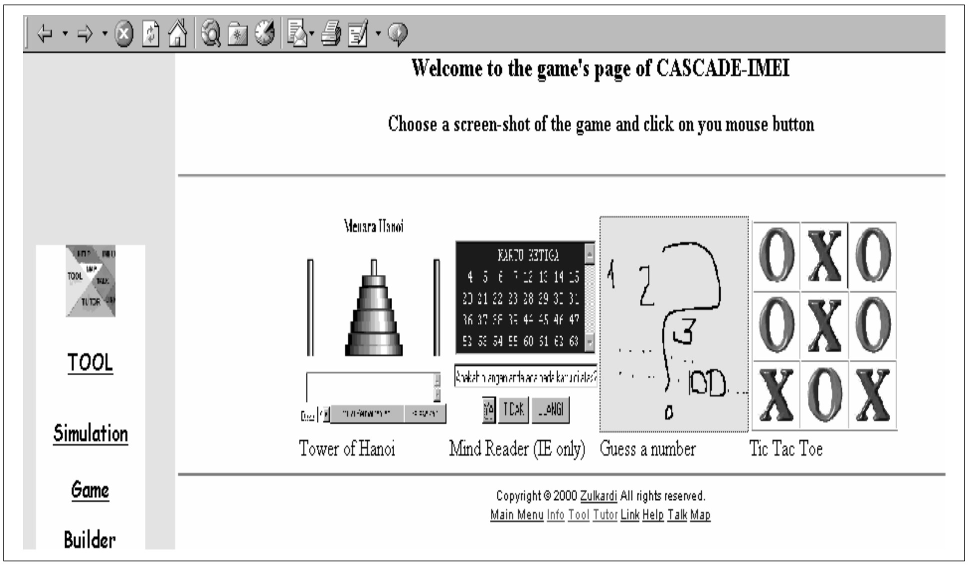


Figure 3.25
The page of mathematical games

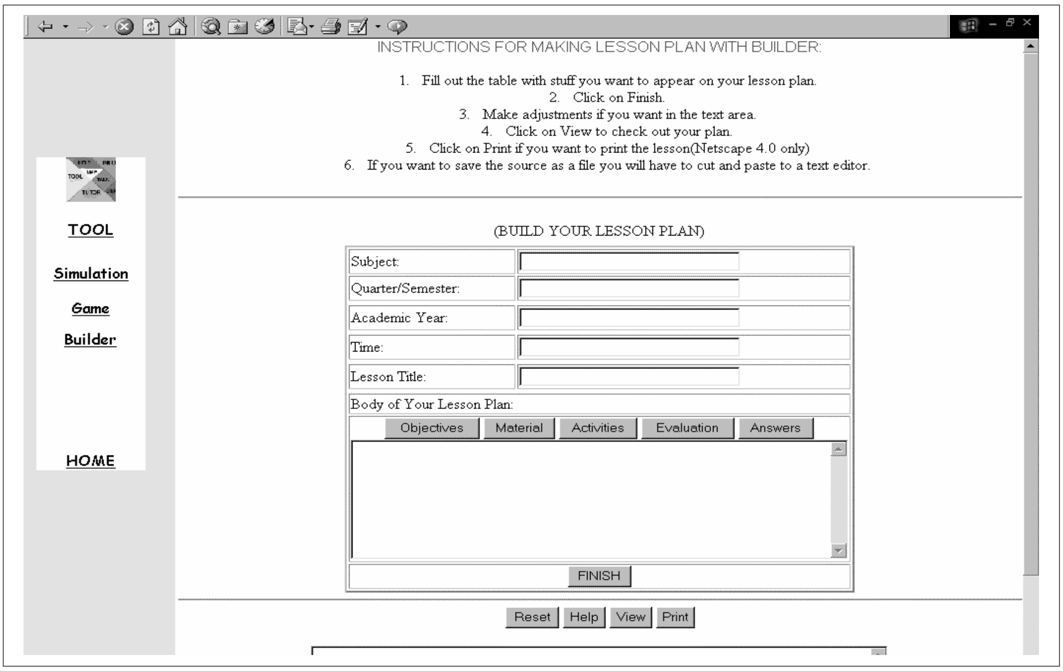


Figure 3.26
Lesson builder: A template for designing lessons

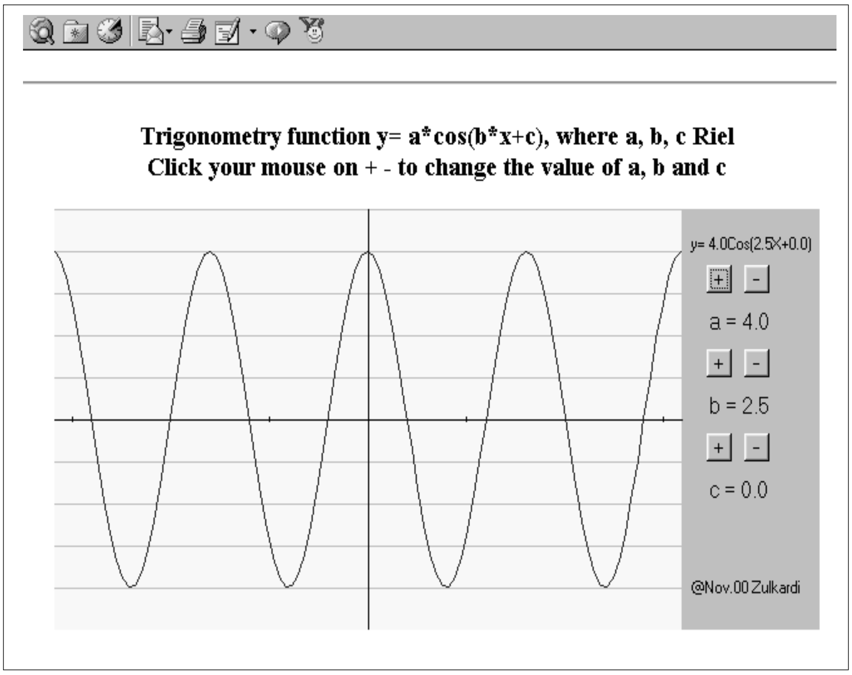


Figure 3.27
An example of simulation program: Trigonometric function

Figure 3.27 shows an example of a Java applet program on a trigonometric function.
A user may change the value of variables a, b and c in order to visualize the graphic on different variables.

In addition, Figure 3.28 shows the simulation program of a quadratic function. A recommended task is given in order to make it easier for a user to carry out a simulation. By changing the value of a, for instance, the user can clearly visualize the form of a parabola, such as whether it has a maximum or minimum value.

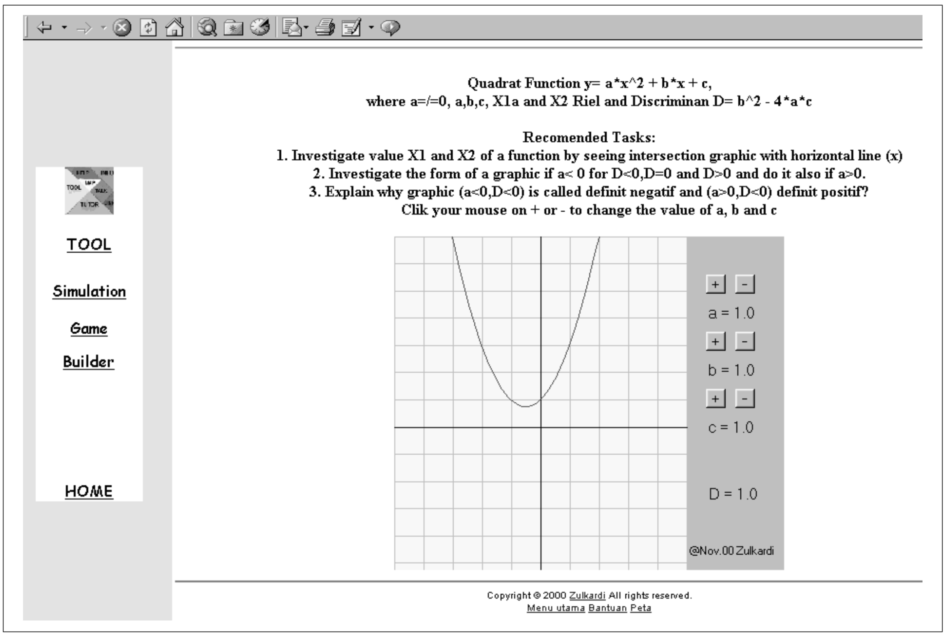


Figure 3.28
An example of simulation program: Quadratic function

Figure 3.29 shows the screen of Talk support or the communication tool. It provides a form using e-mail, a mailing list and chat facilities. The mailing list is provided by 'EgroupYahoo' free of charge. This tool is very powerful, and can be used not only for communication and collaboration purposes, but also for storing data, pictures or files (see also Figure 3.30).

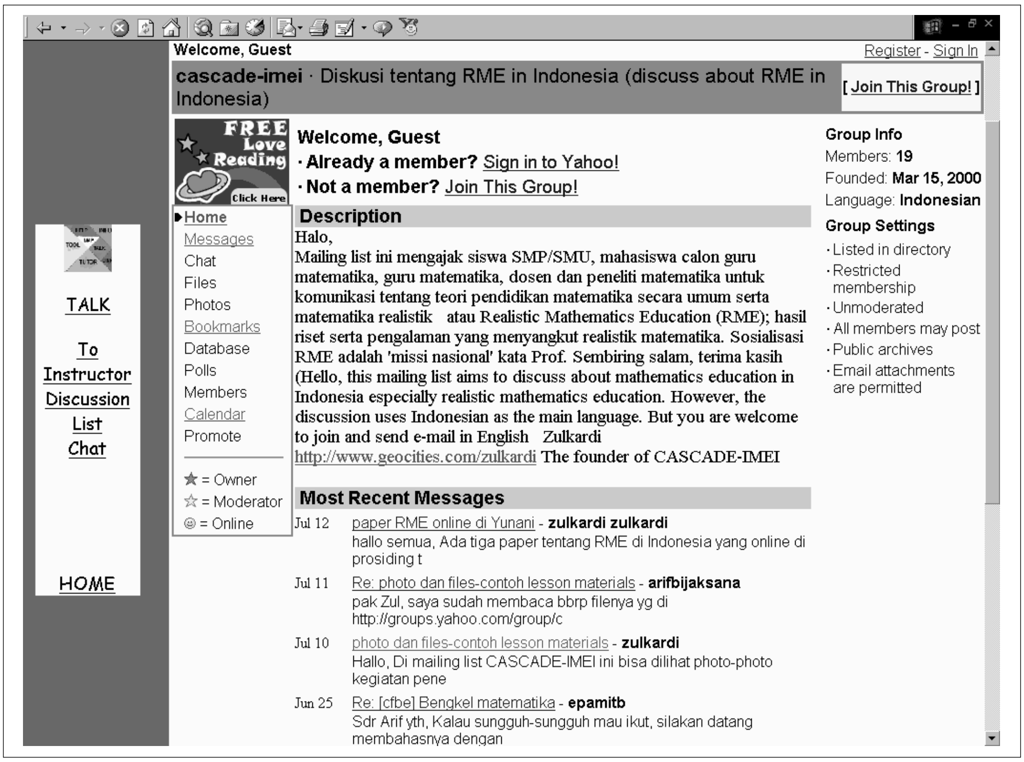


Figure 3.29
The mailing list page of the web site

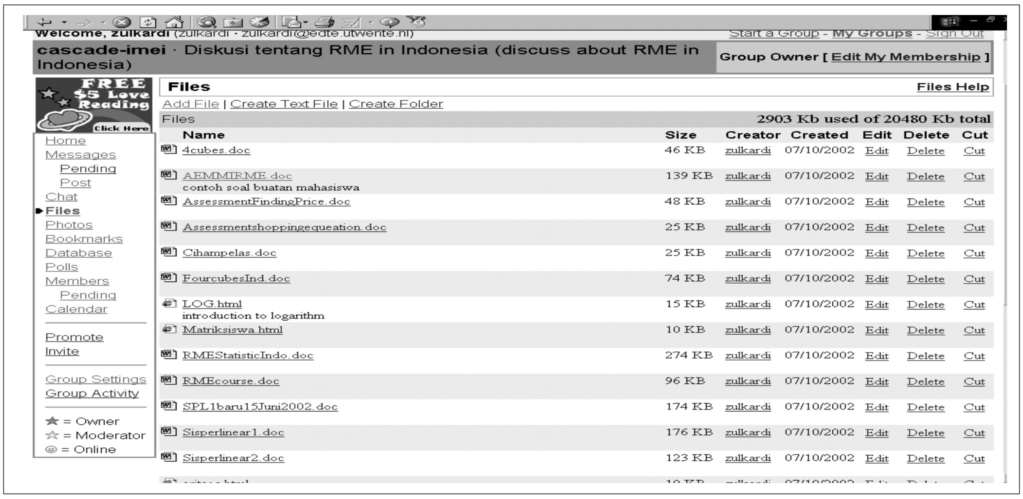


Figure 3.30
List of files of student teachers' lesson materials

Figure 3.31 shows the screen of the Frequently Asked Questions (FAQ) page as a part of the Help option. This screen consists of three options: user guide, glossary, and FAQ. While the first is aimed at helping the users in dealing with the web site technically, the last two are related to the RME.

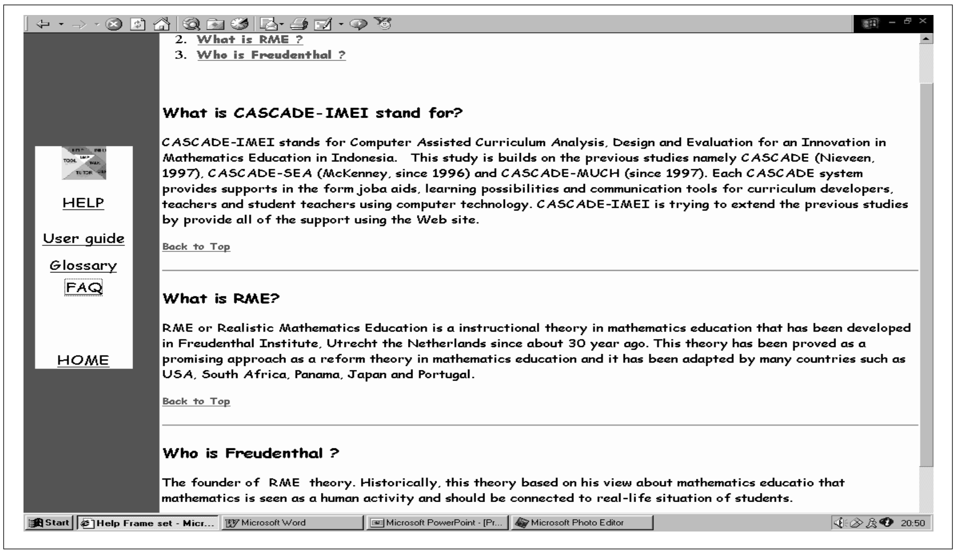


Figure 3.31
Help page: FAQ

Figure 3.32 displays the screen of the Link option. It has three type of links: link to the mathematics web sites, Educational institutions, and educational newspaper clippings. For, instance, the figure shows the web site of the Freudenthal Institute, which contains a wealth of information about RME.

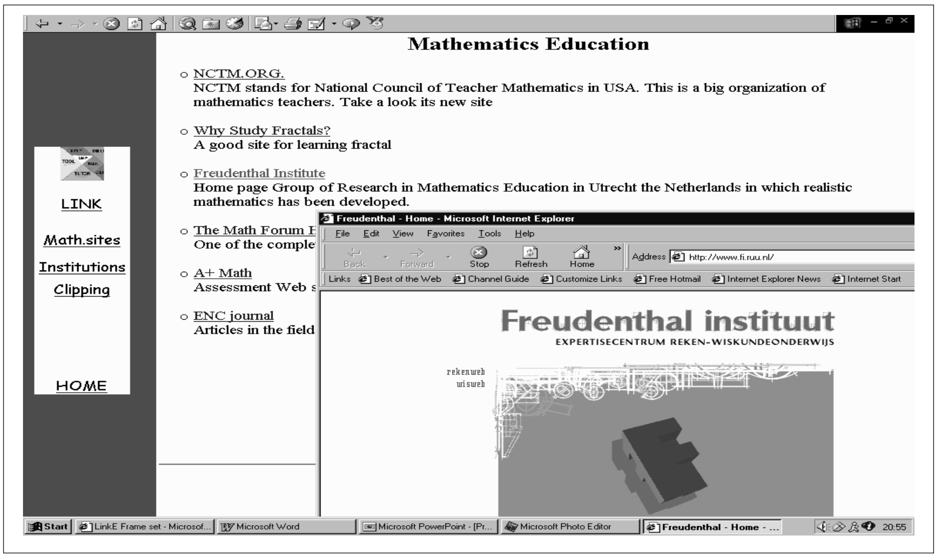


Figure 3.32
Link page and an example of the linked web site

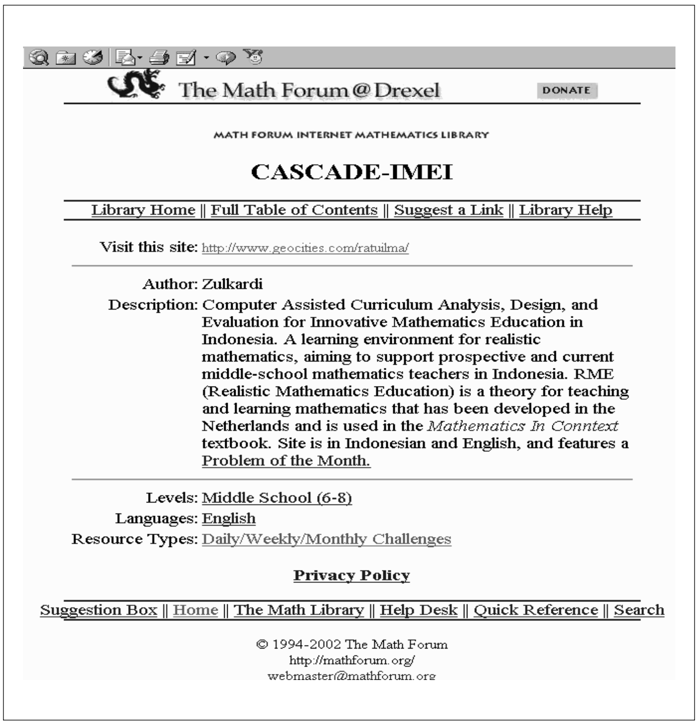


Figure 3.33 displays the screen of a page in the Math Forum web site, one of the world's leading web sites concerning mathematics. This web site contains a reference and a link to the 'problem of the month' page of the CASCADE-IMEI web site.

In addition, the CASCADE-IMEI web site is also one of the links of the Director of Higher Education web site (www.dikti.org) in the 'creativity of civitas academica' page.

Figure 3.33
The CASCADE-IMEI web site on the Math Forum web site

Figure 3.34 shows the 'problem of the month' page. In this page a list of problems are given, along with the utilities for the users such as a form for sending the solution to the problem ('solve it'), a page that consists of a clue for solving the problem ('hints'), and an example of solution to the problem ('solution').

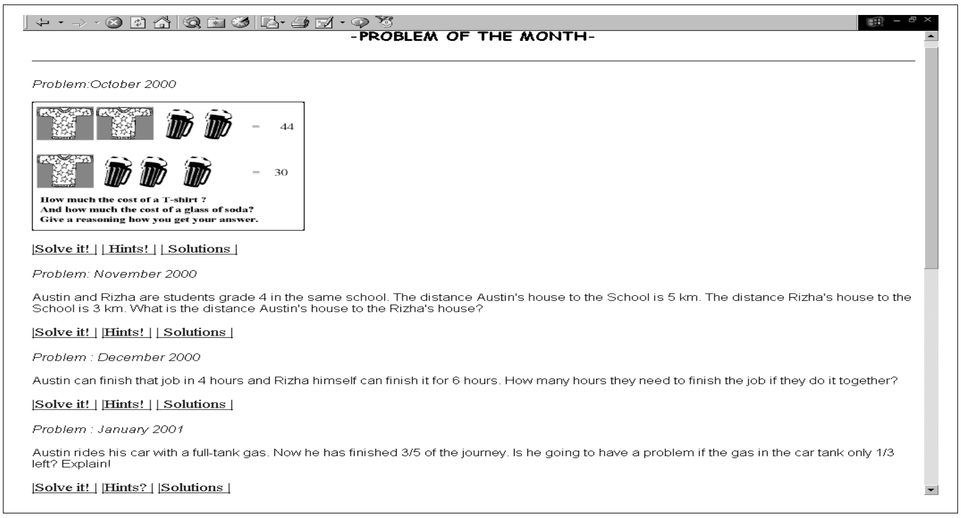
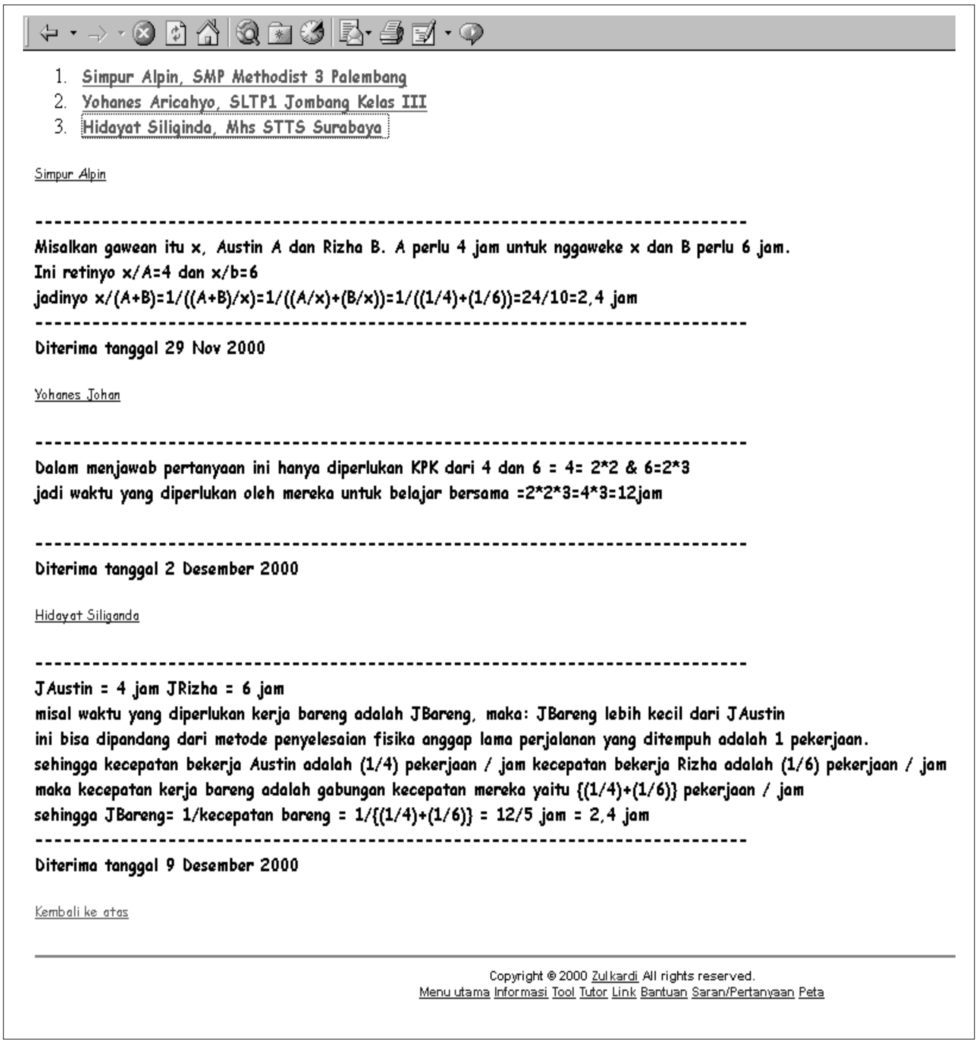


Figure 3.34
The problem of the month page

Figure 3.35 gives examples of solutions to the problem of the month for January, which were submitted by the users. The users were three students, two at the level Junior secondary schools and one at the higher education level, from three different cities in Indonesia. Two solutions are true and one is false. Interestingly, a Junior school students (Simpur Alpha) and a higher education student (Hidayat) have similar correct solutions but different strategies.


1. Simpur Alpin, SMP Methodist 3 Palembang
2. Yohanes Aricahyo, SLTP1 Jombang Kelas III
3. Hidayat Siliginda, Mhs STTS Surabaya

Simpur Alpin

Misalkan gawean itu x, Austin A dan Rizha B. A perlu 4 jam untuk nggaweke x dan B perlu 6 jam.
Ini retinyo x/A=4 dan x/b=6
jadinyo x/(A+B)=1/((A+B)/x)=1/((A/x)+(B/x))=1/((1/4)+(1/6))=24/10=2,4 jam

---

Diterima tanggal 29 Nov 2000

Yohanes Johan

Dalam menjawab pertanyaan ini hanya diperlukan KPK dari 4 dan 6 = 4= 2*2 & 6=2*3
jadi waktu yang diperlukan oleh mereka untuk belajar bersama =2*2*3=4*3=12jam

---

Diterima tanggal 2 Desember 2000

Hidayat Siligonda

JAustin = 4 jam JRizha = 6 jam
misal waktu yang diperlukan kerja bareng adalah JBareng, maka: JBareng lebih kecil dari JAustin
ini bisa dipandang dari metode penyelesaian fisika anggap lama perjalanan yang ditempuh adalah 1 pekerjaan.
sehingga kecepatan bekerja Austin adalah (1/4) pekerjaan / jam kecepatan bekerja Rizha adalah (1/6) pekerjaan / jam
maka kecepatan kerja bareng adalah gabungan kecepatan mereka yaitu {(1/4)+(1/6)} pekerjaan / jam
sehingga JBareng= 1/kecepatan bareng = 1/{(1/4)+(1/6)} = 12/5 jam = 2,4 jam

---

Diterima tanggal 9 Desember 2000

Kembali ke atas

Copyright © 2000 Zulkardi All rights reserved.
Menu utama Informasi Tool Tutor Link Bantuan Saran/Pertanyaan Peta

Figure 3.35
Examples of users' solution to the problem of the month

3.10.2 RME course

The final version of the RME course includes the video display session in which an RME-video was used as a tool for participants to see an example of how to teach based on the RME approach. Also, based on the suggestion from the users in the previous prototype, the 'doing mathematics' session was combined with the theory session. Table 3.25 shows the outline of the final version of the RME course. The total amount of weeks needed to implement the LE course is 8 weeks (6 weeks for the meetings and 2 full weeks for teaching practice).

Table 3.25
Final design of RME course

Session	Course Component	Time (minutes)	Content, activities and goals
1	Overview of RME theory and Doing mathematics	100	This activity is to make participant familiar with RME. Student teachers are treated as learners while the developer performs as a RME teacher. RME exemplary lesson materials are used in this activity. The goal is that the participants learn how to teach using the RME approach. At the end, a discussion of the background of RME is conducted.
2	Introduction to the Internet, e-mail facilities and the web site	120	Selected participants learn how to access the Internet, apply and use of e-mail, and use the web site.
3	Designing contextual problems	200 (2 meetings)	Selected participants learn how to design a lesson, a sequence of contextual problems, by adapting the available RME materials. Here, the focus of this activity is to use the tenets of RME
4	Video session	100	Learning and discussing how to teach RME by seeing a video in which the developer assumes the role of a teacher
5	Peer teaching	200 (2 meetings)	Selected participants learn how to teach using the peer teaching approach. Each of them performs as an RME teacher while their fellow students play the role of learners. At the end, a focus group discussion is conducted.
6	Teaching practice	(2 weeks)	Selected participants teach using the RME approach in the schools. Each of them performs as an RME teacher while the developer is the observer. At the end, a focus group discussion is conducted.
7	Reflection	120	The participants present their experiences in the seminar in front of the developer, their supervisors and their friends.

3.10.3 RME exemplary lesson materials

The RME lesson materials are those accumulated from previous prototypes. A total of five topics were used in the course: linear equation system, matrices, symmetry, cubes and statistics. These materials were adapted to the secondary mathematics curriculum in Indonesia and formatively evaluated by the mathematics student teachers in Indonesia. The lesson materials consist of learner materials, assessment materials and a teacher guide. The teacher guide consists of procedural specifications on how to use them. For instance, it contains concrete suggestions on the role of teachers during the implementation of the lesson.

CHAPTER 4
ASSESSING THE POTENTIAL EFFECTS OF THE LEARNING ENVIRONMENT

This chapter describes the process of assessing the potential effects of the CASCADE-IMEI learning environment (LE) in assisting student teachers in Indonesia learning to apply the RME approach. The evaluation explores the potential effects of the LE on the participants' satisfaction, participants' learning of RME, the organization of the department of mathematics education in UPI Bandung, the performance of student teachers as users of RME instruction in the classroom, and reaction or attitude of pupils toward mathematics after following the RME lessons. Section 4.1 presents an overview of the research design of the assessment stage. Sections 4.2 through 4.6 describe the results of the evaluation at all five levels. Finally, the chapter ends with several overall conclusions regarding the potential effects of the LE (section 4.7).

4.1 RESEARCH DESIGN

The prototyping stage focused of the design and formative evaluation activities that improved the validity and practicality of the LE and resulted in the final version. Based on the results of the prototyping stage, it was concluded that the content, support and interface of the LE were valid and practical. The focus of the assessment stage was on gathering data regarding several potential effects of the LE on assisting Indonesian student teachers with their learning of the RME approach.

4.1.1 Research questions

The overall research question in the CASCADE-IMEI study was:

> *What role can the CASCADE-IMEI learning environment play in assisting Indonesian mathematics student teachers with their learning of the RME approach?*

Based on the five levels of Guskey (2000) (see section 1.4.2), the following four sub-research questions were formulated:

1. What is the perception of student teachers with respect to the LE?
2. What knowledge, skills and attitudes do the student teachers learn from using the LE?
3. What effects does the LE have on the organization at the
4. Department of mathematics education in UPI Bandung?
5. To what extent do student teachers apply their newly acquired knowledge and skills on RME in the classroom?

As stated in Chapter 1, the reaction of pupils after having experienced the RME teaching-learning process was also explored.

4.1.2 Instruments

In this stage a number of instruments were used for collecting data (all of the instruments are incorporated in web pages; the URL can be found in appendix C). Table 4.1 summarizes the instruments that were used in order to gather the data.

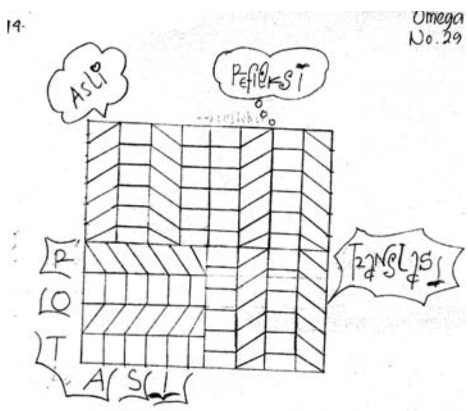
Table 4.1
Overview of questions and instruments in the assessment stage

			Instruments							
	Effectiveness	*Sub-questions*	*Entry questionnaire*	*Test*	*End questionnaire*	*Lesson analysis*	*E-mail journal*	*Teaching profile*	*Video analysis*	*Interview*
Focus		Level 1			X					
		Level 2			X	X	X			X
		Level 3								X
		Level 4						X	X	
		Level 5							X	X
	Characteristics of participants		X	X						

Entry questionnaire. This instrument was used for collecting the background biographical information of the participants such as name, age, teaching background, method courses they had already followed, and the reason why they were interested in the LE program. This instrument was administered on the first day of the RME course. These data were important for the researcher in order to determine those student teachers who were really interested in the LE.

Test. The test was used in order to select about 10 of the 33 student teachers who became the main participants of the LE. The test consisted of five contextual problems at the level of secondary problems. These problems were adapted from the MiC textbooks, and two of them were students' solutions from previous fieldwork. Student teachers were given about an hour to complete the test. As a result, the 10 student teachers with the highest scores were selected for further participation. Hence, these student teachers were invited to follow all sessions of the program, while the rest only followed the first session of the RME course (theoretical background of RME and doing mathematics). Figure 4.1 shows an example of the test materials; the URL of the rest of the materials can be found in appendix C.

Context: Free design
The following figure is an example of an eighth-grade student's solution to a mathematical problem.



1. According to you as a mathematics teacher, what was the problem?
2. As a mathematics teacher, what are your comments to this student's solution?
3. Explain on which topic in school mathematics this context matches?
4. What mathematical concept can be explained using this context?

Figure 4.1
An example of an RME-test problem

End questionnaire. This instrument was given at the end of the LE for gathering data about participants' degree of satisfaction regarding the RME course, the Internet session, designing materials, peer teaching and teaching practice in the schools. Moreover, this instrument was also used for collecting data about participants' overall learning through the whole process of the program.

Lesson analysis. One of the activities student teachers conducted in the course was redesigning a sequence of contextual problems based on the available RME materials. These sequences of problems have dual functions either as lesson materials or as assessment materials. The indicator that was used characterize the lesson analysis was the extent to which the student teachers were able to embed the characteristics of RME into their lesson materials. For instance: Do they use meaningful contexts related to the concept of the mathematics topic? Do their mathematics problems invite pupils to discuss their solutions? Do they intertwine the topics with other strands or subject matter? Do their mathematics problems let pupils produce their solutions freely? Do their mathematics problems guide the pupils to use their informal models or strategies instead of directly using the formal one?

E-mail journal. The LE invites student teachers to be actively involved in the online discussions, both by sending their messages using e-mail and joining the mailing list. Using e-mail facilities, they could communicate their problems, their experiences and other things that were related to their activities. All of their e-mails were registered and sorted into the following three categories:

- *Check visit e-mails:* e-mails sent automatically by the web site when the users fill in the form in the second page of the web. The function of this tool is to check the name of the web user, and register the number of times the user has used the web site and the status of the user, i.e. student teacher, pupils or others.
- *Direct e-mails:* messages concerning the innovation that was sent directly by users to the developer. First, messages were sent asking for information about RME resources. Second, messages were solutions of the users to the problem of the month. The last type of messages related to the conversation between the participants and the developer either using personal e-mail or the mailing list. The content of the conversation was mainly on feedback about what they have learned; and
- *Mailing list:* messages that were sent by the users in the mailing list.

Teaching profile. A *teaching profile* (or *innovation profile*) is a set of essential elements about intended actions of teachers during lessons, while the degree of actual implementation of the innovative materials is called a *practice profile* (Ottevanger, 2001; van den Akker & Voogt, 1994). The teaching profile helps to formulate the relationship between the intended and implemented curriculum in concrete terms. Therefore, the profile can be used to observe teacher performance in using the innovation – in this case a realistic mathematics approach, in the classroom.

The elements in the profile used during the evaluation in the context of the LE are categorized in three sections (Ottevanger, 2001; van den Akker & Voogt, 1994): a threshold, ideal and unacceptable elements. A *threshold* is a minimum set of actions the designer would like to see during the lesson. The threshold sets minimum condition such as 'the teacher uses a meaningful real life example in starting the lesson' or 'the teacher gives pupils more opportunities to explain their thinking and understand someone else's solution'. *Ideal elements* are what the designer finds important during the execution of a lesson. The ideal elements in this study include such things as: 'a teacher can make an effort to involve pupils in practical activities ' or 'the teacher moves around the class during group discussion and gives a hint or suggestion when pupils have questions'. *Unacceptable elements* are those actions the designer would rather not see during the lesson. These elements include 'the teacher offers pupils an alternative solution too quickly' and 'the teacher ignores questions and answers from pupils'.

Scoring of the elements on the teaching profile will use the following criteria: 'yes' if the element is a reflection of what is observed, 'no' if that is not the case and 'n/a' if it is not applicable for a particular situation or lesson. If the statement is marked by 'n/a' then it will not be tallied in the results. The innovation profile is divided into three sections based on the lesson structure: (1) start of lesson; (2) body of the lesson; and (3) end of lesson. Moreover, the statements in the profile are designed based on the five tenets of realistic mathematics education (de Lange, 1987; Streefland, 1991).

Video analysis. Video recordings were used in order to evaluate the process of the teaching practice in the classrooms. Besides, it was also used as a tool for checking the results of the observation, as well as a tool for interviewing student teachers and pupils right after the class over.

Interview. Interviews were used for collecting data on the perceptions and learning experiences of the student teachers and pupils. Two kinds of participants were interviewed: student teachers who had just finished their teaching practice and pupils who had just followed the RME instruction in the schools. The results from the latter interview were used to gain the indications of the RME instruction's effect on the attitude of the pupils toward mathematics.

4.1.3 Participants

The main participants of the assessment study were mathematics student teachers. In addition, school pupils, teacher educators and a senior student teacher were also involved. All of them were differentiated into four categories: working group, pupils, observer and supervisor.

Working group. The members of the working group were mathematics student teachers. They were mainly third-year student teachers in the Department of mathematics education in UPI Bandung. In the first day of the RME course, 41 registered student teachers who were taking the Seminar course came and followed the RME course in order to gain insight in the CASCADE-IMEI research. After the developer explained the goals, time line, requirements, tasks, procedures and activities, 33 student teachers expressed continued interest in the program. From these 33 student teachers, 10 student teachers were selected non-randomly to become members of the working group. In this research, the developer wanted to know whether the LE could have impact at least under favorable circumstances, i.e. with the best teachers. Two selection criteria were used: good ability in solving RME problems (by RME -test), and being highly motivated to learn the new approach (by interview). This selection was made due to the limitation of the time (for instance to evaluate the lesson materials or observe the teaching practice) and budget (for instance to pay the cost of the internet cafe) available to the developer.

During the course, student teachers were asked to find some secondary schools in which they could conduct their teaching practice. It was important to find schools early in the course so student teachers could discuss with school teachers which topic of mathematics they could teach during the teaching practice period. The background information of the 10 selected student teachers (gender, age, topics they taught and the schools and grades of their teaching practice) can be seen in the Table 4.2.

Table 4.2
Background information of the participants and their teaching practice schools

No	Name	Gender	Age	Score test	Topic they teach	Name of the practiced schools	Grade
1	E	F	21	87	Social arithmetic	SLTP KOPRI	7
2	J	F	21	81	Social arithmetic	SLTP KOPRI	7
3	F	F	23	79	Social arithmetic	SLTPN 12	7
4	I	F	22	70	Ratio	SLTPN 29	7
5	D	M	21	70	Fraction	SLTPN 9	7
6	G	F	22	70	Social arithmetic	SLTPN 12	7
7	A	M	22	69	Social arithmetic	SLTPN 27	7
8	H	M	22	68	Ratio	SLTPN 29	7
9	B	M	21	67	Social arithmetic	SLTPN 27	7
10	C	F	22	66	Fraction	SLTPN 9	7

Pupils. In addition to the student teachers, about 400 pupils of grade 7 (age 12-14) from 10 different classrooms in five junior secondary schools were involved. However, as they were not the main subject of the research, only four pupils were interviewed for gaining data about pupils reaction to the instructional process.

Observer. The developer performed as the main observer in the schools. Moreover, another three types of observers participated. First, a teacher educator was invited as an observer during the course program in teacher education. Second, a senior student teacher that had followed the LE in the last fieldwork participated during teaching practice in his school. Finally, the two student teachers who were doing teaching practice at the same school performed as an observer to his/her colleague student in order to directly learn how their colleague manages the classroom as well as learn how to observe a classroom using an innovation profile instrument.

Teacher educators. Six teacher educators were marginally involved in this assessment stage – that is, one person as an observer, one as a lecturer of the Seminar course, and four as supervisors of the student teachers. Two of the supervisors were the Head and Secretary of the Department of mathematics education.

4.1.4 Situations, activities and procedures

The assessment stage of the study was conducted in Indonesia from September to December 2001. The research activities started with a meeting with the head of department and the lecturer of the seminar course discussing about the final try out of the LE. As a result, they agreed to conduct the try out using the framework of the Seminar course. All activities were conducted in three different environments in Bandung: (1) the RME course was conducted in the teacher education institute at UPI; (2) teaching practice was carried out in five selected junior secondary schools; and (3) the web site was used in an Internet cafe nearby campus. The LE activities were conducted within a time frame of 8 weeks: 6 for the course and 2 weeks for school observation. All activities are summarized in Table 4.3.

Table 4.3
Main activities in the LE and instruments used in the assessment stage

No.	LE activities	Instruments
1	Overview of RME theory and doing mathematics	– entry questionnaire – RME-test
2	Introduction to the Internet, e-mail facilities and the web site	– e-mail journals
3	Designing lesson materials or contextual problems	– lesson analysis
4	Video session	– observational notes (their comments on the video show)
5	Peer teaching in teacher education	– teaching profile
6	Teaching practice in the schools	– innovation profile, video recordings, interviews
7	Reflection in a seminar	– e-mail journals, interviews, and end questionnaire

First, participants were invited to complete the entry questionnaire in order to learn about their background. Then, the course started by presenting the information about the basic principles of RME and its characteristics. Some examples of RME problems were given and discussed in small groups, in order to give an idea of each characteristic of RME. Next, the RME-based test was given to all student teachers in order to help select the main group of the LE. This selected group followed the rest of the program.

During the 'doing mathematics' session, the participants worked on a number of RME problems in five topics (*linear equation system, matrices, symmetry*, *cubes and side seeing*, and *statistics)*. In this session, they were treated as learners while the researcher assumed the role of the teacher. After they solved the problems, they were guided in discussing the various strategies in order to identify efficient and adequate strategies. In several cases, they were invited to present their answers in front of the class.

Regarding the web site, several activities were carried out. First, the participants were trained on how to access the Internet. Then, they were guided in making a personal e-mail. They were invited to use this e-mail facility by sending their background information to the researcher as well as to other student teachers. Here, they learned how to compose a new e-mail message, to send it and to access e-mail sent by other users. In addition, they were taught how to use the attachment facility. Second, they were invited to access the web site, to make comments and to send these comments to the developer. Moreover, they were asked to communicate the problems that they encountered during the course to the developer and other participants using the e-mail facility. Finally, they were asked to send a reflective journal using e-mail explaining what they had learned from the learning environment. All of their comments were registered electronically for further analysis.

Furthermore, an RME video demonstration with the researcher in the role of the teacher was used to show how to teach using the RME approach. In about an hour, student teachers saw how to manage a RME classroom. It started from how to open the lesson, make groups, orchestrate the group or whole class discussions, ask pupils to communicate, argue and justify, give the assessment and close the lesson. At the end of the video show, student teachers discussed and reflected on their perceptions about the information from the video.

In addition, as a part of the course, all student teachers learned how to develop lesson materials based on the available materials, as well as the needs of schools in which they were going to teach. Schoolteachers allowed the student teachers to use their mathematics classes, as long as the student teachers would be teaching mathematics topics that coincide with the school's current mathematics curriculum. This commitment is important for both the teachers and the student teachers. For the schoolteachers, their tasks were limited to that of observers, or they were left free to do other work in their office. In contrast, student teachers needed to do a thorough job in teaching the materials to the pupils, so that the schoolteachers would not have to teach that topic again.

Moreover, after designing the materials, student teachers used the materials in front of their peers (peer teaching). Here, they gained experience in how to teach the subject matter and receive input and feedback from both their peers and the researcher. Then, they used the materials 'for real' during the teaching practice in the school classrooms with the researcher and other observers observing their lessons. Finally, at the end of the teaching practice, student teachers were asked to present a seminar to communicate their experiences in front of their colleague students, the developer and teacher educators.

4.2 Results level 1: Participants' satisfactions

The question in this level was: What is the perception of student teachers with regard to the LE? Here, the student teachers' satisfaction is gauged related to the organization and components of the LE, as well as their experiences in using the LE. The instrument used in this level was the end questionnaire.

4.2.1 Participants' satisfactions with regard to the web site

The student teachers' satisfaction was polled via questionnaire related to three main features of the web site: content, support and user interface. The questionnaire consisted of 25 questions: 5 for the content (Table 4.4), 8 for the support (Table 4.5), and 12 for the user interface (Table 4.6). This questionnaire was comprised of four-scale Likert-type questions with statements about the perceived practicality concerning the content, support and user interface.
The *content* of web site relates to the conceptualization of RME. The participants' satisfactions with regard to the practicality of the content of the web are summarized in Table 4.4.

Table 4.4
Participants' (n=10) perceived practicality of the content of the web site

No.	Content	Mean*	S.d.
1	The web site offered me content that was useful for designing realistic mathematics lessons.	3.9	0.3
2	Lesson examples on the web were easy to understand.	3.9	0.3
3	Examples of the pupils' solutions on the web were easy to understand.	3.9	0.3
4	In general, the content of the web site is clear to me.	3.9	0.3
5	In general, the content of the web site is flexible so that I can easily adapt it to my needs.	3.8	0.4

Note: * 4 = highly positive, 1=highly negative.

All key aspects of the content were judged to be practical. All participants agreed that the content of the web is useful, flexible, and clear. The two main parts of the content (lessons and pupils' solutions) were easy to understand. Moreover, Table 4.5 shows the order in which the *support* offered by the web was satisfying to the student teachers.

Table 4.5
Participants' (n=10) perceived practicality of the support of the web site

No.	Support	Mean*	S.d.
6	Video clips on the web site inspired me in managing the RME classroom.	3.9	0.3
7	I like the 'problem of the month' on the web site because it supports me in finding examples of assessment problems in RME.	3.8	0.2
8	The tutor part of the web site gave some practical information on how to teach RME	3.8	0.4
9	The theoretical information about RME was useful for me.	3.8	0.2
10	Mathematical game programs on the web site are interesting to me.	3.7	0.5
11	The other support such as communication tool is useful.	3.7	0.5
12	Mathematical simulation programs on the web site are interesting to me.	3.6	0.5
13	All support was present when I needed it	3.4	0.3

Note: * 4 = highly positive, 1=highly negative.

Overall, the student teachers were highly satisfied with the support. According to them, video clips were of most value. Also, the problem of the month with its RME assessment problems was well received by the users.
Regarding the *user interface* of the web site, the order of satisfaction of the student teachers is summarized in Table 4.6.

Table 4.6
Participant's (n=10) perceived practicality of the user interface of the web site

No.	User interface	Mean*	S.d.
14	Buttons were easy to find.	3.9	0.3
15	Texts on the screens were understandable.	3.8	0.2
16	I would like to work with the web site.	3.8	0.4
17	I like the interface (the layout of the screen).	3.6	0.5
18	It was clear to me how to navigate through the web site.	3.5	0.5
19	My tasks on every screen were clear.	3.5	0.7
20	In general, the web site is simple.	3.4	0.7
21	I could work easily with the web site.	3.3	0.5
22	It was clear how to use the communication tools.	3.3	0.5
23	I knew how to use the communication tools.	3.3	0.6
24	I was always able to locate where I was in the web.	3.3	0.8
25	I never got lost in the web site.	3.2	0.7

Note: * 4 = highly positive, 1=highly negative.

From Table 4.6 it can be seen that the student teachers were satisfied with the practicality of the user interface. The buttons and texts were practical to the users because most of the buttons are provided with easy to recognize icons and the texts are written in Indonesian language. Generally, student teachers agreed that the interface was clear and simple enough to them so they could easily use and work with the web site.
Figure 4.2 shows the visualization of means from 25 questions of the questionnaire.

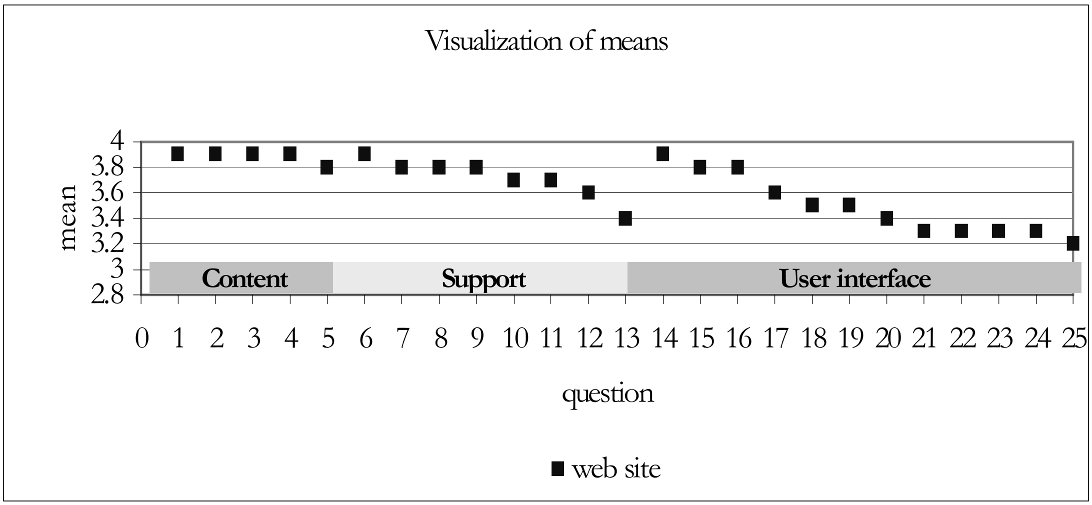


Figure 4.2
Visualization of means from the questionnaire about the web site

Moreover, when student teachers were asked about what potential problems they saw concerning the web site in the future, it appeared that two users (of 10) felt they had only limited training time. In addition, three users mentioned that they had monetary problems renting a computer in the Internet cafe. Also, three users indicated that the Internet cafe was located far from their houses. Moreover, three student teachers reported that some computers in the Internet cafe have slow access especially during the working hours and downloading process.

All of the student teachers answered 'yes' when they were asked whether they would use the web site in the future. They gave the following reasons (see box 4.1)

Box 4.1
Summary of the participants' reasons to use the web

- *it consists of much useful support for my job as mathematics teachers for getting information about RME and mathematics education in general;*
- *if it is updated, I can get up-to-date information about RME, as well as can share my RME materials;*
- *I can get new assessment problems and communicate with other friends and mathematics teachers; and*
- *the web site is very useful and matches to my needs as a student teacher. Through this web site I understand how to learn mathematics based on the realistic approach.*

Based on the comments in the Box 4.1, it can be concluded that most participants believed that an updated version of the web site could provide them with up-to-date information about RME and its activities in Indonesia. Also, it appeared that they want to communicate with other mathematics teachers who deal with RME.

4.2.2 Participants' satisfactions to the RME course and its materials

General perception of the RME course

At the end the course, student teachers were asked about their satisfaction with the RME course. A questionnaire with 25 questions was given consisting of 5 questions on general satisfaction (Table 4.7), 8 for the course characteristics (Table 4.8), 4 for the usability of the course (Table 4.9), and 10 for the participants' learning (Table 4.10). This questionnaire was comprised of five-scale Likert-type questions. This scale is different from the web site questionnaire that used a four item scale. A graph visualizing this differentiation is provided at the end of this section.
Table 4.7 summarizes the results of the first type of the perceptions.

Table 4.7
General satisfaction perceived by student teachers (n=10) to the RME course

No.	Participant's opinions	Mean*	S.d.
1	The course is useful for me as a prospective mathematics teacher.	4.9	0.3
2	The course provides a lot of new information.	4.9	0.3
3	The course inspired me as a student teacher.	4.6	0.5
4	The course is consistent with my expectation.	4.5	0.5
5	The course was interesting to me as a student teacher.	4.3	0.5

Note: * 5 = strongly agree, 1= strongly disagree.

On average, the student teachers were very satisfied with the RME course. They agreed that the course consists of a lot of new information to their job as (prospective) mathematics teachers. In addition, they also were inspired by the course and it was in line with their expectations.

Participants' satisfaction with the RME course characteristics

Table 4.8 summarizes the opinion of the participants to the characteristics of the RME course.

Table 4.8
General opinion of the student teachers (n=10) to the RME course characteristics

No.	Course aspects	Mean*	S.d.
6	In the course a variety of mathematics topics were used	4.7	0.5
7	Student involvement- student's role	4.7	0.5
8	The contexts that are used in the lesson	4.6	0.5
9	Teacher's role	4.5	0.5
10	Teaching approach that is used by the researcher in the course	4.4	0.5
11	Interactivity (classroom activities) such as discussion and presentation	4.4	0.5
12	Assessment strategy used	4.4	0.6
13	Use of materials	4.2	0.4

Note: * 5 = very good, 1=very bad.

Generally speaking, the student teachers were positive about the course. Student teachers agreed that they were satisfied due to the fact that the course consists of various mathematics topics in different contexts. They also believed that there are changes in the roles of students and teachers in RME teaching and learning.

The comments given by student teachers to the RME course characteristics can be found in the Box 4.2. Eight questions were asked to the participants in order to see to what extent they had learned about RME by following the course.

Box 4.2
Summary of participants' opinions on the RME course characteristics

Student teachers' opinions about:

1. The role of contexts that are used in the lesson. *Using contexts, the materials can be directly related to the daily life and the instruction is more meaningful to the pupils. Hence, the materials can increase the pupil's motivation to learn mathematics as well as to solve the problems.*
2. The researcher in the course used teaching approaches. *By using the role of teacher as guide and motivator, they agreed that they are more active and more relaxed.*
3. The interactivity (classroom activities) such as discussions and presentations. *Using this method, student teachers agreed that they could communicate in a discussion. This is good because it trains the students to communicate their opinion and argumentation even in the front of the class. Also, using this method, various solutions and strategies for one problem came up during the discussion. Hence, students can learn from classmates about their solutions and ways of communication. They can compare their solutions with others to find the adequate or efficient strategies. Thus, this way can train students to be more critical.*
4. Evaluation/assessment strategy used. *They agreed that by using formative and summative methods of assessment the teacher can see not only the product or the solutions but also the process used to come to the solutions.*
5. The variety of topics of lesson materials that were used. *By using five topics, student teachers agreed that mathematics not only deals with numbers and rules, but is also intertwined with other subjects and daily life. Moreover, they believed that RME can be applied to all materials in the school mathematics.*
6. The role of pupils in the teaching process or student involvement. *They were glad that all students had a chance to communicate their ideas, although time was limited. Also, since the teacher gave attention to all students' comments or solutions, they felt that it can improve their self-confidence. In addition, they agreed that by students' involvement the materials would be more easily remembered. In other words, this way of learning can be categorized into the long-term memory of learning.*
7. The role of teacher. *Some of student teachers realized that the role of teacher become more difficult in which they have to be a facilitator, motivator and guide. But, they agreed that this role could guide pupils to get more insight in the problems and make it easier for them to learn math. However, one of the student teachers mentioned that teachers need more energy to conduct the class discussion and guide students.*
8. The use of exemplary lesson materials. *All of them agreed that this strategy is interesting and makes it easier for them to understand RME. But, they would like more materials on new mathematics topics.*

In general, it can be concluded that student teachers were not only satisfied with the characteristics of the course but also that they gained a better understanding about the characteristics of RME. In other words, they could explain the meaning and function of the RME characteristics in the instructional process. For instance, the benefits of the use of meaningful context, the role of teacher and pupils, interactivity, the use of (integrated and various) materials and the assessment strategies.

The usability of the RME course session

Table 4.9 presents the order of student teachers perceptions on the usability of the four course sessions.

Table 4.9

The usability of the RME course session as perceived by student teachers (n=10)

No.	Course sessions	Mean*	S.d.
14	Didactic component	4.9	0.3
15	Practical component	4.8	0.4
16	Mathematical component	4.7	0.5
17	Assessment component	4.6	0.5

Note: * 5 = highly useful, 1=highly not useful.

As can be seen in the Table 4.9, all participants believed that all of the course sessions were useful, especially the didactic part. They chose the didactic component as the most usable session based on the following reasons: (1) they were treated as learners so that they could see and learn for themselves how to teach RME and could remember teaching steps and critical teaching moments; (2) the didactic session provided a number of lesson materials that they would use; and (3) by displaying a video presentation, they could see how a teacher might manage the RME classroom. Moreover, the didactic session was also perceived by student teachers as the easiest session of the RME course. The reasons given by the participants were: this session only covers learning theory; they performed as pupils in doing mathematics; and watching a video. Based on this it can be concluded that the three strategies that were used in the didactic session (teachers as learners, use of exemplary lesson materials, use of a video) were powerful (useful with least difficulty) in promoting student teachers in learning a new approach.

In addition, the six out of ten students agreed that the hardest session of the RME course was the practical session. The reasons were: (1) they have to make teaching preparations and use them in teaching practice both in the simulation and the classroom; and (2) designing lesson materials was difficult, especially finding real life examplesthat match with the mathematics concepts to be taught. However, even tough they felt that the practical part was the most challenging, they agreed that they learned a lot and had good experiences. For instance, by visiting and teaching in schools they learned how to collaborate with practicing schoolteachers. Besides, they also learned what the schoolteachers are usually doing such as: designing lesson plans, meeting with other teachers and the principal, teaching, dealing with pupils, and reflecting on their experiences.

Figure 4.3 shows the visualization of means of data from 25 questions of the course questionnaire.

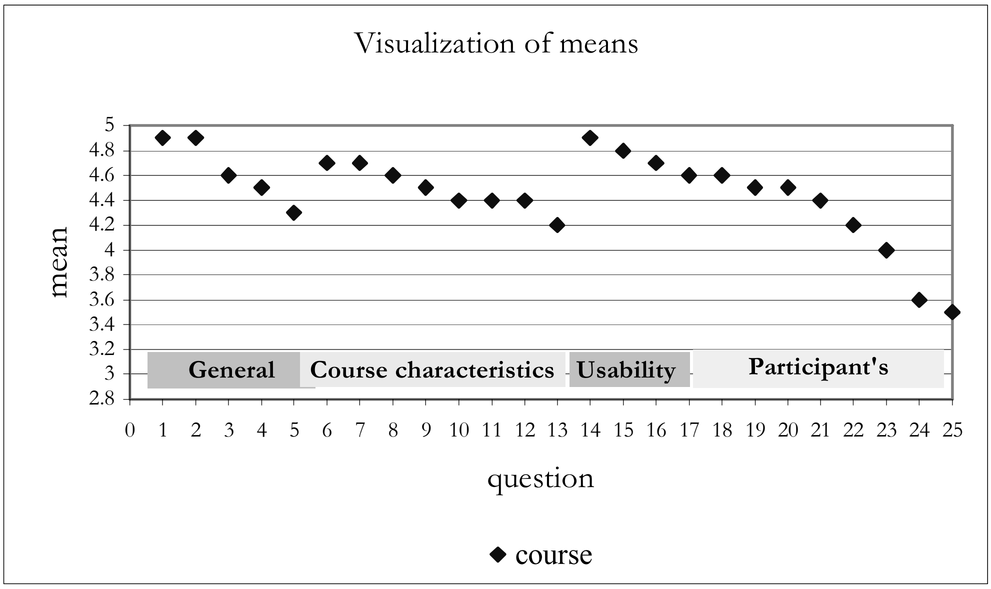


Figure 4.3
Visualization of means from the course questionnaire

In summary, Figure 4.4 displays the superimposed mean scores of the web site and the course (note that the website and course use different scales).

The left (vertical) axis refers to the scale that is used in the web site questionnaire while the right refers to the scale that is used in the course questionnaire. Both questionnaires have 25 questions.

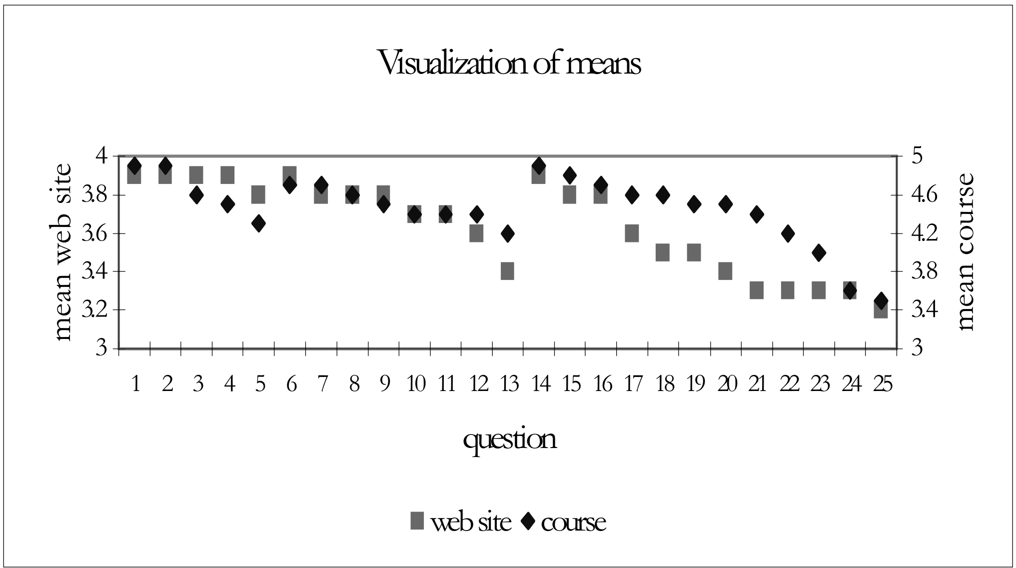


Figure 4.4
Visualization of means from both the web site (from Figure 4.2) and the course questionnaires (from Figure 4.3)

4.2.3 Conclusion for level 1

Based on the results and interpretations above, it can be concluded that the participants were satisfied with the LE. They were satisfied with the organization and components of the LE (both the web site and the RME course). Regarding the web site, they were satisfied with the practicality of the content, support and interface. All of them indicated a desire to use the web in the future, either for finding new information about RME or to share their new experiences with other mathematics teachers. In addition, participants were also satisfied with the RME course in terms of materials used, teaching method, roles of teacher, classroom management and assessment strategy. This satisfaction could be seen as a prerequisite for or even in some cases as a part of participants' learning.

4.3 RESULTS LEVEL 2: PARTICIPANTS' LEARNING

The question central to this level was: What knowledge, skills and attitudes did student acquire by using the LE? That means, student teachers have learned if changes occurred in their knowledge, skill level and attitude or beliefs with regard to the content and didactic part of RME. Instruments that were used in this level were the end questionnaire, lesson analysis, e-mail journals and interviews.

4.3.1 Participants' learning based on the questionnaire

After following the RME course, student teachers were invited to fill out the end questionnaire in order to find out about their experiences from the course as well as to see what they had learned. Table 4.10 presents the eight questions asked as well as the data that were generated from the questionnaire.

Table 4.10
Student teachers' (n=10) learning from the RME course

No.	**Course aspects** *The course has given me sufficient information and suggestions on:*	Mean*	S.d.
18	how to conduct the RME teaching learning process.	4.6	0.5
19	how to manage the interactive classroom in using RME materials	4.5	0.5
20	how to use contextual problems as a starting point for teaching mathematics	4.5	0.6
21	how to use informal strategies (drawing, model, counting, estimation, etc) in solving contextual problems before they use the formal mathematics	4.4	0.6
22	how to connect the materials among other topics or strands.	4.2	0.4
23	how to conduct assessment either during or at the end of the instructional process.	4.0	0.5
24	how to search additional resources or help through Internet in order to learn more about RME and implement the RME approach in my classroom	3.6	0.5
25	how to comment or score on the student productions or student solutions.	3.5	0.7

Note: * 5 = strongly agree, 1=strongly disagree.

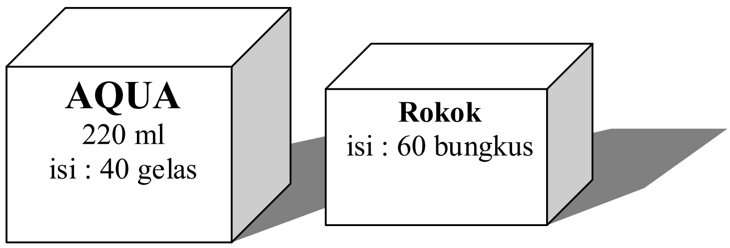
From Table 4.10, it can be seen that student teachers learned most about how to teach using the RME approach. This table illustrates that some student teachers agreed less on how much they had learned from additional resources or help through Internet (point 7) and how to score on the students' solutions. These findings can be explained as follows. First, they could not get additional information about RME in Bahasa Indonesia. The web site of the CASCADE-IMEI appeared to be the only web site that uses the Indonesian language. Second, although the information on how to score pupils' solutions was available, they probably still have difficulty to apply or use it. They need additional support in this teacher activity (for instance with real examples on the grading process).

Generally speaking, however, student teachers reported that the course has given them enough information and suggestions on how to: use contextual problems as a starting point for teaching mathematics; integrate one mathematics strand to other strands; conduct the RME teaching learning process; manage the interactive classroom; and to assess the pupils during and at end of the lesson.

4.3.2 Participants' learning based on lesson analysis

In this part, a number of lessons that were developed by the student teachers were evaluated. Figure 4.5 presents an example of the lesson developed by M.

Pedagang Asongan (*Street seller*)
Cilung adalah seorang pedagang asongan. Dia akan membeli barang-barang keperluan dagangannya berupa 1 dus aqua dan 1 dus rokok.
[*Cilung is a street seller. He want to buy materials for his vendor that is a dozen Aqua-cup and a dozen cigarettes]*.



Rp 10.000,00 Rp 30.000,00
Kemudian Cilung menjual setiap gelas aqua seharga Rp 500,00 dan setiap bungkus rokok Rp 600,00. *[Then, Cilung sells a cup of aqua- 500 Indonesian rupiah and a pack of cigarettes 600 Indonesian rupiah]*

1. Berapakah modal yang dikeluarkan Cilung untuk membeli 1 dus aqua dan 1 dus rokok? [*How much money did Cilung use for buying a dozen aqua and a dozen cigarettes?]*
2. Jika rata-rata setiap hari aqua terjual 4 gelas, kapan 1 dus aqua terjual habis dan berapa banyak uang yang dikumpulkan Cilung? Jelaskan alasanmu! [*If he sells 4 cups of aqua every day, when will he have selled a dozen? How much money does he collect?]*
3. Berapa keuntungan yang diperoleh Cilung dari penjualan 1 dus aqua? [*How much money does the revenue get?]*
4. Ketika 1 dus aqua habis terjual, rokok yang terjual hanya 5 bungkus. Bagaimana pendapatmu tentang apa yang dialami Cilung? *[When a dozen of aqua have been sold, only 5 packs of the cigarettes were sold. Can you explain why that is happened?]*.

Figure 4.5
An example of a contextual lesson of a student teacher

The mathematical topic is Social arithmetic. This topic is taught in grade 7, or the first year of junior secondary school (more of this lesson can be seen in the web pages and its URL can be found in Appendix B).

The main indicator that was used for analysis was the extent to which the student teachers embed the characteristics of RME into their lesson materials. First, did he use meaningful context related to the concept of the mathematics topic? Here, he used the context of a street seller. As Bandung is a big city with many street sellers, this context seems meaningful to the pupils in the junior secondary school level. Second, did he integrate the topic with other strands or subject matter? None of the four problems was integrated to other strands of mathematics. But, this mathematics topic originally intertwined with economic subject matter. Third, did his mathematics problems invite pupils to discuss their solutions? The answer is yes. As problem numbers 2 and 4 use the word *explain* and *how,* these problems invite pupils to think and if they are working with other class-mates in a group then they can discuss how to explain and answer the questions. Fourth, did the mathematics problems let pupils produce their solutions freely? No, because all of the problems can be solved by a single strategy and resulted in one solution. Finally, did the mathematics problems guide the pupils to use their informal models or strategies instead of directly use the formal one? This tenet was also not represented by the problems since the previous tenet (student's free production) was not present.

Therefore, the lesson developed by M only matches with three tenets: the use of context, intertwined with another subject and interactivity. Although, this is not an optimal lesson, at least the student teacher learned how to apply the RME tenets on the lesson materials. This result is similar to that of other participants. The developer gave feedback to the lessons regarding polishing language and fixing general mathematical errors (such as symbols and structure), but not on the use of RME characteristics. So, they used the first prototype of their own lesson materials in their teaching practice in the actual classroom. During the reflection session (in the seminar), they reflected on their experiences including the quality of their lessons.

4.3.3 Participants' learning based on e-mail analysis

Three types of e-mails were collected; namely: check-visit e-mails, direct e-mails and e-mails in the mailing list (see also section 4.1.3). All of them were registered from August 2001 to August 2002 and analyzed as follows.

Check-visit e-mails

The users who enter the web site automatically sent this type of e-mail by filling in the form that is put right after the front page of the web site. Specifically, in this research, these e-mails were used to make a registry of the participants who enter the web site. The total number of users who filled in the 'welcome' form is 627 (Total of the users from August 1999 to August 2002 is about 4500 users). 447 users visited the web site for the first time, 74 visited for the second time, 51 visited for the third time, and 55 visited for more than three times. All student teachers in this assessment stage were included in the more than three times users. Based on these results, it can be claimed that the student teachers come back after they used the web site for tree times. This could be taken as an indicator that the web site is interesting for them.

Direct e-mails

In total, 174 e-mails were sent directly to the developer from August 2001 until August 2002. These emails are categorized into four types:

- need information and resources about RME (n = 55);
- solution to the problem of the month (n = 50);
- conversation (n = 38);
- feedback (n = 36); and
- mathematics education in general (n = 5).

Similarly, the participants of the LE sent e-mails (especially of the first four types). This shows that they have learned how to use the e-mail facility in order to get involved in the activity (solve the problem of the month) and ask for information. Also, they have used the e-mail facility as a tool for communicating their experiences or feedback.

Mailing list

In total, 125 e-mails were sent to the mailing list. They were categorized as discussion about RME (40 e-mails) and distribution information about RME (85 e-mails). The total of e-mails sent by the student teachers in this assessment stage was only 17 e-mails. This number of e-mails shows that the participants were not too highly involved in the mailing list. They preferred probably to send their e-mails directly to the developer. Another reason might be the limited time to use the Internet as well as the fact that they had face to face contact with their friends on the campus almost every day. Examples on each type of all e-mails can be found in appendix E.

In summary, student teachers learned not only how to use the communication tools (e-mails, mailing list, chatting facilities) but also how to use the tools for learning from each other. Also, they learned how to communicate and reflect on their job or gave feedback on their experiences to the developer. Reflection is a powerful way of learning for student teachers (Goffree & Oonk, 1999). However, they seemed to prefer to communicate their experiences to the developer using personal e-mail instead of discussing it in the mailing list. One could suppose that they did not want their colleagues to know their problems.

4.3.4 Participants' learning based on interview

The interview was conducted right after the student teachers taught a class in the school. The interview was video recorded. Box 4.3 contains an illustration of the interviews with D and Z.

Box 4.3
Transcript of interview with student teachers after they conducted their teaching practice

R: Ms. D, after teaching realistic mathematics in the real classroom, how do you feel now?
D: After teaching I am happy. It was happen without any obstacles although I felt that I still have the weaknesses.
R: What are they?
D: I felt that I still could not manage the time properly; the volume of my speech was so small and managing the classroom especially during the whole class discussion..
R: During teaching using RME teaching approach, what are you found?
D: With this approach, I think pupils more confident to speak in order to communicate their solutions and they learn how to discuss and collaborate in solving a problem.
R: What do you learn from this teaching practice?
D: Well, a lot. This was the first teaching experience for me. I also learned how to manage a crowded classroom and to get involved with the pupils..........
R: According to you, what activities that hardest in the LE program?
D: Preparing the lesson materials was the hardest part.
R: Mr. Z, after teaching realistic mathematics in the real classroom, how do you feel now?
Z: I am happy because the pupils were also happy.
R: Why they are happy?
Z: Because I used the context that all of them know Mango.
R: According to you, what are your weaknesses?
Z: I felt that the class too crowded and I could not manage the classroom in properly.
R: But, the class was ok. It was still in control.

To be continued

Box 4.3 *(Continued)*

Z: Yes, but I run out of time. I remembered that when the bell rang, I was managing the whole class discussion. Therefore, I did not have chance to conclude the lesson appropriately.
R: During teaching using RME teaching approach, what are you found?
Z: All pupils were not afraid to me as a teacher and to mathematics as well. When I was a school student, most of my friends afraid to mathematics teacher and to mathematics. Especially when teacher asked you to solve a problem in the front of the class. But, not now.
R: According to you, what activities that hardest in the LE program?
Z: Preparing the lesson materials. I hope Pak. R (the researcher) will add more lesson materials on the web so I can use and adapt it.

From the transcript in box 4.3, it can be concluded that both D and Z had good experiences in their teaching practice using their own lesson materials. Both were happy because they could overcome the obstacles commonly faced by new teachers such as personal problems. Although they felt that they still had weaknesses, such as time managing and guiding the discussion. Nevertheless, they agreed that they learned a lot from the LE. On top of that, they believed that they would be more able to teach using RME mathematics in their future than currently practicing mathematics teachers would. These changes are quite similar with other student teachers as can be seen from the scores of their teaching profile in the Section 4.5. In summary, the changes that took place with regard to the student teachers' beliefs and their knowledge and skills are an important result for the LE.

4.3.5 Conclusion for level 2

From the results described in this section, it can be concluded that participants learned from the LE in terms of:

- gain in knowledge of the theory and content of RME (to be taught in the school);
- knowledge and skills of adapting the lesson materials based on the support from the LE;
- skills how to teach RME to the pupils (didactic and practical part);
- how to use the web site and e-mail facilities to support their performance as mathematics teachers; and
- change in beliefs, as student teachers as well as mathematics teachers. (E.g. they believed that after following the LE, they could learn more about a new approach

(RME), that they could perform as real teachers using the new approach in the school practice, and could use Internet or web technology in learning mathematics. Also, all of them trusted that they would use their new knowledge and skills in their job).

4.4 RESULTS LEVEL 3: ORGANIZATIONAL EFFECT AND CHANGE

On this level, the question to be answered was: What effects did the CASCADE-IMEI LE have on the organization at the department of mathematics education in UPI Bandung? In the following, the recent activities (1999 to 2002) and observational data are accumulated.

4.4.1 Activities related to the implementation of RME

Various activities regarding RME were conducted during the research in UPI Bandung. In the first year of research (1999), the head of the department of mathematics suggested to conduct a seminar for teacher educators in order to give them a general overview of the CASCADE-IMEI research, RME and the LE. About 20 mathematics teacher educators attended the seminar. Many questions and comments were given. As a result, teacher educators were very receptive to the developer and all activities that related to the LE. Moreover, several teacher educators who are interested to learn more about RME founded an RME-group. Later, this group was directly involved in the CASCADE-IMEI LE activities.

Then, in the second fieldwork (2001), a one-day seminar about RME was organized by the RME team at the department of mathematics education in order to introduce the new approach to mathematics teachers in Bandung. About 100 mathematics teachers followed the seminar from different schools in Bandung. Here, the developer, two teacher educators from the department of mathematics education UPI Bandung and a RME expert from the Netherlands presented. This seminar showed the example of the CASCADE-IMEI LE in the Department of mathematics in UPI.

Finally, in the third fieldwork (2001), a workshop for primary school teachers, who were involved in an RME pilot project in three primary schools in Bandung, was conducted in the framework of the LE. Several sessions of the RME course were given such as: theoretical background, doing mathematics, and peer teaching. This activity had at least three advantages for the CASCADE-IMEI study. First, it gave the evidence that LE can be of benefit not only to the in-service secondary school teacher, but also at the primary school level. Second, the Department of mathematics education and the Pilot project team in Bandung believed that the LE could stimulate the primary school teachers in learning about RME (see the video clips on the web at http://www.geocities.com/ratuilma). Finally, it shows the real impact of the LE in supporting the activities of the department of mathematics education in UPI.

4.4.2 Changes supported/initiated by the Department of mathematics education in UPI Bandung

Generally, there were two changes that took place to the department as an organization as a result of the LE . First, a small RME team was developed soon after the final version of the LE was implemented. It consisted of six teacher educators who were interested in RME as an innovation in mathematics education. This team was aimed at using RME as a new method in teaching and learning in their courses, and as a new topic of research. Interestingly, the members of this team were also involved either in conducting seminar and workshop on RME as well as in supervising the student teachers that participated in the final version of the LE.

Second, a new model was formed for the Seminar course. The student teachers who followed the LE were also the participants of the Seminar course. All of them gained advantages as participants both from the course and the LE. After completing the LE and achieving good results in the Seminar course, all of them built on what they had learned by taking the final project course. Their supervisors also supported this idea since RME is the new and important issue in mathematics education in Indonesia, not only at the faculty level but also at the national level. This model of shifting directly from the LE to the Seminar and the final project is relatively new in this department. Until recently, not many student teachers took on the added challenge of a final project.

4.4.3 Conclusion for level 3

Based on the explanations above, it can be concluded that the LE had potential effects on the organization at the department of mathematics education in UPI

Bandung. For instance, the LE could inspire and stimulate the teacher educators in accepting RME as a part of their activities such as lecturing, research, and scientific meeting. Also, the program offered a new model for the Seminar course by providing a learning environment that provides rich support and resources about mathematics education in general and RME in specific. This model could shorten the number of course meetings. Also, it could increase the number of student teachers who are willing take on the final project. Finally, the LE was also judged to have potential effect for helping primary school teachers to learn RME.

4.5 RESULTS LEVEL 4: PARTICIPANTS' USE OF KNOWLEDGE AND SKILLS

At this level, the research focused on the impact of the LE on the student teachers when they used their knowledge and skills in their teaching practice in the school classroom. The evaluation was based on the following question: *To what extent do student teachers apply their RME's knowledge and skills in the classroom?* In assessing the teaching performance of the student teachers in the schools, two instruments (teaching profile and video recordings) were used. The teaching profile was used in order to find data on what knowledge and skills they were actually using in their teaching. Moreover, video recordings were used both as an instrument for seeing the use of student teachers' skills in the learning process and as a tool for checking the results of observation.

Observers were present for 30 lessons. Both the researcher and other observers observed the lessons. Also, a video recorder taped the class activities. After the lesson was over, the observers discussed their main observations from the lesson. The videotapes were very useful not only for making clear the differences, but also for completing the instrument items when this was not finished in the classroom.

Table 4.11 shows the scores of the teaching performance for all students teachers (A-J) on each element: start of lesson, during the lesson, end of lesson and whole lesson. It shows also a row with the number of lessons that were conducted by student teachers. For all elements, the scores were given in two forms that are number and percentage. For instance, the number 35/42 indicates that 35 out of 42 items were 'yes' (implemented by student teachers). While 83% was the percentage of 35 to 42. The scores on the whole of lesson were the average score of the three main elements of lesson (start, during, and end of lessons). The results from the three elements are explained in the following sub-sections.

Table 4.11
Innovation profile scores of the lesson sections for teachers A-J

No	Lesson elements	A	B	C	D	E	F	G	H	I	J
	# lessons	*3*	*3*	*4*	*2*	*2*	*3*	*3*	*4*	*3*	*3*
1	Start of lesson	35/42 83 %	35/42 83 %	46/56 82 %	26/28 93 %	26/28 93 %	36/42 86 %	36/42 86 %	42/56 75 %	34/42 81 %	38/42 90 %
2	During of lesson	57/66 86 %	60/66 91 %	76/88 86 %	38/44 91 %	40/44 91 %	55/66 83 %	53/66 80 %	80/88 91 %	60/66 91 %	60/66 91%
3	End of lesson	22/30 73 %	22/30 73 %	30/40 75 %	17/20 85 %	17/20 85 %	22/30 73 %	23/30 77 %	33/40 83 %	23/30 77 %	21/30 70 %
4	Whole lesson	114/ 138 83%	117/ 138 85 %	152/ 184 83 %	84/ 92 86 %	83/ 92 90 %	113/ 138 82 %	112/ 138 81 %	109/ 184 79 %	117/ 138 85 %	109/ 138 86 %

4.5.1 Start of the lesson

In this element, 14 items were formulated. One item is called the threshold; that is: *the teacher introduces the realistic lesson and the context that is used as a starting point of the lesson.* All student teachers remembered to introduce the context that was used in their lesson. All of them appeared to be well prepared for the start of the lesson. All of them could manage the start of the lesson by giving the pupils' worksheet and general overview of the materials. Also, they gave clues on how to work on a problem either individually or in groups. They also reacted positively to the pupils' comments or questions. In addition, pupils were attentive and appeared to enjoy the lessons. Some of them started by giving comments on the context used by the teachers. Only a few pupils volunteered to give their examples when teachers asked for examples that were similar to the sample problem. As a result, the high score in this part of the lesson was 93%, the average was 85.2%, and the lowest was 75%. Appendix F shows all the sections of the curriculum profile.

From these results, it can be concluded that most of the student teachers were able to use the knowledge and skills that they gained from the course. For instance, they had gained confidence since they had practiced peer teaching. Also, they were knowledgeable concerning the materials since they used real world problems that they had developed themselves. However, some student teachers still had problems in questioning skills, such as how to make pupils be directly engaged with the mathematics lesson.

4.5.2 During the lesson

In this element, 22 items were used. Four items were used as thresholds to represent the characteristics of RME. Also, 14 positive statements and four negative statements were used in the instrument. During the lesson, all student teachers managed the classroom by guiding the pupils either in the group discussion or in the whole class discussion. They moved around the groups and assisted some groups or pupils. Some of them were skilled in encouraging pupils to communicate their arguments or solutions. Also, some of the student teachers asked the pupils to argue or comment on the solutions proposed by others. Several pupils presented their solutions to the class, and in some cases they even came to the front of the class and wrote their solution on the blackboard. However, most of them were afraid or shy when the teacher asked them to describe their solutions to other pupils. Interestingly, all pupils followed the class seriously. To conclude, observers noticed that all student teachers performed better in this part of the course compared to the previous try-outs. With the average score was 84%, it can be concluded that the results in this part of the lesson were good (see also Table 4.11 for all scores of this part). Appendix F shows the URL of all the sections of the curriculum profile.

4.5.3 End of the lesson

In this element, ten items were formulated. Two threshold, four positive and four negative statements were used. In this part, the threshold was that the teacher should conclude the lesson based on the student contributions or solutions after the whole class discussion. Also, teachers should give the pupils assignments (either as an end-unit assignment or as homework). Also included in this profile was the amount of time used by the teacher to finish the whole lesson. As illustrated by the Table 4.11, only one participant got a very high score (90%), while the average was only 77%. Instead, most of the student teachers encountered problems with closing the lesson and managing time. Appendix F shows all the sections of the curriculum profile.

4.5.4 Whole lesson

Overall, the score of the whole lesson is shown in the end row of the Table 4.11. This score is a result of the scores from the three parts of the lessons. The maximum score was 90%, while the minimum score was 79%. The average score for the whole lesson was 84%. This score shows that all student teachers were able to perform as a good teacher in teaching mathematics based on the realistic approach.

Table 4.12 shows the sorted scores of participants both on the RME-test and on the curriculum profile.

Table 4.12
Participants' score test versus their curriculum profile

No	Name	Score	Curriculum profile
1	E	87	90 %
2	J	81	86 %
3	F	79	82 %
4	I	70	85 %
5	D	70	86 %
6	G	70	81 %
7	A	69	83 %
8	H	68	79 %
9	B	67	85 %
10	C	66	83 %

Student teachers who got high scores on the test mostly have high scores in teaching practice. The same holds true for student teachers who got a low score in the test. In summary, the teaching performance of the student teachers are not merely dependent from the test. Thus, it may be concluded that the participants' teaching performance was good due to the fact that they used their knowledge and skills that they gained from the LE.

4.5.5 Conclusion for level 4

From the results in this section, it can be concluded that the student teachers have used their knowledge and skills in teaching mathematics based on the RME approach. They used their own materials. From their scores, it can be concluded that all student teachers performed well in teaching mathematics using the RME approach. Nevertheless, some of them were also faced with some problems such as closing the lesson, motivating pupils to presents, having low volume of speech and managing the time.

4.6 INDICATIONS OF PUPILS' REACTION AND EXPERIENCE

At this level, the evaluation deals with the pupils' reactions or the experiences of the pupils toward mathematics after they followed the learning process. The evaluation was guided by the following question: What *is the reaction of pupils after they experienced the RME teaching-learning process?* In this very tentative part of the study the focus was only on indications of pupils' reactions since the student teachers only taught in the classroom for a short period of time. Therefore, in this stage the data represents interviews with only four pupils.

4.6.1 Interview results

The interview was conducted at the SLTP KOPRI, one of the practice schools. Four pupils, three males and one female, were interviewed by a teacher (D) a day after she had used the RME approach three times . They are Ia, Ai, Wi and Wa. The transcript is outlined below.

Box 4.4
The pupils experience to the RME teaching and learning

a. D: Many students don't like mathematics, can you explain why?
Ia: *Hard to count.* Also, I don't want to go to the front for solving problems because *I am afraid I'll make a mistake.*
D: What do you mean by hard?
Wi: That 's about counting such as percents and fractions.
D: And why afraid of?
Ai: Same with Ia.
D: But, you can try first and teacher together with you friends will help you.
Ai: No, If I made a mistake, the teacher sometimes gets angry and my friends will be laughing
....
b. D: Ok, now Wi, do you like mathematics?
Wi: Sometimes.
D: What do you mean by that?

To be continued

Box 4.4 *(Continued)*

Wi: t depends on the way of mathematics teacher is taught.
D: If the teaching process that you just followed?
Wi: Interesting.
D: Why?
Wi: Because I can explain my solution to my classmates in front of the class without feeling afraid.
....

c. D: Now, Ai, what do you think of the lesson yesterday?
Ai: Generally speaking it was interesting, but.....
D: But what?
Ai: I don't like the way of discussion in the group. From the four of us, two of my friends didn't want to think.
Wa: But, I like working in a group because we can solve a problem together. That makes me easier than I do it myself. On top of that we can Communicate to others.
D: But, Ai told us that in her group some members didn't do anything in Collaboration.
Wa: Yes, but in my group we followed the teacher's instruction that we have to do by ourselves first and then compare your solution.
D: Oh.... How did you compare?
Wa: By seeing the final result of the problems. Sometimes by explaining.
D: If your solution different with your friends?
Ia: Yes, changing it.
D: How?
Ia: Waiting the true solutions from the whole class discussion.
....

d. D: In yesterday lessons, did the teacher help you?
Wi: Yes, the teacher was helpful.
Ai: Yes, but the teacher (student teacher) doesn't give the example like our Mathematics teacher.
D: Yes, but you have the exemplary lesson materials, don't you?
Ai: Yes, that's true, but my experience I couldn't do anything until the teacher gives us the clue how to solve the problems.
....

e. D: Ok now the last question, are you boring with the yesterday's lesson?
All: No..
D: Why?
Ai: Because the lesson about our daily live.
D: Other reasons?
Ia, Wa, and Wi: Same!.
D: Same to me.... (in my heart). Thank you very much my kids. And the raining still heavy outside.

Although this was a reaction and experience of only four pupils, it gives some indications that these pupils enjoyed and had positive attitude toward mathematics. From the transcript, it can be concluded that:

1. The pupils did not like mathematics before because their teacher sometimes got angry and their friends were laughing.
2. The pupils like the RME class they followed because they could explain their solution to their classmates in front of the class without feeling afraid.
3. They like the way of working in a group discussion (except one pupil who argued that in her group there were pupils who did not want to work). All of them agreed that they can learn from each others' strategies.
4. They experienced that the teacher was helpful, as well as the exemplary lesson materials. In their regular mathematics class, their teacher was not so helpful, and exemplary lesson materials were not available.
5. Generally, the pupils experienced that the RME class was interesting. One of the reasons they mentioned that the lesson was about their daily life.

4.6.2 Conclusion for indications of 'level 5'

Based on the results from this interview, it can be concluded that pupils in the schools were satisfied with the RME instructional process that was taught by the student teachers. These results were also similar to the results of try-outs described in Chapter 3.

First, in relation to the content materials, pupils agreed that the context is meaningful to them and this encouraged them to engage in solving the problems. Then, they could do mathematics independently and collaboratively, in solving mathematics problems. They started to take intellectual risks by communicating either by asking questions or explaining their solutions. They also found that one of the advantages of the whole-class discussion was to find the most efficient or adequate solutions. In summary, they experienced that the RME instructional process was interesting and they believed to get a better understanding on mathematics if their mathematics teacher would apply the same approach all the time.

4.7 OVERALL SUMMARY ON POTENTIAL EFFECTS OF THE LE

This part summarizes the findings of the assessment stage related to the five levels of potential effects of the LE in supporting student teachers learning RME as an innovative approach in mathematics education in Indonesia in the context of Indonesian teacher education (department of mathematics in UPI Banding) . It can be concluded that the LE has potential effects on four levels that are suggested by Guskey (2000), and some indications of the positive effects on the reaction and experience of pupils in learning mathematics. All of the levels are listed below.

- The student teachers were satisfied with the LE, both with regard to the web site, the RME course and the lesson materials. They were satisfied with the content, support and interface or organization of the LE.
- The LE has played a role in assisting the participants in learning what RME is, how to design their own lesson materials, how to teach in a peer teaching situation and how to use the web support. Although they encountered obstacles and felt it was difficult to develop their own lessons, they agreed that they had learned a lot about RME.
- One of the potential effects of the LE was in stimulating and supporting the organization of the department of mathematics education in dealing with the new approach in mathematics education. This also holds true, by decreasing the number of meeting times as well as on increasing the number of student teachers who are taking the final project.
- The LE has had positive effects on improving the teaching performance of the student teachers. All student teachers performed well in the class.
- The pupils react positively to the RME instruction. They had good experiences – especially with their role as pupils who are more involved in the lesson, the role of their teacher and the role of the materials. This might be an indication and a starting point for pupils in Indonesia to develop a more positive attitude toward mathematics. In the future, this might be an opportunity for pupils in Indonesia to have better understanding of mathematics. These preliminary results are in line with the results of other parallel studies that dealt with introducing RME to the pupils in Indonesia, such as in several junior secondary schools in Jogyakarta (Hadi, 2002), several primary schools in Surabaya and Padang (Fauzan, 2002), and several primary schools in Jogyakarta and Medan (Armanto, 2002).

CHAPTER 5
SUMMARY AND DISCUSSION

The CASCADE-IMEI study was started to explore the role of a learning environment (LE) in assisting mathematics student teachers learning Realistic Mathematics Education (RME) as a new instructional approach in mathematics education in Indonesia. The LE for this study has been developed and evaluated using a development research approach. This chapter starts with a brief summary of the study, followed by the design principles derived from the study. Next, discussion and reflection on the learning environment, the development research approach and the main findings that relate to RME are presented. Based on that, some recommendations are offered to the Indonesian government and the department of mathematics education in Indonesian teacher education. Finally, some suggestions for further research are offered.

5.1 INTRODUCTION

The main problems facing mathematics education in Indonesia – especially in the arena of secondary schools – are the low achievement of pupils in mathematics and their poor attitude toward mathematics. Research cites various potential causes, including inaccurate learning materials, inadequate mechanistic teaching methods, and poor forms of assessment. The Indonesian government, through the PGSM project intended to improve the quality of mathematics education in Indonesia by introducing realistic mathematics education (RME).

The CASCADE-IMEI study was initiated in order to support that initiative. Contrary to the teaching approach that is commonly employed in Indonesia, RME uses contextual problems or applications as a source and a starting point for mathematics teaching. However, introducing RME as a new instructional approach is a complex task. As described in Chapter 1, there are at least three issues that should be considered. First, RME curriculum materials are not easily designed or adopted by teachers because RME materials focus on middle-level and high-level order thinking instead of the low-level thinking only. Second, teachers need training in how to use RME materials in their classroom. Their new role is more that of a guide than of an instructor. Finally, the implementation of RME is not a short-term program or project, but it needs many years to be institutionalized.

This study used several strategies for introducing RME in Indonesia that try to effectively tackle these challenges. First, by choosing teacher education as a research context and prospective teachers as target users, RME is introduced not only to the student teachers, but also to the pupils in the schools through the teaching practice that is conducted by these student teachers. Second, by using the Internet in combination with classroom-based activities, the student teachers are supported in terms of resources and tools for communication and collaboration about the complexities they encounter while they are learning and teaching RME in the schools. Finally, the computer is viewed as a tool that may support teachers and curriculum developers dealing with curriculum development (exemplary lesson materials) and implementation activities.

The aim of this study was to explore the role of a learning environment in assisting Indonesian mathematics student teachers in UPI Bandung learning and teaching RME as a new instructional approach. At the beginning of the study and throughout the development of the LE, guidance was sought from literature relating to RME, curriculum development and implementation, teacher learning in teacher education, exemplary lesson materials, and web-based performance support. Insight from these sources helped to shape the structure of the study as well as the LE itself. More detailed information about the context and origins of the study can be found in Chapter 1. A review of the relevant literature can be found in Chapter 2.

The CASCADE-IMEI study used a development research approach aiming at exploring the potential impact of a valid and practical learning environment on Indonesian student teachers' learning of the RME approach. In so doing, the study was guided by the following main research question:

> *What role can the CASCADE-IMEI learning environment play in assisting Indonesian mathematics student teachers with their learning of the RME approach?*

Using the development research approach, this study deals with designing and evaluating a learning environment as an intervention. In this study, the intervention is the learning environment, composed of three main components: 1) Internet support, 2) a course and 3) exemplary lesson materials. Also, the study deals with the extracting of design principles of the learning environment through the development and evaluation processes.

The LE has been developed and evaluated in three main phases: 1) preliminary investigation stage, 2) prototyping stage and 3) assessment stage. Throughout the first two phases, five prototypes of the LE were designed and formatively evaluated in both the Netherlands and Indonesia. At the end, the final version of the LE was field-tested in Indonesia. A description of the design and evaluation of the prototypes can be found in Chapter 3.

The development activities of the LE prototypes were conducted at the University of Twente, the Netherlands, while the evaluation activities were conducted either at the University of Twente or at the University of Indonesian Education (UPI) Bandung, Indonesia. In the Netherlands, the evaluation activities were centered on expert appraisals, in which six experts from various disciplines (RME, computer support curriculum development, web design, course development and teacher learning in teacher education) were mainly involved. In Indonesia, the evaluation activities were focused on cooperative evaluations and try-outs. A total of 34 mathematics student teachers (pre-service and in-service) at the department of mathematics education in UPI Bandung were mainly involved. In addition, 6 mathematics teacher educators from UPI Bandung and about 800 pupils from 12 junior secondary schools in Bandung, were peripherally involved. While the teacher educators were involved either as supervisors of student teachers or as observers, the pupils were involved as learners when student teachers conducted their teaching practice.

During the assessment stage, the final version of the LE was field-tested in Indonesia in order to find out about its potential impact in assisting the professional development of student teachers learning and teaching RME as a new approach in mathematics education. In order to study the potential effects of the LE, the five effectiveness levels of a professional development program were used (Guskey, 2000). The fifth level was not directly addressed, however, since the main target users of the study consisted of student teachers in teacher education. At this level, the researcher only explored indications of the potential effects of the LE on pupils. As a result, four sub-research questions were posed:

1. What is the perception of student teachers with regard to the LE?
2. What knowledge, skills and attitudes did the student teachers acquire as a result of following the LE?
3. What effects did the CASCADE-IMEI LE have on the organization at the department of mathematics education in UPI Bandung?
4. To what extent do student teachers apply their RME knowledge and skills in the classroom?

The results of the formative evaluation and field test in Indonesia are described in Chapters 3 and 4, respectively. Ultimately, the study resulted in a final version of the LE. The following sections will explore the design principles and discuss each of the components.

5.2 DESIGN PRINCIPLES

Van den Akker (1999, 2002) suggests that knowledge gained from development research can be presented in the form of 'design principles', which are usually heuristic statements of a format such as:

> *'If you want to design intervention X [for the purpose/function Y in context Z], then you are best advised to give that intervention the characteristics $C_1, C_2,...,C_n$ [substantive emphasis], and to do that via procedures $P_1, P_2,...,P_n$ [procedural emphasis], because of (theoretical/empirical) arguments $A_1, A_2,...,A_n$.*

Relating to the CASCADE-IMEI study, an overarching design principle can be represented as follows.

> *If you want to design a valid, practical, and effective learning environment for supporting Indonesian mathematics student teachers with a new instructional approach (like RME) then you are best advised to give the learning environment the following characteristics:*

- use exemplary lesson materials as the main component of content (consisting of learner materials, assessment materials, and teacher guides) with clear guidelines on how to use the materials;
- use a face-to-face course (which is integrated in one of the method courses in the teacher education) with several activities related to learning the new theory, materials, teaching method and assessment strategy based on the new approach (e.g. RME); and
- use Internet-based support for the course participants that provides additional information, training facilities, advice and communication tools for collaboration and reflection;

and to do the above via the following procedures:

- adapt and develop the lesson materials from the available (RME) lesson materials that were derived from both theory and practice into the context of Indonesian teacher education and Indonesian schools;
- design and develop the learning environment (course and web support) by initiating subsequent prototyping cycles until a satisfying LE has been reached; and
- improve the quality of the content, support and structure of the learning environment by conducting formative evaluation activities (expert appraisal, cooperative evaluation, and try-out) with the involvement of experts and target users and make revisions at the end of each prototyping cycle; and
- assess the potential effects of the LE by conducting a summative evaluation via a field test in real practice;

because of the following arguments:

- by using lesson materials, student teachers can decide to use the materials as the learning resources during their course of study, as examples when they learn how to redesign lesson materials, and as additional materials when they conduct teaching practice;
- by following the course, student teachers can overcome the obstacles of being novice teachers and they may learn not only the content and pedagogical knowledge of the new approach, but also how to redesign materials and teach with their materials using the new approach, either in a peer teaching situation or with the pupils in the schools;
- by using Internet support, student teachers (and other Internet users as well) can learn the new approach (e.g. RME) whenever and wherever they want, either during the course (short-term) or afterwards (in the long term);

- by using a prototyping approach with several cycles, the intervention can evolve towards a valid and practical final version;
- by conducting formative evaluation activities with experts and target users, the validity and practicality of the intervention can be improved and the content can be enriched; and
- by conducting a summative evaluation via a try-out, the potential effects of the intervention can be empirically assessed.

All characteristics of the LE, the procedures and the arguments in this design principle will be elaborated in the next sections.

5.3 REFLECTIONS ON MAIN CHARACTERISTICS OF THE LEARNING ENVIRONMENT ON RME

In this study, the intervention is a learning environment for student teachers who are learning RME as a new instructional theory in mathematics education. The LE consists of both an Internet-based and a classroom-based component. The main content of these two components consists of RME exemplary lesson materials. This section summarizes the main characteristics of the web site, the course and the exemplary lesson materials, and provides several reflective notes.

5.3.1 RME web support

The use of Internet pages on the World Wide Web ('web site') to provide support in teacher education appeared to be a promising tool for an expansive country made up of many islands, such as Indonesia. As a result, a web site has been designed and evaluated as a part of the learning environment (LE). This section discusses the main characteristics of this web site with its three main components: content, support and user interface.

The *content* of the web site refers to the philosophy and characteristics of RME. During the development of the web site, the validity and practicality of the content evolved greatly. Based on synthesizing the theory in the literature study, as well as feedback collected from the evaluations, the following aspects of RME are emphasized in the web site:

- the background information of RME, as well as its characteristics, in order to give users a general view of what mathematics is, how pupils learn mathematics, and how mathematics should be taught from the RME perspective;
- flexible ready-made exemplary learner and teacher materials in various topics, in the sense that the student teachers can adapt the materials to their needs, or use them directly in the classroom;
- a number of computer simulation and game programs in which the users can visualize and simulate mathematical phenomena (e.g. function graphics, geometry concepts) by changing the variables or manipulating the figure by using the mouse;
- examples of students' products or solutions to the lesson materials, so the student teachers or other users can learn from, and gain insight into the learning process of pupils in solving mathematics problems;
- guidelines for developing lesson materials, for teaching in an RME classroom and for assessing pupils; and
- examples of assessment problems at all school levels, so the users can learn from them, or use the problems in the classroom.

In the web site, various types of *support* are provided. Some of them are inherent to the medium of the Internet, such as tools for communication (e-mail facilities and the mailing list) and links to other resources about RME and mathematics education in general. Others were specifically designed and developed by the developer, including:

- a tool for designing lesson plans or templates;
- a number of Java applet simulation programs on several mathematics topics, and a number of mathematical games;
- a tutor component; and
- a number of video clips showing examples of how to teach using the realistic approach.

The *user interface* of the web site was designed in order to accommodate users so they can easily navigate and access information. The main characteristics of the interface are listed below:

- the menu and submenus are consistently located in the same area on the screen throughout the web site;
- buttons and text, which use two languages (English and Indonesian) are easy to read;

- graphics, text and background colors are clear and simple;
- some screens of simulation and game programs are interactive, which means that users can simulate the phenomena by changing the variables;
- some documents and information are provided in Word document files to make it easy to retrieve or print them from the web site.

The programming language that was used was mainly HyperText Markup Language (HTML). In addition, some mathematical parts were programmed using Java applet and Java script programming languages.

Based on the results of the prototyping and assessment stages, the web site was evaluated both by experts (on web design, computer support and RME) and by target users as being valid and practical. More details about the characteristics of the LE and the formative evaluation activities and results can be found in Chapter 3.

5.3.2 RME course

In this study, teacher education in Indonesia is seen as one of the places to start the innovation. Through teaching practice, the innovation may also reach the pupils in the schools. This sub section discusses the content, support and structure of the teacher education course.

The *content* of the course and the *support* provided during the course also refer to the philosophy and characteristics of RME. Based on synthesizing the theory as well as feedback from several rounds of evaluation, the following aspects of RME (content and support) are emphasized in the course.

- *Theoretical background*. This aspect focuses on the background information of RME as well as its five characteristics. For instance, the role of context in learning and teaching mathematics and the way the context can be used in the lesson materials.
- *Doing mathematics*. This aspect focuses on the learning process with an RME approach. Here, student teachers assume the role of pupils. They are not only learning mathematics (content knowledge), but also the way pupils in the schools come to understand mathematics (pedagogical knowledge).
- *Support in lesson redesign*. This aspect refers to the process of applying the characteristics of RME when (re)designing RME lesson materials. Ideally, all of the RME characteristics are used. As this is not an easy task, student teachers are

supported in learning how to adapt the available materials for other relevant contexts and how to use the materials in their teaching practice. As a result, they mainly focus on two tenets of RME: the use of context and the intertwining among strands of mathematics.

- *Teaching method.* This aspect refers to the use of interactivity (one of the RME tenets) in the teaching process in the classroom. Several critical moments of teaching are presented and discussed. These critical moments consist of interaction, individual work, group work, classroom discussion, student presentation and teacher presentation. Moreover, an RME teaching video is shown and discussed. Finally, student teachers are invited to apply their knowledge and skills in their own teaching practice in the school.
- *Assessment strategy.* In RME, the assessment should get attention not only at the end of the instruction (summative evaluation), but also during the instructional process (formative evaluation). While the former focuses on the pupils' achievements in the form of scores, the latter focuses on the improvement of pupils' learning. In this course, assessment problems are included in the exemplary lesson materials. During the 'doing mathematics session', for instance, a sequence of assessment problems is given to the student teachers. These problems are designed in such a way that they may guide and enhance the student teachers in presenting a mathematics concept. In RME, assessment problems usually cover all three levels of students' thinking: low, middle, and high-level thinking. Therefore, in some cases, students will not directly get the formal solutions; instead, they have to discuss their informal solutions in pairs or in a small group.

The course was organized based on the main activities such as doing mathematics, redesigning lesson materials, teaching practice, and reflection. In the final version of the course, the meetings required six weeks (each meeting about two-hour or 100 minutes courses) and two weeks for teaching practice in the school. Results from the prototyping and assessment stages show that the RME course was perceived to be valid, practical and having several potential effects. More details about the RME course can be found in the Chapter 3.

5.3.3 RME exemplary lesson materials

Exemplary lesson materials play an important role in this study. The materials include learner materials, assessment materials and a teacher guide. The teacher guide contains procedural specifications, very clear guidelines and specific directions in using the materials and focuses on the essential parts of the innovation – in this case the RME approach. It provides recommendations on how to deal with RME lessons (start, manage and close) and the assessment in RME. Five mathematics topics have been developed and adapted to the Indonesian context: linear equation system, symmetry, matrices, side seeing and statistics. These materials were used in the 'doing mathematics' session and used as a guide for student teachers in developing or adapting their own materials. The materials were provided and used in the course, in the schools and on the web site. Findings from the expert appraisals and try-outs during the prototyping and assessment stages show that the RME exemplary lesson materials were perceived to be valid, practical and having some potential effects. More details about the RME exemplary lesson materials can be found in the Chapter 3.

5.4 REFLECTION ON THE DEVELOPMENT RESEARCH APPROACH

The CASCADE-IMEI study used a development research approach in order to develop a valid, practical and effective learning environment (the intervention), and to generate design principles for such an intervention. Here are a few reflective remarks on this approach.

Limitation of context of try-out

The final try-out was conducted in the department of mathematics education in UPI Bandung. The working group consisted of 10 student teachers who were non-randomly selected from 33 student teachers participating in the Seminar course. Consequently, results of this try-out cannot be generalized to all student teachers. Also, a number of different instruments were used for data collection, inhibiting the pooling of data. Yet, although about 400 pupils from 5 different schools were involved, the main focus of the research was on the 10 student teachers. In other words, the data collected from pupils were only for exploring some indications of the potential effects of the fifth level, and as such were not key to answering the main research question.

Prototyping approach and formative evaluation

The prototyping approach appeared to be effective in improving the quality of the learning environment. The formative evaluation activities in particular offered many suggestions for improvement. For example, the initial prototype of the LE consisted only of a web site. Although the web site itself seemed to be valid, it was not practical for learning about how to apply the RME approach in practice. Based on literature findings, context and problem analysis, and suggestions from experts on the subsequent prototypes of the LE, the web site was combined with a course-based learning environment in which the web site functioned as a support tool for the course participants.

During the development process, the ideas and intentions of the developer dynamically evolved, based on the state-of-the art knowledge of the components used in the LE, as well as on the suggestions, comments and needs from both experts and target users. For instance, experts suggested including several Java applet simulation programs so the users can realistically visualize the concepts of several mathematics topics on the web site. Also, they suggested including several short video-clips to provide the users with more clear and vivid images of how to teach using the RME approach. In the course, moreover, users showed their needs to learn to redesign RME lesson materials. Based on these and other suggestions, revision decisions were made and the LE was revised. Hence, the quality and the richness of the LE evolved.

Methodological reflection

One of the benefits of the development research approach was that it stimulated the researcher to learn and perform a number of (new) roles. In this study, for example, the researcher also performed as a designer (web site, course), a developer (exemplary lesson materials, video clips), a web-programmer (web site, Java applet, and Java script), a trainer (course trainer), and observer (in the Internet cafe and classrooms). These roles were needed in order to develop and evaluate the intervention (the learning environment). The researcher gained a great deal of knowledge and many new skills from those roles. However, it was often not an easy task because the intended intervention was an innovation in itself without ample experiences to draw from. On some occasions, it seemed that working as a development researcher was difficult and taking a lot of time. However, after the development and evaluation of the intervention, the difficulties paid off by the short line between the formative evaluation and the revision decision and by the success of that intervention in reaching the aim of the research.

Furthermore, although the researcher had good reasons to perform the various roles, several potential weaknesses should be mentioned – especially the potential threats to the validity and reliability of the results when those many roles are filled by one person. As reported in the previous chapters, much efforts was made to reduce this risk by applying the principles of triangulation as much as possible in data collection and analysis through a variety of procedures, instruments, respondents and timing.

5.5 DISCUSSION ON THE EVALUATION FINDINGS

This section summarizes and discusses the main findings of the try-out of the CASCADE-IMEI study that were represented in four levels of effectiveness. These findings show the potential role of the learning environment (LE) in assisting student teachers in UPI Bandung learning and teaching RME.

5.5.1 Student teacher satisfaction with the LE

The effects of the LE on the student teacher satisfaction were indicated based on the data from questionnaires and interviews. Results show that the participants were satisfied with the content, support, interface and the organization of the LE. First, related to the content, they perceived the content of the LE to be practical. They agreed that the content of LE (RME exemplary lesson materials and examples of pupils' solutions) was useful for helping them in learning RME. They also agreed that the content was consistent with their expectations, as well as interesting from the mathematics point of view.

Second, results show that participating student teachers were also satisfied with the support offered by the LE. The most valuable forms of support offered via the web site, according to the student teachers, were the video clips (Tutor part). They also appeared to be satisfied with other parts such as the problem of the month, RME papers and Java applet simulation programs.

Moreover, the student teachers were content with the RME course, especially with the didactic component. They were impressed when treated as learners in the 'doing mathematics' part of the course. In the role of the learners, they could perceive first-hand the teaching methods that belong to RME and they could remember several critical teaching moments. Also, the RME-video display gave them a vivid idea of how to manage the RME classroom, guide the discussions and assess the pupils formatively.

In addition, they were also satisfied with the interface of the web site. Being novice Internet users, they were even proud of the fact that the web site was developed mainly for them as Indonesian mathematics student teachers. Moreover, they were gratified by the fact that some of their activities and pictures were recorded and put online. Finally, they were also satisfied with the organization of the course. Most student teachers agreed that the course was rich with the support (exemplary lesson materials, video, etc.) and the activities (doing mathematics, peer teaching, teaching practice, group discussion, and seminar).

Up to now, the web site still gains about 15 hits per day. Most users are student teachers from Indonesia, while others come from all over the world. Some of the student teachers from the working groups are still working on their final projects on RME. Most of them return to the web site to find additional information and to ask questions. This is also seen as a positive indicator of their satisfaction with the LE. In addition to that, some new student teachers and pupils from Indonesian junior secondary schools stopped by and used the web site in order to use the simulation and game programs, as well as practice with RME problems. In summary, although the CASCADE-IMEI study is finished, the aim of the LE, to assist Indonesian student teachers learning RME, remains alive.

5.5.2 Student teachers' learning of RME

The knowledge, skills and beliefs that have been learned by the student teachers in the CASCADE-IMEI learning environment can be summarized as follows:

- knowledge of RME's theoretical background as a new approach to teaching and learning in mathematics education, including its philosophy and tenets;
- content and pedagogical knowledge of RME that they learned when they were treated as learners in the 'doing mathematics' session and when they were shown the RME-video;
- knowledge and skills on how to redesign RME lesson materials on a mathematics topic that they want to teach in the school; (By using the available materials and guided by the five tenets of RME, they designed their teaching materials that

consisted of sequences of problems in different meaningful contexts. Although the quality of their lessons is far from the standard of RME materials, they have tried to include at least two tenets of RME in their materials, i.e. the use of context and the integration of mathematics strands.) and

- knowledge and skills on how to use the web site and communication tools for finding additional resources and as a way of communicating, collaborating and reflecting on RME. (For instance, through e-mails all student teachers reflected their experiences; they believed that they had learned a lot from this way of reflection.)

In addition, based on their reflections, the student teachers believed that they would use all knowledge and skills in their daily job either as student teachers or as practicing teachers. In other words, there are indications that there are changes in the beliefs or attitudes of student teachers toward mathematics and their jobs after they followed the LE.

5.5.3 Organizational support and change

Results from informal discussions with some teacher educators, interviews with the head of the department of mathematics education in UPI Bandung and with a member of the RME-team, provided insights in the following changes that have happened in the department of mathematics education in UPI Bandung.

- Soon after the developer gave a seminar in the department of mathematics education in the beginning of the research in September 1999, an 'RME-team' was formed by six teacher educators . During a number of try-outs of the LE, the team members were formally involved in supervising the student teachers.
- The dean of faculty and the head of the department of mathematics education provided facilities and gave permission for all activities that were related to the evaluation of the LE during the four tryout periods (October 1999 until December 2001).
- The LE offered a new model to the Seminar course by providing a number of activities during the course and integrating the course with the web support. By using the web support, the number of weekly meeting for the course is reduced from 16 to 8 (including 2 weeks for teaching practice).
- The LE could increase the number of student teachers who opt to carry out a final project. Before the LE was launched in the department of mathematics

education in UPI Bandung, only a small number of student teachers carried out a final project (research), in which they have to write a final report or thesis (*skripsi*). Instead, they would typically take only the Seminar course with an additional mathematics course before graduation. After each round of try-out of the LE in UPI Bandung, fortunately, almost all of the student teachers that were involved also conducted a final project. They were inspired to take a RME-related topic for their research project.

5.5.4 Student teachers' use of knowledge and skill in teaching RME

Results from observational notes, the teaching profile, and video show that participants used their knowledge and skills both in the peer teaching and teaching practice in the schools. The results show that they achieved good performance on the basic critical moments of teaching in RME classroom such as: at the start of lesson, during the lesson and at the end of lesson. All of them were able to teach and manage their classrooms in an appropriate way. In general, they could use their knowledge and skills that they learned from the LE. However, they also encountered several technical problems such as use of time (most of them ran out of time) and use of volume of speech (almost half of them, especially female, had low volume). These problems seem to be typical for novice teachers and could be solved by practice and coaching.

5.5.5 Indications of pupils' experiencing the RME instruction

The teaching profiles, questionnaires, interviews and video provided some indications that pupils in the schools who participated were satisfied with the RME teaching process that was taught by student teachers. They perceived that the exemplary materials were interesting due to the use of daily applications that are real to them. They liked their roles both as an individual in learning mathematics problems and as a member of a group discussion. They actually experienced the new ways in learning mathematics. For example, they could freely discuss, communicate and justify the adequacy and the efficiency of their solutions. They learned from others' strategies. Finally, they learned that a mathematics problem can have multiple solutions or multiple strategies. Although in some classes the student teachers provided end-unit tests, these results were used only for reporting either in their seminar course or for school teachers' files. This study was limited to the preliminary evaluation of pupils' experiences and their attitudes toward mathematics.

5.5.6 Conclusion on the evaluation findings

Based on the discussions on the evaluation findings, it can be concluded that the LE developed in this study could play a role in assisting Indonesian mathematics student teachers in UPI Bandung in learning and teaching RME as a new approach in mathematics education in Indonesia. The roles of the LE are outlined below.

1. The LE could enhance the student teachers' satisfaction with the content (RME), support, interface and the organization of the LE. This seems to be mainly due to the consistency of the LE and the fact that the LE matches with their needs.
2. The LE could assist the student teachers in learning the mathematical, didactic and practical part of the RME course. As a result, the LE could promote the student teachers' understanding about RME. The LE could also support student teachers in learning how to redesign lesson materials for the classroom level. In addition, student teachers also use the Internet in learning RME. This may stimulate learning how to use e-mail facilities, for instance for reflecting on their experiences. This way of teachers' learning could enhance their understanding of RME and change their beliefs toward mathematics as well as towards their jobs.
3. The LE could bring about changes in the organization and staff of the department of mathematics education as well as on the practicing mathematics teachers at the various secondary schools where student teachers were active. For instance, the LE could promote change in that organization with respect to the activities of teacher educators and the process of Seminar and final project courses.
4. The LE could have positive impact on developing teaching performance of the student teachers. Because of the LE, they were able to perform as real teachers in the school classroom using the RME approach.
5. The results indicate that the LE could have impact in changing the pupils' beliefs, or in increasing the positive attitude of pupils in the secondary schools toward mathematics.

5.6 RECOMMENDATIONS ON MATHEMATICS EDUCATION IN INDONESIA

In this section, recommendations are given to the Indonesian government, to the department of mathematics education in Indonesian teacher education, to the CASCADE-IMEI study, and to future researchers in the field of mathematics education. It includes the use of the Internet in mathematics teaching and learning, professional development for mathematics teachers, curriculum development and implementation, and development research.

5.6.1 Indonesian government: The RME-pilot project team

Since 2001, the Ministry of National Education through DIKTI (Direktur Jenderal Pendidikan Tinggi or the Directorate General of Higher Education) and the PGSM project have been developing a team for implementing RME in Indonesia called PMRI (Pendidikan Matematika Realistik Indonesia, or Indonesian Realistic Mathematics Education). This team has been conducting a RME pilot project in 12 Primary schools in three cities in Java: Bandung, Jogyakarta and Surabaya (Sembiring, 2001). In addition to the 12 primary school teachers, the main members of this project are also mathematics teacher educators from four educational universities in three cities that are Universitas Pendidikan Indonesia Bandung, Universitas Sanata Darma Yogyakarta, Universitas Negeri Yogyakarta, and Universitas Negeri Surabaya. Moreover, in the years 2002-2003, PMRI will still focus on the first grade of primary school, but they will extend the duration of the project time from a quarter to a full year (Sembiring, 2001). As the CASCADE-IMEI study started in order to support the idea of the PGSM project and was tried out during a workshop (third prototype of the LE) for the primary school teachers who are also members of the RME pilot project in Bandung, recommendations for the PMRI team are important. The recommendations for the team are outlined below.

RME exemplary lesson materials. Exemplary lesson materials should be designed based on the RME characteristics. The materials usually consist of a sequence of contextual problems that guide the learners to understanding of a mathematics concept. It is recommended that teachers become involved in developing the lesson materials. In addition, the materials should be evaluated formatively by the RME experts. The materials consist of learner materials, assessment materials and a teacher guide. The teacher guide should provide procedural specification to the teachers on how to implement the materials. Gravemeijer (2001) pointed out that teachers or curriculum developers can use the available curriculum materials as a guide and then make their own adaptations based on the RME characteristics. This suggestion was put to good use in this study, in which the student teachers in UPI Bandung adapted the available materials provided in the LE to their own situations. Hence, the LE with its materials can be used as examples or resources for the curriculum developers and teachers that are involved in the PMRI pilot project.

Teaching methods. Based on the results of this study, it is recommended that the teachers should receive training in how to teach using RME materials before they use them in their own classroom. A promising way to train teachers is by using:

- video display that consists of examples of a situation of RME instruction ;
- a teachers-as-learners strategy, in which the teachers should be treated as learners by an RME teacher, so they can directly see and experience the role of RME teacher in managing the classrooms; and
- peer teaching and teaching practice activities followed by reflection in a focus group discussion.

Assessment strategy. In addition, teachers should be trained how to assess the pupils both formatively and summatively, and how to evaluate the students' product or solutions. The formative evaluation focuses on the improvement of the instructional process as well as the learning process of pupils, while summative evaluation focuses more on the pupils' product or solutions. Finally, the assessment materials should cover all three levels of thinking: low, middle and high.

Use of the LE. It is suggested that the LE be used as follows. First, use the RME course in a similar framework and the materials of the LE such as the exemplary curriculum materials, the video, and the course program that have been shown to be valid and practical. Second, as the RME pilot project activities are placed in the three different cities, it might be helpful to use the web site as dissemination resources and a tool for communication and collaboration among the members of the pilot project. In this case, the designers and teachers from three cities can collaborate and communicate their experiences in teaching RME in their classrooms. In addition, their materials can be made available on the Internet so they can learn from each other's experiences and materials. Therefore, while using this communication tool, they may able to sharpen their understanding of RME.

5.6.2 Department mathematics education in teacher education

This study started in order to support the idea of the PGSM project to improve the quality of mathematics education in the secondary level through teacher education. In addition to that, the CASCADE-IMEI study provided empirical evidence on the validity, practicality and potential effectiveness of the LE in supporting student teachers in UPI Bandung. This university is one of the bigger teacher education institutions in Indonesia that provides a LE on RME as an innovative approach in mathematics education in Indonesia. Based on these results, it is suggested that other departments of mathematics education in Indonesian teacher education institutions also use the LE as a new model in supporting some method courses, such as the Seminar course, Teaching and learning strategy, Evaluation methods, etc. Since RME is a new instructional approach in mathematics education, it can be made a compulsory topic to be learned by all student teachers in those courses. In addition, by using the web site technology, student teachers or even teacher educators can use the Internet as a new technology in mathematics teaching, not only about RME but also about other elements related to mathematics that are available on the Internet.

5.6.3 The future of the CASCADE-IMEI LE

This section describes how the LE can be extended and implemented in the future.

The quality and quantity of RME exemplary curriculum materials may be improved and extended. For instance, with a number of development research cycles, the materials may be developed as a local theory of that topic in the Indonesian context. In this study, five mathematics topics have been adapted and developed both in English and Indonesian and used in the LE. By adding more topics in the Indonesian version, the LE will be more helpful for the mathematics (student) teachers in Indonesia.

At the time of publication of this dissertation (October 2002), the web site developed for this study is the first and only mathematics education web site in the world that uses the Indonesian language. About 15 users access the web site every day. The number of users who used the web site since 17 August 2001 was about 5000. About 25% of them were Indonesian. Most of them were student teachers, teacher educators, school teachers, pupils and parents.
Of all pages available on the web site, the simulation page was the one most often accessed by the users. E-mails sent by users reveal that this page is seen as interesting, since one could learn mathematics interactively. The second most accessed was the 'problem of the month' page. Interestingly, most of the solution forms were sent by the pupils either from secondary or primary level. This page is followed in frequency of use by the tutor part of the web site as well as the papers page that consists all theoretical information about RME as well as several video clips.

Because of this success, it is important to start a new study or to secure funding for further research that may provide special time and attention to improve and maintain this web site in terms of its content, support and interface. For instance, the papers part can be extended to an online publication since, up to now, there is no such journal on mathematics education both offline or online in Indonesia. Furthermore, more examples on various topics might be added to the Java applet simulation pages. The same holds true for the 'problem of the month'. This component may be changed into 'problem of the week' so more examples of assessment problems at all school levels can be offered.

With the new decentralized education system in Indonesia, the LE could function as a vehicle in supporting teachers in other provinces learning and teaching RME as an innovation in mathematics education. For instance, the LE may be used as a part of a regular method course in assisting mathematics student teachers to learn and to teach using an RME approach in the Faculty of teacher training and education at the University of Sriwijaya, South Sumatera, where the developer is currently working.

5.6.4 Further research on the learning environment

The CASCADE-IMEI research aimed at supporting Indonesian student teachers in learning RME as an innovation in mathematics education. More precisely, this study brought together the domains of both realistic mathematics education and the use of technology in curriculum and professional development of student teachers in the context of Indonesian teacher education. Thus, further research of this study extends to both research domains and can be formulated as follows.

First, the RME exemplary materials have been adapted to the Indonesian context and have been evaluated as being valid and practical for Junior secondary school level. These materials can be used as initial exemplary lesson materials for a new development research study (e.g. at the theoretical level of designing RME materials) at the same school level for other contexts, either in Indonesia or other countries around the world (several contextual adaptations should be made). In addition, the research may be extended to a new mathematics topic in all school levels.

Second, the CASCADE-IMEI LE appeared to be potentially effective in supporting student teachers in learning RME. Using Guskey's five levels of effectiveness, the study paid the least attention to the perceptions of the pupils, and no attention to the learning outcome of pupils. Therefore, an avenue of development research lies open in investigating the extent to which the LE will improve the perceptions and mathematics learning outcomes of pupils after they have been taught by (prospective) teachers using the LE.

Finally, the CASCADE-IMEI study is in line with three previous CASCADE studies: CASCADE (Nieveen, 1997), CASCADE-SEA (McKenney, 2001) and CASCADE-MUCH (Wang, 2001). Of course, there are similarities and differences. They are similar in the sense that all of them deal with the use of electronic tools to support teachers or curriculum developers in the domain of analysis, design, evaluation and implementation of curriculum materials. The differences with the CASCADE-IMEI study were 1) all previous CASCADE studies used stand-alone computers while this study used the Internet as a platform for delivery, 2) the content and context were also different. Therefore, the line of CASCADE research can be extended in this direction using the web platform.

Finally, at the end of this dissertation, it seems easy to see and formulate all kinds of promising and challenging suggestions for further research. However, as Robert Frost (1874-1963) wrote in the last four lines of his poem "Stopping by the woods on a snowy evening":

...
The woods are lovely, dark and deep,
but I have promises to keep,
and miles to go before I sleep,
and miles to go before I sleep.

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SAMENVATTING
DUTCH SUMMARY

AANLEIDING EN ONDERZOEKSVRAAG

Het Indonesische wiskunde-onderwijs in het voortgezet onderwijs kampt met grote problemen: leerlingen presteren slecht en hun houding ten aanzien van wiskunde laat zeer te wensen over. Onderzoek wijst op een aantal mogelijke oorzaken: gebrekkige lesmaterialen en inadequate les- en beoordelingsmethoden. De Indonesische regering probeert via het PGSM-project de kwaliteit van het wiskunde-onderwijs te verbeteren door de invoering van realistisch wiskunde-onderwijs [in deze samenvatting wordt de Engelse term gehanteerd: 'realistic mathematics education', RME].

Het CASCADE-IMEI-onderzoek is uitgevoerd onder de vlag van dit initiatief. In tegenstelling tot de gangbare lespraktijk in Indonesië, neemt RME wiskundige problemen of toepassingen uit het dagelijkse leven als inspiratiebron en vertrekpunt voor de wiskundedidactiek. Echter, het introduceren van RME als een nieuwe instructiebenadering is een niet te onderschatten taak. Ten eerste is het ontwikkelen en het doorgronden van RME-lesmaterialen een complexe aangelegenheid. Ten tweede zullen docenten nascholing moeten ontvangen over adequaat materiaalgebruik in de lespraktijk. Ten slotte zal de implementatie van RME een proces van lange adem zijn voor de betrokkenen.

In een poging aan deze uitdagingen tegemoet te komen, zijn binnen dit onderzoek op weloverwogen wijze meerdere strategieën gehanteerd voor de invoering van RME in het Indonesische wiskunde-onderwijs (zie hoofdstuk 2). Als onderzoekscontext werd de lerarenopleiding gekozen waarbij de doelgroep bestond uit studenten (de aankomend docenten). Op deze wijze kwamen zowel studenten aan de lerarenopleiding als leerlingen van de diverse scholen voor voortgezet onderwijs waar de studenten stage liepen in aanraking met RME. De betrokken studenten werden toegerust met een leeromgeving die bestond uit een combinatie van een cursus en een website met hulpbronnen en communicatiehulpmiddelen. De computer werd tevens ingezet als hulpmiddel voor de studenten bij het ontwikkelen/aanpassen van voorbeeldlesmaterialen. Aan de hand van de leeromgeving konden studenten inzicht krijgen in de complexiteit van de vernieuwing.

Tijdens het onderzoek stond de volgende vraag centraal:

> *Welke rol kan een leeromgeving hebben bij het toerusten van Indonesische studenten aan de lerarenopleiding voor wiskunde bij het leren van de RME-benadering?*

Meer informatie over de aanleiding en de onderzoeksvraag is te vinden in hoofdstuk 1.

ONDERZOEKSAANPAK

Binnen het onderzoek is een ontwerpgerichte onderzoeksbenadering toegepast, waarbij de leeromgeving werd ontworpen en geëvalueerd (zie hoofdstuk 1). Naast de leeromgeving streefde het onderzoek ook de formulering na van algemenere ontwerpprincipes voor het ontwerpen van dergelijke leeromgevingen.

Binnen drie hoofdfasen werd gewerkt aan het ontwerp en de beproeving van de leeromgeving: 1) vooronderzoek; 2) prototyping; en 3) eindevaluatie. Gedurende de eerste twee hoofdfasen zijn vijf opeenvolgende prototypes van de leeromgeving ontworpen en formatief geëvalueerd (zie hoofdstuk 3). Alle ontwerpactiviteiten vonden plaats in Nederland aan de Universiteit Twente (UT), terwijl de evaluatie-activiteiten plaatsvonden in Nederland (UT) en in Indonesië (University of Indonesian Education (UPI), Bandung). De evaluatie-activiteiten in Nederland concentreerden zich op het bevragen van deskundigen op de volgende terreinen: RME, computerondersteunde curriculumontwikkeling, web design, curriculum-ontwikkeling en het leren van toekomstige leraren. In Indonesië richtten de evaluatie-activiteiten zich op praktische try-outs met toekomstige gebruikers. In totaal hebben 34 studenten aan de lerarenopleiding (zowel pre-service als in-service) aan die evaluaties deelgenomen. Zij hebben onder andere lessen verzorgd op 12 scholen voor voortgezet onderwijs in Bandung (waarbij in totaal 800 leerlingen de lessen hebben gevolgd). Zes docenten aan de lerarenopleiding waren bij de evaluaties betrokken als begeleider en/of als observator. Binnen de leeromgeving trad de onderzoeker op als docent.

KENMERKEN VAN DE LEEROMGEVING

De leeromgeving bestaat uit drie componenten: een website; een cursus; en voorbeeldlesmaterialen. In deze paragraaf zullen de belangrijkste kenmerken van deze componenten kort beschreven worden (zie hoofdstuk 3).

RME-website

De *inhoud* van de website is gebaseerd op de RME-filosofie. De volgende RME-gerelateerde kenmerken zijn in de website benadrukt:

- achtergrondinformatie over RME;
- voorbeelden van leerling- en docentmateriaal voor een variatie aan onderwerpen die de studenten aan de lerarenopleiding kunnen aanpassen aan of direct kunnen gebruiken in hun lespraktijk;
- een aantal computersimulaties en –spelletjes waarmee gebruikers wiskundige fenomenen kunnen simuleren en inzichtelijk kunnen maken;
- voorbeelden van leerlingwerk of –oplossingen behorend bij het voorbeeldlesmateriaal;
- richtlijnen voor het ontwikkelen van lesmaterialen, voor het vervullen van de docentrol in de klas en voor het toetsen van leerlingen;
- voorbeelden van wiskundige problemen voor alle schoolniveaus die gebruikt kunnen worden in de lespraktijk.

De website biedt diverse vormen van *ondersteuning* aan de studenten aan de lerarenopleiding. Sommige daarvan zijn op een natuurlijke manier afgeleid van het internet, zoals communicatiehulpmiddelen (e-mailfaciliteiten en mailinglijst) en links naar andere bronnen over RME en wiskunde-onderwijs in het algemeen. Andere zijn speciaal ontworpen voor de doelgroep, zoals:

- een instrument voor het ontwerpen van lesplannen;
- een aantal simulatieprogramma's en spelletjes over wiskundige onderwerpen;
- een tutor-gedeelte; en
- een aantal videofragmenten over hoe het lesgeven van realistische wiskunde in de praktijk eruit kan zien.

De *gebruikersinterface* van de website is zo ontworpen dat gebruikers op eenvoudige wijze door het programma kunnen navigeren en de benodigde informatie kunnen vinden. De belangrijkste kenmerken van de gebruikersinterface zijn:

- ieder scherm is opgedeeld in verscheidene gebieden (zoals het menu en de submenu's) met elk een eigen functionaliteit; de plaats van de gebieden blijft door de hele website gelijk;
- de buttons en de tekst (Engels en Indonesisch) zijn goed te lezen;
- op sommige interactieve schermen (zoals de simulaties) kunnen gebruikers de wiskundige fenomenen zichtbaar maken door de variabelen te wijzigen;
- sommige documenten zijn beschikbaar gesteld als Word-file, zodat het eenvoudig geprint kan worden vanaf de website.

RME-cursus

De *inhoud* en *ondersteuning* van de cursus volgen de filosofie en kenmerken van RME. Op basis van een synthese van RME-theorie en feedback van deskundigen op dit terrein zijn de volgende aspecten benadrukt tijdens de cursus:

- achtergrondinformatie over RME en de vijf belangrijke kenmerken van RME;
- 'ervaringsles' waarin studenten zich plaatsen in de rol van leerling en in die hoedanigheid ervaring opdoen met het rme-gerelateerde leerproces;
- ondersteuning bij het herontwerpen van lessen op grond van de vijf RME-kenmerken;
- didactiek gericht op het gebruik van interactie (als een van de RME-kenmerken) in de lespraktijk, waarbij een aantal kritische momenten in de les gegeven en bediscussieerd worden;
- beoordeling binnen RME, waarbij zowel aandacht is voor summatieve evaluatie (beoordeling aan het eind van de les) als voor formatieve evaluatie (beoordeling tijdens het instructieproces).

De *cursusorganisatie* volgde de hoofdactiviteiten 'ervaringsles' (met student als leerling), herontwerp van lesmaterialen, stage en reflectie. De laatste versie van de cursus omvatte in totaal zes wekelijkse bijeenkomsten (van ongeveer 100 minuten) en twee weken stage op een stageschool.

RME-voorbeeldlesmaterialen

Voorbeeldlesmaterialen spelen een belangrijke rol in dit onderzoek. De materialen omvatten leerlingmateriaal, beoordelingsmateriaal en een docentenhandleiding. De docentenhandleiding bevat procedurele specificaties. Dit zijn heldere richtlijnen en aanwijzingen voor het gebruik van de materialen, gericht op belangrijke onderdelen van de innovatie, in dit geval de RME-benadering. De docentenhandleiding voorziet in specificaties van de start, de kern en de afsluiting van de les en de wijze van beoordeling binnen RME. In totaal zijn voor vijf wiskundige onderwerpen voorbeeldlesmaterialen aangepast aan de Indonesische context. Deze materialen zijn gehanteerd bij de ervaringsles en tijdens het herontwerpen van de eigen lesmaterialen. De materialen zijn opgenomen in de cursusinformatie en in de website.

RESULTATEN

De resultaten van de formatieve evaluatie-activiteiten tijdens de prototypingfase laten zien dat de deelnemers de uiteindelijke versie van de website, de cursus en de voorbeeldlesmaterialen valide en praktisch bruikbaar achtten (zie hoofdstuk 3).

Tijdens de eindevaluatie werd een try-out uitgevoerd met de laatste versie van de leeromgeving (zie hoofdstuk 4). Doel van deze try-out was te achterhalen welke invloed de leeromgeving kan hebben op de professionele ontwikkeling van studenten aan de lerarenopleiding. De volgende vragen stonden centraal:

1. Wat vinden de studenten van de leeromgeving?
2. Wat hebben de studenten in de leeromgeving geleerd?
3. Welk effect heeft de leeromgeving op de organisatie van de afdeling wiskunde-onderwijs van UPI Bandung?
4. In hoeverre waren de studenten in staat de kennis en vaardigheden m.b.t. RME toe te passen in de lespraktijk?

De eindevaluatie bij de studenten heeft geleid tot de volgende bevindingen:

1. De studenten zijn tevreden over de inhoud, ondersteuning, interface en organisatie van de leeromgeving. Dit wordt met name veroorzaakt doordat de leeromgeving in hun behoeftes voorziet en de onderdelen van de leeromgeving consistent zijn.
2. De leeromgeving ondersteunt de studenten bij het leren van het wiskundige, didactische en praktische deel van RME. De leeromgeving bevordert het begrip van RME en assisteert studenten bij het herontwerpen van lesmaterialen. Daarnaast leren studenten webtechnologie gebruiken tijdens het leren over RME en het reflecteren over het geleerde in de praktijk.

3. De invoering van de leeromgeving heeft invloed op de organisatie van de afdeling wiskunde-onderwijs van UPI Bandung en de wiskunde-docenten in de verschillende stagescholen.
4. De leeromgeving heeft het lesgedrag van de studenten beïnvloed. De studenten waren na het doorlopen van de leeromgeving in staat om in de praktijk les te geven volgens de RME-benadering.

Ten slotte zijn er enkele indicaties dat de leeromgeving (via de studenten) een positieve invloed kan hebben op de verandering van de houding van leerlingen in het voortgezet onderwijs ten aanzien van wiskunde.

AANBEVELINGEN

Op basis van de conclusies van het onderzoek zijn aanbevelingen geformuleerd (zie hoofdstuk 5). De eerste serie van aanbevelingen is bedoeld voor het RME-pilot-project op 12 basisscholen in drie steden op Java waarvoor in 2001 door de Indonesische regering opdracht is gegeven. De aanbevelingen richten zich op het gebruik van voorbeeldlesmaterialen, nascholing van leerkrachten en de manier waarop de ontwikkelde leeromgeving gebruikt kan worden binnen dat pilot-project.

Het CASCADE-IMEI-onderzoek richtte zich op studenten van de lerarenopleiding aan de UPI in Bandung. Een tweede serie aanbevelingen is gericht op de verspreiding van de leeromgeving naar andere lerarenopleidingen in Indonesië.

Een derde serie aanbevelingen is gericht op de toekomstige ontwikkelingen van de leeromgeving zelf. Ze betreffen onder meer de uitbreiding van de leeromgeving en de manier waarop de leeromgeving verder geïmplementeerd kan worden.

Ten slotte zijn aanbevelingen geformuleerd voor vervolgonderzoek aan de leeromgeving. Daarbij kan gedacht worden aan nader onderzoek naar de effectiviteit van de leeromgeving, onderzoek naar een verdere benutting van webtechnologie binnen de leeromgeving en onderzoek naar de toepasbaarheid van de leeromgeving in andere contexten.

APPENDIX A

EXAMPLES OF RME EXEMPLARY LESSON MATERIALS

Topics:

1. Linear equation systems
2. Matrices
3. Symmetry
4. Side seeing
5. Statistics

All of these examples can be found at the following URL:
http://projects.edte.utwente.nl/cascade/imei/dissertation/appendixA.pdf

APPENDIX B

EXAMPLES OF EXEMPLARY LESSON MATERIALS ADAPTED BY STUDENT TEACHERS

Topic:

1. Linear equation system
2. Matrices
3. Arithmetic social

All of these examples can be found at the following URL:
http://projects.edte.utwente.nl/cascade/imei/dissertation/appendixB.pdf

APPENDIX C
INSTRUMENTS USED DURING THE PROTOTYPING AND ASSESSMENT STAGE

1. entry questionnaire
2. participant questionnaire for the web
3. participant questionnaire for the course
4. expert appraisal questionnaire for the course and web
5. RME-test
6. innovation profile

All of these examples can be found at the following URL:
http://projects.edte.utwente.nl/cascade/imei/dissertation/appendixC.pdf

APPENDIX D
EXAMPLES OF DATA E-MAILS

Types:

1. the form as check-visit e-mail
2. the form as solutions to the problem of the month
3. direct e-mail as feedback
4. direct e-mail that need information and resources about RME
5. direct e-mail that need information about mathematics education in general
6. conversation

All of these examples can be found at the following URL:
http://projects.edte.utwente.nl/cascade/imei/dissertation/appendixD.pdf

APPENDIX E
CURRICULUM PROFILE OF STUDENT TEACHERS

All of these examples can be found at the following URL:
http://projects.edte.utwente.nl/cascade/imei/dissertation/appendixE.html

ABOUT THE AUTHOR

Zulkardi (1961) grew up in the small city of Prabumulih in South Sumatera, Indonesia. Following in the footsteps of his father, a primary school teacher, he enrolled in a program of teacher education at the Department of mathematics education, Faculty of Teacher Training and Education at Sriwijaya University. He graduated in 1984 and became a mathematics teacher educator. He earned his Master's degree in Computer science at the University of Indonesia in collaboration with the University of Maryland, USA (1989-1990). In 1995, he was selected by the Indonesian government as one of the teacher trainers that were sent to the University of Houston, USA, for three months for studying mathematics education in primary schools. In 1998, he joined the University of Twente in collaboration with the Freudenthal Institute to investigate mathematics education and educational (web) technology, which resulted in this book.