

Developing a 'rich' learning environment on Realistic Mathematics Education (RME) for student teachers in Indonesia

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Abstract. This paper deals with the design and evaluation of a 'rich' learning environment (LE) for assisting student teachers in Indonesia learning and teaching realistic mathematics education (RME), a Dutch mathematics education approach. The LE can be rich in the sense that: (1) it has of two main environments i.e. a web site and a face-to-face course; (2) it uses various of tools such as Java applet simulation programs, online communication and video clips (the web) as well as a full video as well (the course); and (3) it provides student teachers experiences in teaching practice in the secondary school classroom environment. Using development research approach, three prototypes of LE have been developed in Holland and evaluated mainly in Indonesia. However, in this paper is only focused on the results of the third prototype of the LE. Results suggest that the LE program potentially effective in assisting student teachers understanding RME and in improving their performance in teaching mathematics using realistic approach in the schools.

Key words: learning environment, realistic mathematics education, web site support,

Introduction

There is no question that the current main problems of mathematics education in Indonesia, especially in the arena of secondary schools, are both low achievement of pupils on mathematics and poor attitude of them toward mathematics. The problem of low achievement is revealed, for instance, by the average of mathematics scores on the national test. This test is conducted by the government annually and taken by all last year's students of junior high school in Indonesia. From 1990 to 1997 the average score was always below 5.0 in a scale of 1 to 10 and it was the lowest score among other subjects taught in the school (Manan, 1998). Furthermore, findings from two diagnostic tests that were conducted by Suryanto (1997) and Somerset (1996) inform that the results in mathematics education for 16 different urban and rural junior secondary schools in several provinces in Indonesia was very low. The result of the test indicates that most pupils lack understanding of the basic skills that they learned in primary school and in everyday application problems. Finally, in the international level, based on the results of the Third International Mathematics and Science Study (TIMSS), the achievement of pupils in mathematics education in Indonesia was ranked 34th out of 38 participating countries (Mullis et al., 2000).

The problem of mathematics anxiety in Indonesia was informed formally (Marpaung, 1995) that most pupils in a number of selected primary schools in Yogyakarta were afraid to mathematics. He pointed out that mathematics teachers less confident and lack of smile so the classroom situation have no interaction and pupils have no chance to communicate their solutions. Likewise, as informally discussed in either in seminars, national newspapers or among mathematics teachers, many pupils even adult who had 12-year experiences in learning mathematics in the schools, mathematics was seen as a *ghost* (in Indonesian language well known as *momok*) that made children scare. However, in some cases it was not the mathematics but the teachers. Teachers who lack of understanding on the content and the pedagogic of mathematics could made it hard to be learned by her/his pupils. On top of that, pupils poor attitude toward mathematics due to the fact that in school mathematics too many exercises and homework need to be solved, too many rules need to be proved but lack of real-life applications which might be helpful for their daily life.

In an attempt to combat the low achievement and poor attitude toward mathematics, the Indonesian government through the PGSM project (Secondary School Teacher Development project) has attempted to identify probable reasons for these problems. Research cites various causes, including inaccurate learning materials, inadequate mechanistic teaching methods, and poor forms of assessment (Zulkardi, 1999). Hence, a new approach in mathematics education that can overcome those problems is needed. One of the promising approaches toward the teaching and learning of mathematics that is thought to address these problems is realistic mathematics education (RME).

This study was aimed at exploring the roles a LE in the form of a face-to-face course and a web site support in supporting student teachers in UPI Bandung learning and teaching RME as an innovation in mathematics education in Indonesia.

Theoretical framework

Philosophy of RME

RME is mostly determined by Freudenthal's view on mathematics (Freudenthal, 1991). Two of his important point of view are: mathematics must be connected to reality; and mathematics should be seen as human activity. First, mathematics must be close to children and be relevant to every day life situations. However, the word 'realistic', refers not just to the connection with the real-world, but also to problem situations which are real in students' mind. Second, the idea of mathematics as a human activity is stressed. Mathematics education organized as a process of *guided reinvention*, where students can experience a similar process compared to the process by which mathematics was invented. In this case, the reinvention process uses concepts of mathematization as a guide. Later, it is categorized by Treffler (1991) into horizontal mathematization and vertical mathematization.

Principles and Characteristics of RME

The characteristics of RME are historically related to three Van Hiele's levels for of learning mathematics (de Lange, 1996). Here it is assumed that the process of learning proceeds through three levels: (1) a pupil reaches the first level of thinking as soon as he can

manipulate the known characteristics of a pattern that is familiar to him/her; (2) as soon as he/she learns to manipulate the interrelatedness of the characteristics he/she will have reached the second level; (3) he/she will reach the third level of thinking when he/she starts manipulating the intrinsic characteristics of relations. Traditional instruction is inclined to start at the second or third level, while realistic approach starts from first level. Then, in order to start at the first level that deals with phenomena that are familiar to the students, *Freudenthal's didactical phenomenology* that learning should start from a contextual problem, is used. Furthermore, by the *guided reinvention* principle and *progressive mathematizations*, students are guided didactically and efficiently from one level to another level of thinking through mathematization. These two principles and the concept of *self developed models* (Gravemeijer, 1994) can be used as design principles in the domain-specific instruction theory of mathematics education. The LE used these learning principles both in the course and the web site.

The combinations of three Van Hiele's levels, Freudenthal's didactical phenomenology and Treffer's progressive mathematization result in five basic characteristics of realistic mathematics education or five tenets of RME (de Lange, 1987, Gravemeijer, 1994). In short those are:

- (1) *Use of contextual problems* (contextual problems figure as application and as starting points from which the intended mathematics can come out).
- (2) *Use of models or bridging by vertical instruments* (broad attention is paid to development models, schemas and symbolization rather than being offered the rule or formal mathematics right away).
- (3) *Use of students' contribution* (large contributions to the course are coming from student's own constructions, which lead them from their own informal to the more standard formal methods).
- (4) *Interactivity* (explicit negotiation, intervention, discussion, cooperation and evaluation among pupils and teachers are essential elements in a constructive learning process in which the student's informal strategies are used as a lever to attain the formal ones).
- (5) *Intertwining of learning strands* (the holistic approach implies that learning strands can not be dealt with as separate entities; instead an intertwining of learning strands is exploited in problem solving).

Strategies for introducing RME in teacher education in Indonesia

As reported by de Lange (1996), RME has been adopted and adapted in some projects in different countries such as USA, Portugal, England, Germany, Spain, Brazil, Denmark, South Africa, Japan, and Malaysia. For example, in the USA, through a collaboration project between the Freudenthal Institute and the National Science Foundation, RME is adopted and redesigned in the *Mathematics in Context (MIC)* textbooks for grade 5-8. After the books were used by students in several school districts from different states, preliminary research showed that the student achievement in the state tests increased. In one of these examples, ninth-grade students in the Ames district (Iowa state) with three years experience using these books were recently tested with the *Iowa Tests of Educational Development*. 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, 1998).

However, these positive results were achieved after facing some obstacles. As Clarke, Clarke & Sullivan (1996) mentioned that in the beginning implementation of MIC textbooks, teachers found difficulties to teach the book materials in the classrooms. Although each pupil has his/her own book, teachers were used to make their own teaching materials. They want to use the books but in some cases they want to make their own materials by adapting the materials in the books. Therefore, the project provided a professional development program for teachers learned how to teach new materials using a new approach and how to redesign the materials based on teacher needs. This experience can be used as a good example if RME materials want to be introduced then teachers are need to be trained and supported in implementing such materials.

In the country where RME originally has been developed and implemented for about 30 years, the Netherlands, there are also positive results that can be used as indicators that RME might be promising to increase the quality of mathematics education. For instance, the results of the Third International Mathematics and Science Study (TIMSS) showed that pupils in the Netherlands gained high achievements in mathematics education which was ranked 6th out of 38 participating countries and the gap between smart pupils and weak pupils was very small (Mullis et al., 2000). The latter achievement might be interpreted that RME philosophy of mathematics as human activity was achieved or more precisely that mathematics not only for the smart pupils but also for the weak. Thus, "mathematics for all" which is only slogan for some countries including Indonesia has been achieved in the Netherlands. Still, these positive results could be achieved not in the short-term but in the long-term endeavor.

Based on the explanations in the previous sections, RME looks promising to be introduced and implemented in Indonesia because it could increase pupil's understanding and pupil's motivation toward mathematics. For instance, RME content materials are developed using the contexts that are experientially real to the pupils. This can increase pupil's motivation toward mathematics. Also, the teacher using that materials can guide the pupils learn from real level to abstract level of mathematics concepts. With the interaction and construction, this way of learning leads pupils to understand the concept of mathematics.

Yet, in order to do so, there are three warnings are should be considered. First, RME curriculum materials are not easy to be designed and learned by teachers because the mathematics materials differ from former ones in that they emphasize application problems with a loose structure and a redefinition of basic skills. For instance, the assessment materials focus on middle-level and high-level order thinking instead of the low level only. Second, teachers need to be educated how to use RME materials in their classroom. According de Lange (1993) the role of teachers in RME changes from teaching to 'un-teaching'. Finally, the implementation of RME is not a short-term program or project, but it needs many years to be institutionalized. These changes 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: (1) new curriculum materials or changed use of existing materials; (2) new knowledge and skills required by the teacher; and (3) 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 in to account the obstacles that were faced either by the MIC project or Dutch experts. Related to the Fullan's suggestion, the following questions arise: How to develop or adapt new curriculum materials to the new context? How can teachers be helped in implementing these materials in the classroom practice? What advice can be given? What support can be offered? Selter (1997) pointed out that these are all mediated through the teacher, specifically through teacher's beliefs about how to organize and facilitate pupil's learning of mathematics. In this context, teacher education (pre-service as well as in-service) plays a vital role. One key strategy in this situation is to engage teachers or student teachers in their professional development using the following strategies (Loucks-Horsley, Hewson, Love & Stiles, 1998): (1) a short course (for *building knowledge* by teachers or student teachers); (2) curriculum development (by *adapting the innovative materials into the school practice*); and (3) using technology (in order to *provide teachers or student teachers with a sustainable tool which support rich information about the new approach*).

Learning environment

In this four-year study, RME will be introduced to Indonesian student teachers by developing a LE in which the face-to-face RME course and the web site both containing background information and RME curriculum materials. Figure 1 shows two main components of the LE: a face-to-face RME course and a web site.

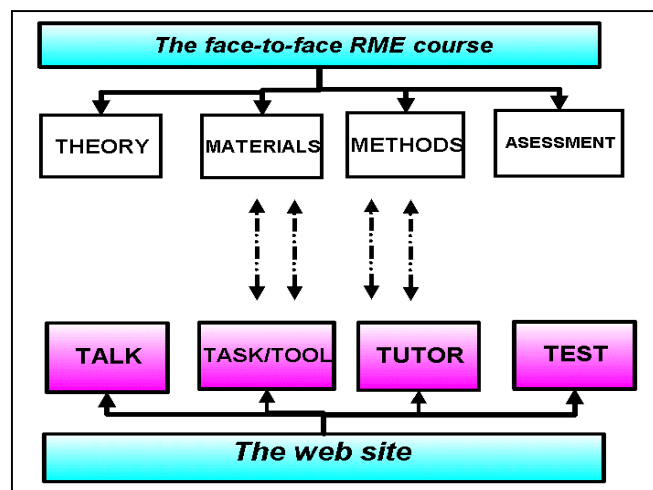


Figure 1. Structure of the learning environment on RME

The course and its materials

The RME course was developed in order to make student teachers understand what RME is and how to implement RME in the classroom. The main contents of the course includes: (1) overview of the RME theory; (2) learning how to make or solve a number of contextual problems; (3) learning how to teach RME in the classroom; and (4) learning how to assess the students in the RME classroom.

The course materials were adapted from RME books that were developed by Freudenthal Institute experts as well as materials from the "Mathematics in Context" books (mathematics books for student grade 5-8 in USA) that were developed during the collaboration project between Freudenthal Institute and University of Wisconsin-Madison (Romberg & de Lange, 1998). Special adaptation to the Indonesian contexts occurred such as examples, curriculum level, and number of mathematics problems. Two topics were developed and used in the course, that is linear equation system and matrices.

The web site

Figure 2 shows the front page of the web site. It is called CASCADE-IMEI. While CASCADE refers to the line of study at the University of Twente which deals with development electronic support systems in the area of education, IMEI stands for innovation in mathematics education in Indonesia. The address of the web site is at: <http://www.geocities.com/ratuilma> or <http://projects.edte.utwente.nl/cascade/imei>



Figure 2. The front page of the web site

All course materials are also put on the web site, giving the student teachers the opportunity to refer the course materials whenever they feel a need.

The main components of the web site are: (1) online info consisting of exemplary RME materials (students materials, teacher guide, and assessment materials) and students' productions from the RME classrooms; (2) online tools containing a number of tools for web users such as: simulations and games on mathematics education which are made using a Java applets and Java script program; and (3) online talk elements that can be used to communicate to: the developer using e-mail; other online users using a chat utility; and all users using a mailing list.

Figure 3 shows an example of web page that is the simulation page. It consists of Java applet programs on mathematical simulation such as geometry and graphic functions.

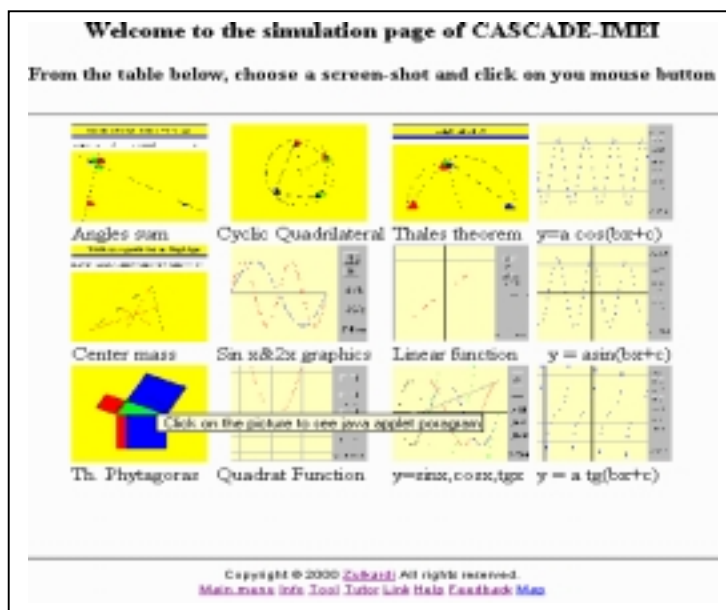


Figure 3. Java applet programs in the web site

For example, figure 4 shows an example of trigonometry function in which users can simulate the graphic in various forms by changing the variables such as a, b, and c in the quadratic function.

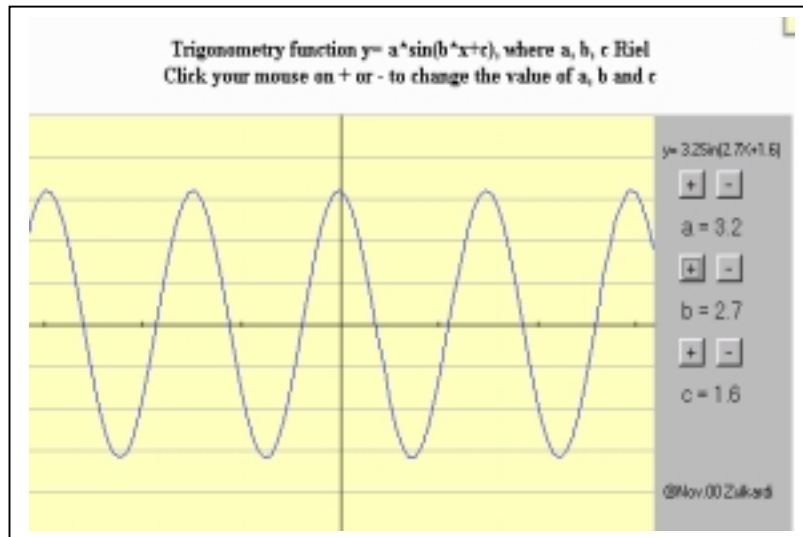


Figure 4. An applet of $y = a \cdot \sin(b \cdot x + c)$

Research Methodology

Development research

This study deals with the design, development and evaluation of a LE in order to support student teacher in Indonesia learning RME as new approach in mathematics education. It can be seen as a catalyst for an initiate change in mathematics education in Indonesia. Due to various uncertainties about how to develop such LE which arise in the beginning of the study and its effectiveness is mostly unknown beforehand, therefore, development research has been chosen as a research approach (van den Akker, 1999, Nieveen, 1997).

The prototypes of the LE has been designed and evaluated with several experts in the Netherlands. Then after revising the prototypes and adapting them to the Indonesian context they were implemented to the target group in teacher education in Bandung. In this stage two prototypes, the first and the second prototype of the learning environment has been developed. Based on results and suggestions of these two prototypes, the third prototype is developed and evaluated from February to May 2001.

Research questions

The results of the formative evaluation of third prototype are discussed in the rest of this paper based on the following questions:

- (1) *What are participants' reactions to the LE?*
- (2) *What is the practicality of the third prototype of the web site based on the comments of student teachers?*
- (3) *What are potential effects of the LE to the performance of mathematics student teachers in UPI Bandung?*

Participants

The participants of the formative evaluation of the course were 8 pre-service student teachers (see also the characteristics of the participants in the next session) at the Department of Mathematics Education, Indonesian Educational University in Bandung, Indonesia. They don't have prior knowledge on RME. At the end of the course two participants, Mr. D. and Mr. S., were selected based on their knowledge and skill as well as their highly motivation during the course to participate in a working group in implementing the RME materials in the schools. Mr. D implemented the RME materials in the class with 24 pupils (age 12-15) while Mr. S. implemented the RME materials in the class with 37 pupils (age 16-19). The evaluation of the web site was carried out with the same two student teachers.

Instruments

The instruments that were used in the course were an entry and a final questionnaire, an end-of-unit test and an interview. Instruments were used in the school are a final questionnaire and observation form. Furthermore, the instruments that were used in evaluating the web site are an observation form, a logbook, and e-mails.

Procedure

1. The course

The course was implemented in UPI Bandung. The activities were conducted within a time frame of four blocks of two-hours. After the participants filled out the entry questionnaire the course started by giving the participants information about the basic principles of RME and its characteristics. Then some examples of realistic mathematics problems were given and discussed in the groups so they got the idea of each characteristic of RME. Next, the student teachers were given a number of RME problems in two topics (*linear equation system* and *matrices*). After they solved the problems, they were guided in discussing the various strategies and in several cases they were invited to present their answers in front of the class. Finally, at the end of the course they were tested to see their performance in solving the problems. In addition, they filled out the final questionnaire. Two course participants were followed when they implemented the RME lessons in their classes. They developed the lesson materials in collaboration with the researcher. The researcher observed their lessons.

2. The web site

There were some activities held regarding the web site. First, participants got some technical training. They were trained how to get access to internet and were guided in registering a personal e-mail using free-email utility in *Yahoo*. Then, they were invited to send their identities to the researcher as well as to other participants. Here, they learned how to compose a new e-mail, to send it and to receive other's e-mail. In addition they were taught how to use the attachment facility. Moreover, they were asked to access the web site, to give comments and to send them to the developer by e-mail. Further, they were guided to communicate their experiences and problems in the course to the developer and other participants using e-mail. Finally, the web site was evaluated using a cooperative evaluation, during which four student teachers were asked to work aloud while using the web site. All of their comments were recorded on tape for analysis.

Results and Discussion

(1) What are participants' reactions to the LE ?

Based on the data resulted from the questionnaire, participants' reactions to the LE program can be summarized in the table 1.

Table 1. Participant's reactions to the overall LE

Overall perceptions to the course	N	Mean	S.d.	Max.	Min.
Helpful for me as a math. student teacher	8	4.9	0.35	5	4
Rich with new information	8	4.6	0.52	5	4
Interesting	8	4.6	0.52	5	4
Educative	8	4.1	0.35	5	4
Consistent with the needs	8	4.0	0.53	5	3

Note: 5 = highly positive, 1 = highly negative

The results illustrate that the participants are satisfy with both the content and the process of the LE. Almost all of them realized that the LE was helpful for them as mathematics student teachers as it provided an extremely new environment for learning a new approach mathematics. Also, they agreed that the LE has rich information and interesting content that is consistent with they needs.

(2) What is the practicality of the third prototype of the web site based on the comments of student teachers?

Based on the data from the questionnaire and interview, the third prototype of the web site can be judged to be practical for student teachers. However, there are still remarks from users which suggest some parts of the web site need to be improved. The following are the overall results of the formative evaluation of the web site:

- + The web site is easy to use
- + Support such as tutor, talk, tool and task seem to be helpful
- + User interface seems to be easy to understand
- + Navigation seems to be easy to use
- + The content is consistent with the school curriculum
- Need options or tool for saving or printing the materials on the web site.
- Need more explanations with examples how to design RME materials or assessment

(3) What are potential effects of the LE to the performance of mathematics student teachers in UPI Bandung?

In order to answer this question three kind of results are used. First, student teachers solutions on a test at the end of the course. An example of a test item is the "t-shirt and soda" problem below (figure 5).

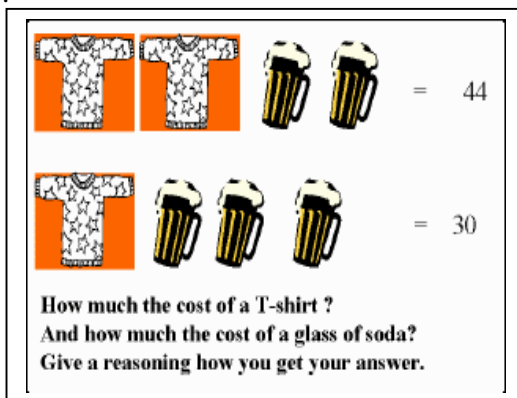


Figure 5. T-shirt and soda problem

Before starting the test, 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 6 shows two types of solutions: one is formal (Syukur's) and one is 'informal' (Eulis'). 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 leaves 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 is 4.

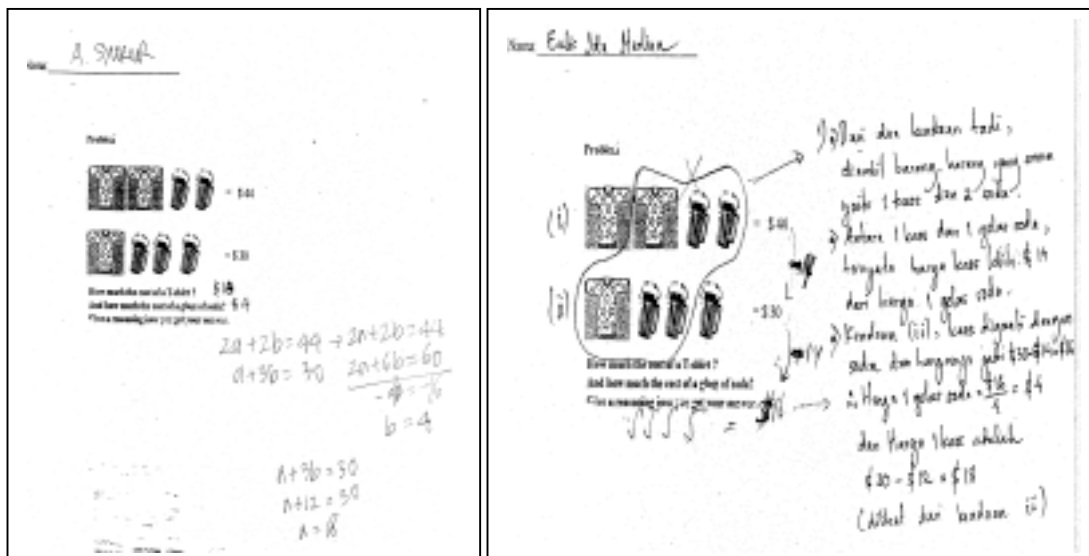


Figure 6. Two strategies in solving "t-shirt and soda " problem

Second, the knowledge of student teachers in developing lessons based on the RME tenets. Here, two lessons based on the RME tenets that were developed by Mr. D. (the cube) and Mr. S. (the general graph) were evaluated. Figure 7 illustrates two examples of the cube problems that were tested in his class. On the left, pupils were asked to draw a cube they are familiar with. One can see from the figure that the pupil knew that a dice is a cube. On the right, pupils were asked to complete the graph by drawing the 'dash-line' and to explain what the line means. This is an example of true solution of the pupil.

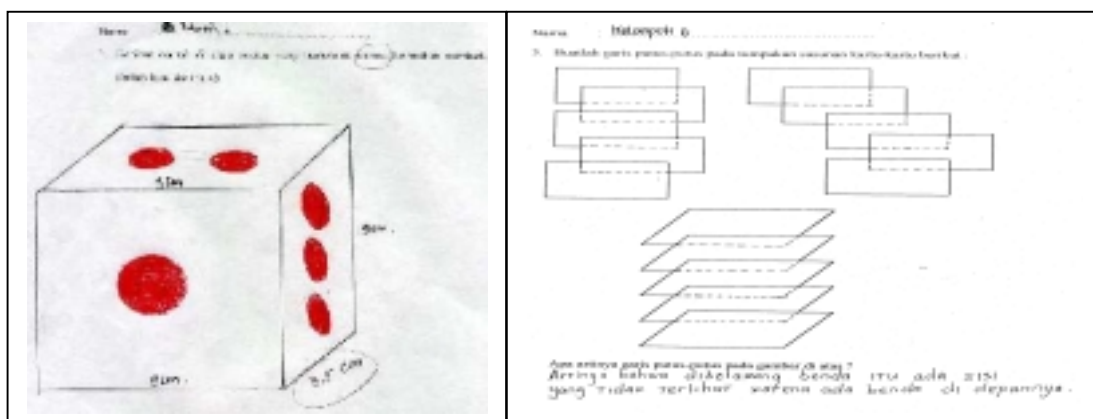


Figure 7. Two examples of the cube problems

Finally, the teaching skills of Mr.D. and Mr. S. were observed by the researcher. An overall impression was that they were able to teach using 'realistic materials'. 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.

Conclusions

Based on the results in the previous section it can be concluded that:

- The learning environment was perceived as an interesting program (its content, session and process) by mathematics student teachers in UPI Bandung.
- The web site was judged to be practical by student teachers as a part of LE. However, this positive feedback also came with a number of remarks or revision suggestions in order to improve the practicality of the prototype of the web site.
- The learning environment could increase student teachers performance in developing RME materials and teaching the materials in the schools. However, in the development part they found difficulties in finding contextual problems that are based on the real life situation. 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 evaluation and redesign in order to improve the quality of their lessons.

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