12th International Congress on Mathematical Education
Program Name XX-YY-zz (pp. abcde-fghij)
8 July – 15 July, 2012, COEX, Seoul, Korea (This part is for LOC use only. Please do not change this part.)

MATHEMATICS EDUCATION REFORM MOVEMENT IN INDONESIA

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The reform of mathematics education in Indonesia started in mid-nineties. This was the second attempt after the first movement to reform traditional mathematics to modern mathematics (1975 – 1990) was a complete failure. Several mathematicians and mathematics educators have dedicated their expertise and experiences to rebuild mathematics education from the remnant of modern mathematics. Their concerns were directed particularly to weakest group of students. After a long consideration they came to decision to choose the theory of realistic mathematics education (RME) as a basic concept for developing the local theory of mathematics teaching and learning. They had the same view that RME could be a vehicle for improving mathematics teaching and learning and at the same time as a tool for social transformation. They began with four teacher education institutes and 12 schools as pilot. Now, RME has expanded to 23 universities that supervise over 300 schools and thousands trained teachers. In this process of mathematics education reform the theory of RME has been transformed to be PMRI, the Indonesian version of RME, and has been widely accepted as a movement to reform mathematics education.

Key words: mathematics learning, RME, teacher education, PMRI

INTRODUCTION

Why do we need to give our children mathematics education? Is it to create a group of great mathematicians? If it is, then we do not need to think of. Every year, a number of Indonesian receives a PhD in mathematics from universities in country and overseas. Many Indonesian participants in the Math Olympiad back home with gold medals. The concern is not only to a small percentage of very smart students, but mostly also the majority. The gap between the top and the weakest math students is very wide in Indonesia.

The aims of mathematics teaching in Indonesia are twofold. First, preparing students to be able to face the changing dynamic global world through practical works based upon logical reasoning, rational, critical, cautious, honest attitude, efficient and effective reasoning. Second, preparing students to be able to use mathematics and mathematical reasoning in their life and study (Hadi, 2002). These aims are not easy to realize. Most of students fear mathematics and are math phobic. They tend to skip mathematics subject, and are happy when mathematics teacher not able to come to the class. This implies to low quality of mathematics education and students' achievement.

A group of mathematicians and mathematics educators were deeply worried to the situation. They wanted to reform mathematics education in the country. Their concerns are based on two reasons. Firstly, they realized that Indonesia needed a larger body of mathematically literate citizens for country to develop and prosper. Secondly, they foresaw that mathematics education that aimed at developing students' understanding and reasoning could help the country to become a democratic society (Sembiring, Hoogland, & Dolk, 2010).

They researched mathematics education in different countries and choose to develop an Indonesian form of realistic mathematics education (RME). They decided to create a local version of RME. Why local? Because, past experiences (the implementation of modern mathematics) show that it is not enough to import and disseminate what worked in another country. Also, the group understood that a top-down reform had a low chance of success. In their view, mathematics education reform needed to be bottom-up and start from specific Indonesian situation. This led to the development of realistic mathematics education in Indonesia or PMRI as it is called (Sembiring, Hoogland, & Dolk, 2010).

PMRI is defined as a domain-specific instruction theory, which offers guidelines for instruction that aims at supporting students in constructing, or reinventing mathematics in problem-centred interactive instruction. It refers to Freudenthal's concept of mathematics as human activities. According to Freudenthal (1973) students should engage in mathematical exploration and should be given the opportunity to reinvent mathematics using well-chosen task, with the help of teacher. Students are not merely being taught mathematics as a ready-made product. This point of departure, for some decades, formed the basis of design research in the Netherlands and later on in Indonesia, which resulted in a range of local instructional theories, and domain-specific instruction theory, known as the RME theory (Gravemeijer, 2010; Widjaja, Dolk, & Fauzan, 2010).

The challenges faced by mathematics educators in Indonesia in transforming teacher-centred to problem-centred interactive instruction are also in teacher preparation. The implementation of RME in Indonesia was a complex innovation process because it relates to the changing of teachers' beliefs, implementation of new methods, and use of new materials. Often time, the introduction of a new approach faces challenges from teachers who are already stable with their own approach. Therefore, from the beginning the PMRI team has been exercising an effective strategy to make teachers gradually come to understand, and become skill-full and competent in the use of new ways. The grounding principle in PMRI is the bottom-up approach. This principle is accompanied by other principles of learning by modelling, ownership at the right place, and co-creating (Sembiring & Hoogland, 2008). So, PMRI is not only dealing with developing local instructional theory on mathematics teaching and learning, but also developing effective professional development program.

REFORM STRATEGY

The preparation for PMRI implementation in Indonesia was started when in 1998 six very talented young Masters were sent to the Netherlands to study for PhD in mathematics education. Keuper-Makkink (2010) noted that preparing experts on RME was a first step for

PMRI movement. The next step was to gain support from larger audiences, especially policy makers in the Ministry of National Education (MoNE). A proposal to start a Dutch project to improve mathematics education found little support. The opposition was understandable because too many projects in Indonesia, and a project means 'earning money' and that is a wrong approach for starting a movement. During their visit to the PhD-candidates in Netherlands representative of Indonesian experts met Dutch mathematics education experts. They come to conclusion that program must be authentically Indonesian, while Dutch experts can assist with setting up workshops, which would contain mostly hands-on activities, not top-down, but especially bottom-up activities, teachers would have much influence. Every workshop would be preceded by trial in the schools: classroom research is obligatory. (Keuper-Makkink, 2010).

The initiative was supported by the Directorate General of Higher Education, MoNE. Dutch consultants, based at the Freudenthal Institute and APS (Dutch National Centre for School Improvement) were involved in the development starting in 2001. Both Dutch institutes initially invested support in the movement by offering conceptual RME knowledge, knowledge on learning from pilot projects, and knowledge about strategies for dissemination and implementation (Hoven, 2010).

In 2006, PMRI won a large grant from the Dutch Government. It offered the PMRI team the opportunity to design a support project for expanding the PMRI movement. The basic principles of the movement were identified, strengthened, and coined in the project plan (Hoven, 2010). Those principles are (Sembiring & Hoogland, 2008; Sembiring, Hadi, & Dolk, 2008):

- bottom up implementation;
- materials and framework based on and developed through classroom research;
- teachers being actively involved in design investigation and developing associated materials;
- day-by-day implementation strategies that enable students to become more active thinkers; and
- the development of contexts and teaching materials that are directly linked to school environment and interest of students.

The bottom up strategy means that although the initiative was first taken by PMRI team schools should play an active role. The change process would take place when each individual within the organisation had the same view about the innovation and contribute their part. Since the main concern was improving teaching and learning, innovation might be initiated from classroom experiments. These have not only provided the base for the development and refinement of PMRI theory but also informed those involved in the development of workshop for teachers and learning materials (students' books and teachers' guides). In fact, teachers played very active role in PMRI workshops, and PMRI materials are mostly written by teachers.

Teachers' Role in PMRI Workshop

The nature of educational reform in large country, like Indonesia, is different from that of a small scale project. In most cases, the activities that make small scale program successful are not helpful when used on a larger scale. This may because of the complexity of problems that are encountered in a large project, such as the number of schools and teachers and the area to be covered. Large scale projects ask for different interventions than do small scale projects. So, there is a need to develop a model that is appropriate for the large scale implementation of PMRI.

The main concern when you plan for dissemination to the wider audiences is the limitation of human resources. A strategy chosen to resolve this limitation was developing stratified workshops (local and national levels) for teachers and mathematics educators (university lecturers) while at the same time selecting talented teachers/lecturers to be partners in the following supporting activities like workshop program and learning materials development. There were several task forces for each intended goal, like task force for design research, task force for learning materials development, and task force for quality assurance.

In every PMRI workshop, teachers played active role in planning, executing, and reflecting. It had been shift from teachers as objects to teachers as subjects. Workshops were consisted of theory and practices, doing mathematics, and modelling of lesson. At the end of each session teachers were asked to reflect on what they know and perceive of what mathematics, how students learn mathematics and how mathematics should be taught to students.

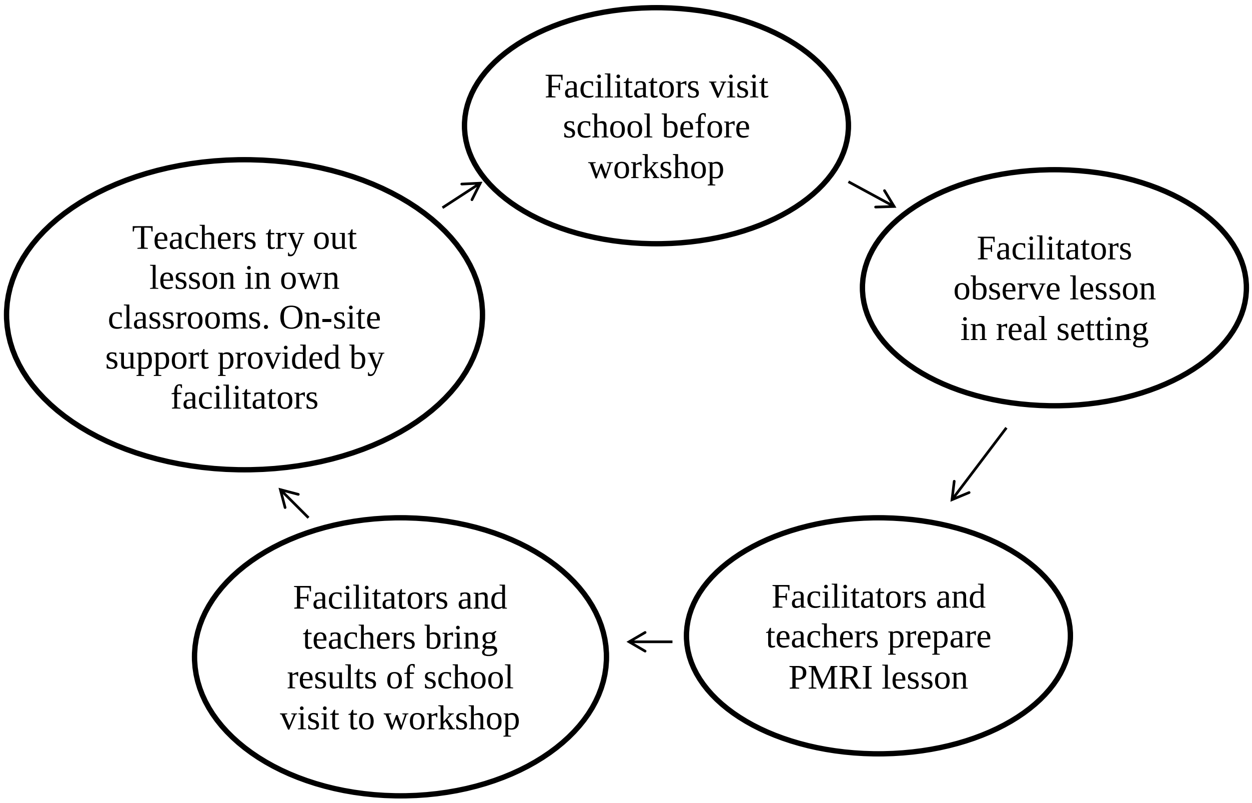


Figure 1. Full cycle of activity during PMRI workshop

Since its introduction there are thousands of primary schools teachers who are familiar with PMRI. Most of them are able to shift from mechanistic way of teaching to problem based, interactive instruction. The implementation have been supported by a series of workshop, namely start-up workshop, follow-up workshop, and quality boost program (Hadi, Dolk, & Zonneveld, 2010; Haan, Meiliasari, & Sari, 2010). However, it was realized that workshop did not stand alone in the professional development program. One strategy only will not be sufficient (Loucks-Horsley, et al, 2010). The PMRI workshops were put on teachers' own setting. Classroom practices became a critical component in the program. Teachers should be provided with opportunity to practice and observe how the idea looks like in a real situation in the daily basis. There were pre-workshop and after-workshop activities. During pre-workshop activity facilitators came to schools and observed lesson. This was followed with reflection and ended with designing the new lesson that refinement of the lesson being observed. During after-workshop activity facilitators and participants visited one of participants' schools to observe lesson (Figure 1). The school visit was then conducted regularly in the following months by facilitators of local PMRI centre. In this way teachers received sustained time and support for reflection, collaboration, and continued learning. (Hadi, Sumartono, Danaryanti, & Arifin, 2011).

A case study conducted by Haan, Meiliasari, and Sari (2010) found that PMRI workshops had achieved their intended for hands on activity, doing mathematics, reflection after each activity, and connection to daily practice. PMRI workshops fulfil most of the conditions for effective workshops. Moreover, the workshops meet the expectations of the great majority of the participants; during the workshops, there is a slight change in the attitude toward PMRI. At the start of the workshop, most participants indicated they wanted to know more about PMRI; at the end of the workshop, the larger part of the participants declared they wanted to start implementing PMRI.

Developing PMRI Learning Materials

Another key factor in transforming from a pilot project to a large scale innovation is availability of learning materials. In the first phase of the project it was clear that materials had to be developed; teachers who were involved in PMRI workshop repeatedly asked for it. Starting in 2001, a first version of materials was made by the four early adapting universities. The first version of the learning materials was based on the national curriculum, the knowledge of the learning process of the children at the time. The materials were tried out in the 12 pilot schools (Amin, Julie, Munk, & Hoogland, 2010). This first version was used to help teachers actualizing the idea of PMRI lesson in practice. After gain experiences from practices, the PMRI team realized that further development of classroom learning materials was an essential ingredient for institutionalizing of PMRI, both in teacher education institutes as well as in the pilot schools that are associated with these teacher education institutes.

For the purpose of developing learning materials, a task force was created. The leaders of the task force, supported by Dutch consultants, got assignment to develop a workshop for prospective authors and form a team of authors capable to design a complete set of learning materials for Grades 1 to 6 (Amin, Julie, Munk, & Hoogland, 2010). Members of the task force are mathematics educators and teachers. Since, they developed something that was different from the ordinary textbooks in the country they looked for inspiration from RME materials in other countries, like for instance the Dutch textbook series *Pluspunt* and *Wereld in getallen* or American textbook series like *Mathematics in Context* and *Context for Learning Mathematics*. (Amin, Julie, Munk, & Hoogland, 2010).

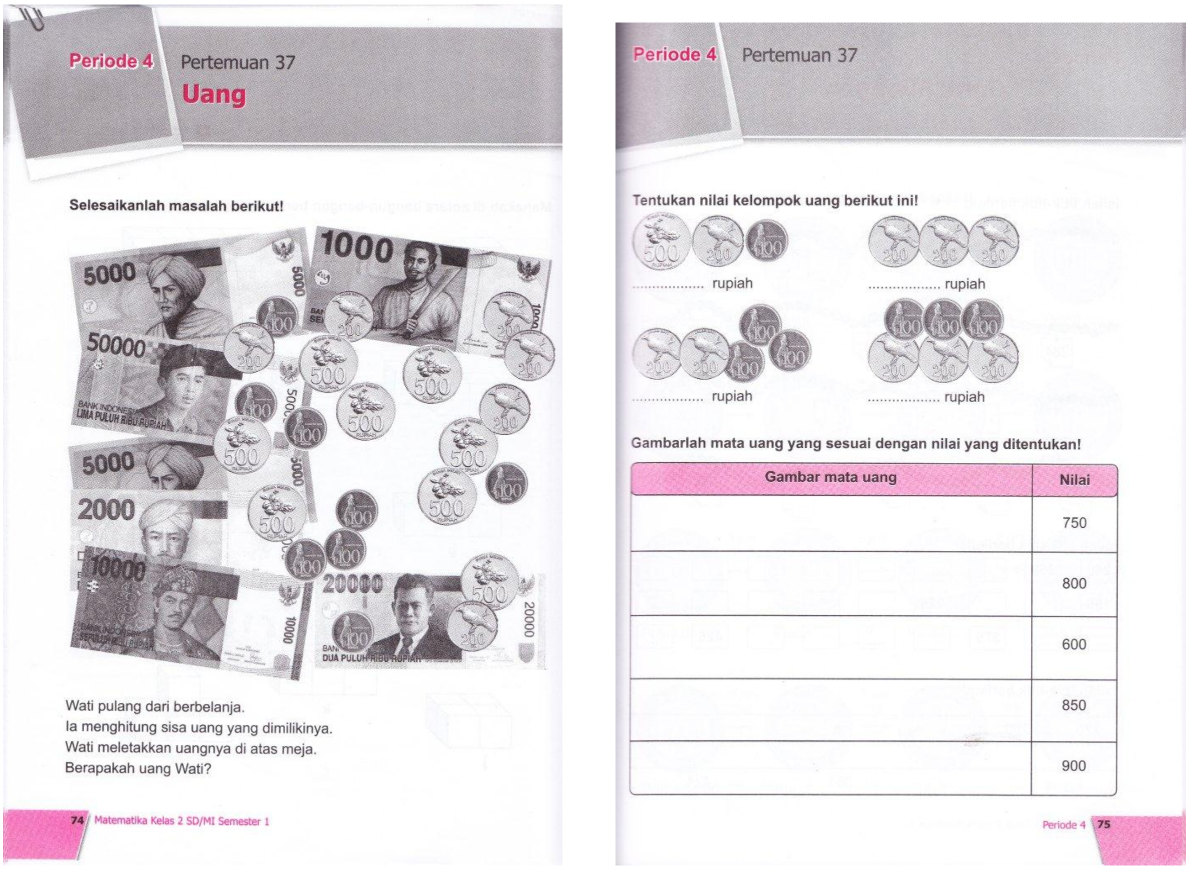


Figure 2. Example of pages from the learning materials for Grade 2

Design of Standard for PMRI

Since its first initiation PMRI has passed several phases. The first was preparation (initiation) phase (1998-2002), the second was pilot phase (2003-2005), the third was development (implementation) phase, and the fourth was maturation (institutionalization) phase (2010 – present). After 14 years of initiation, pilot and development, a vast body of knowledge has been acquired on PMRI and on what is considered good PMRI education in Indonesia. The current phase requires assurance for PMRI standards to anticipate the increasing number of schools and universities wanting to join PMRI movement. Within the PMRI movement, there has been a strong belief in a bottom-up approach, so new universities in new region could adapt materials and ideas of PMRI to fit the local cultures, needs, and circumstances.

For the purpose of maintaining the quality and integrity of PMRI concept, a set of standards has been developed. Those standards are standards for a PMRI teacher, lesson, learning material, lecturer, workshop, and local centre (Hadi, Zulkardi, & Hoogland, 2010).

Standard for a PMRI Teacher

- A teacher has a repertoire of mathematics and PMRI didactics to develop a rich learning environment.
- A teacher coaches students to think, discuss, and negotiate to stimulate initiative and creativity.
- A teacher guides and encourages students to express ideas and find their own strategies.
- A teacher manages class activities in such a way as to support students' cooperation and discussion for the purpose of knowledge construction.
- The teacher, together with the students, summarizes mathematics facts, concepts, principles through a process of reflection and confirmation.

Standards for a PMRI Lesson

- A PMRI lesson fulfils the accomplishment of competences as mentioned in the curriculum.
- A PMRI lesson starts with a realistic problem to motivate and help students learn mathematics.
- A PMRI lesson gives students opportunities to explore and discuss given problems so that they can learn from each other and to promote mathematics concept construction.
- A PMRI lesson interconnects mathematics concepts to make meaningful lesson and intertwine knowledge.
- A PMRI lesson ends with a confirmation and reflection to summarize learned mathematical facts, concepts, and principles and is followed by exercises to strengthen students' understanding.

Standards for PMRI Learning Material

- Learning materials are in line with the curriculum.
- Learning materials use realistic problems to motivate students and to help students s
- Learning materials intertwine mathematics concepts from different domain to give opportunities for students to learn a meaningful and integrated mathematics.
- Learning materials contain enrichment materials to accommodate different ways and levels of students' thinking.
- Learning materials are presented in such a way to encourage students to think critically, creatively, and innovatively and to stimulate students' interaction and cooperation.

Standards for a PMRI lecturer

- A lecturer uses PMRI principles during the courses to help student-teachers experiences and understand PMRI.
- A lecture teaches in a way that supports interactivity in the classroom as a reflection of the principles of PMRI teaching.
- A lecture observes PMRI classrooms to collect data and information that can be integrated in the courses at the university and can be used as a basis for research to develop PMRI.
- A lecture supports teachers who implement PMRI in School.

- A lecturer conducts research and make publications about PMRI.

Standards for a PMRI workshop

- Activities in a workshop are process-oriented which can support the participants to understand PMRI ideas and are product-oriented aiming at providing materials that can be used in school.
- A workshop facilitates participants to experience the PMRI characteristics themselves in order to build their knowledge and skills.
- Contents of a workshop are in line with curriculum demand and the internal and external condition of schools, and it envisions an ideal situation in order to enhance the adaptability of PMRI in schools.
- During a workshop, participants reflect on the relation between the activities, mathematical concepts, and PMRI theories.
- A workshop empowers and builds the confidence of the participants to sustain the implementation of PMRI in schools.

Standards for a Local PMRI Centre (LPC)

- A LPC is an organization for lecturers, teachers, and student-teachers to do research and develop PMRI.
- A LPC is an information and consultation centre about PMRI that provides information, books, teaching materials, teaching media, agendas for professional development, workshops and trainings, journals, magazines, and videos.
- A LPC is a training centre that offers attractive and well-organized training on PMRI that focus on the process and content.
- A LPC is a communication centre that creates cooperation between partner schools, teacher training colleges, other LPCs, and national and international centres.
- A LPC is an organization that is legalized by the rector of the university as a semi-independent organization with an office and staff.

As an umbrella above these standards some more general principles and characteristics were formulated.

PMRI Principles

- Guided reinvention and progressive mathematization
- Didactical phenomenology

PMRI Characteristics

- Use of contexts for phenomenologist exploration
- Use of models for mathematical concept construction
- Use of students' creations and contributions
- Student activity and interactivity in the learning process
- Intertwining mathematics concepts, aspects, and units
- Use of typical characteristics of Indonesian nature and cultures

EXAMPLE FROM PRACTICE

Thousands primary school teachers from at least 23 cities in Indonesia use PMRI in their mathematics lesson. In the following two examples are given. The first example is taken from the mathematics lesson at Grade 3 (8 years old) of Mrs Dewi Mustikawati from Al Hikmah Primary School in Surabaya. Her lesson was about fraction.

A day before the lesson Mrs Dewi announced to her students about the learning materials that students need to bring for the lesson.

Mrs Dewi: "Students, tomorrow we are going to have lunch together. You are going to be divided into groups and each group bring their own bread, knifes, and jam”

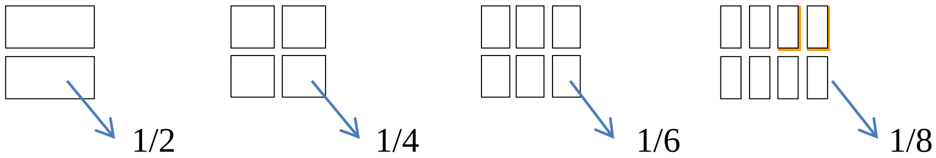
Students imagined how cheerful the lesson would be.

A student: “I don’t like jam, Mom. May I bring such butter or sugar?”

Mrs Dewi: “That’s alright you may also bring cheese or whatever you like.”

On the day of the lesson Mrs Dewi divided her students into 5 groups. She arranged the activities for each group as following:

Activity-1: Four loaves of bread were sliced differently.



Activity-2: Four loaves of sliced bread were spread with jam.

Figure 3. Students exhibit their works

Activity-3: Four loaves of bread were sliced spread with jam that show the same fractions

Figure 4. A student writes a fraction represents sliced bread spread with jam.

By using these simple activities Mrs Dewi gave students stimulant to comprehend fraction as division (in activity-1), fraction as part of a whole (in activity-1 and activity-2), comparing fractions with the same denominator (activity-2), putting fraction with the same denominator in the right order (activity-2), and equivalent fraction and simplifying fractions (activity-3).

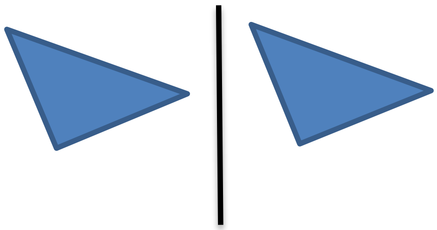
Figure 5. Students celebrate their lesson by eating their breads.

Mrs Dewi realized that she rarely found a situation where students were so exciting looking forward to their mathematics lesson. PMRI made mathematics lesson so real and she saw her students seem like playing but actually they learned mathematics even from the first minutes of lesson. They did not only easily digest mathematical concepts, but also enhance their understanding since they experienced with hands on activities. However, Mrs Dewi realized a challenge she faced in PMRI lesson that was to reconcile the limitation of pacing time and the content of the curriculum. Nevertheless, this challenge could be solved using a good design of contextual problems that promote intertwining of learning strands. Having good contextual problems teacher would be able to link among units in curriculum, and she did not need to explain mathematics to students from page to page.

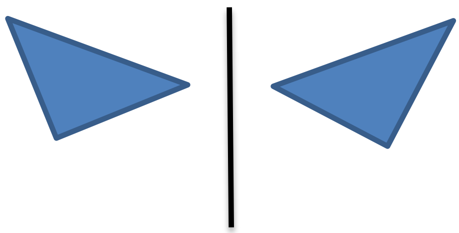
The second example is the PMRI lesson of Grade 4 (9 years old) on the topic of reflection conducted by Mr Yusri Zani from Antasan Besar 7 Primary School in Banjarmasin. Mr Yusri found that his students faced difficulty in comprehending the concept of symmetry. He knew that students every day look at the mirror, but never realized its connection to mathematics. He used this fact to design his lesson. He started with the following problems.

1. Which pictures below show the correct reflection?

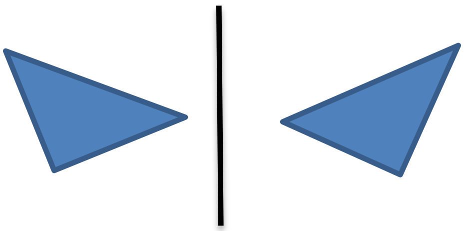
a.



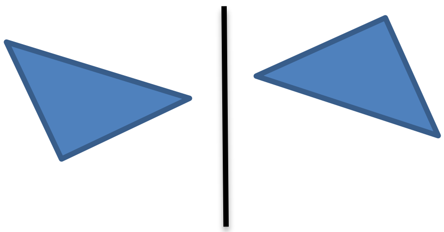
b.



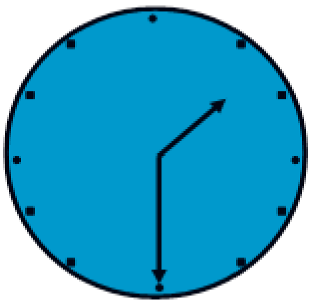
c.



d.



2. The following picture is a shadow of a clock. What time is showed by the clock?



In the first problem, several students chose option “a” as the answer, while for the second problem most students answer that the time is 01:30 PM. Having these facts Mr Yusri designed his lesson. The materials needed for the lesson were a squared-shape mirror (dimension of 10x10 cm^2) and a worksheet (grid paper). Students were divided into several groups. Each group get a 10x10 cm^2 dimension mirror and a worksheet (Figure 6). Each group did the following activity.

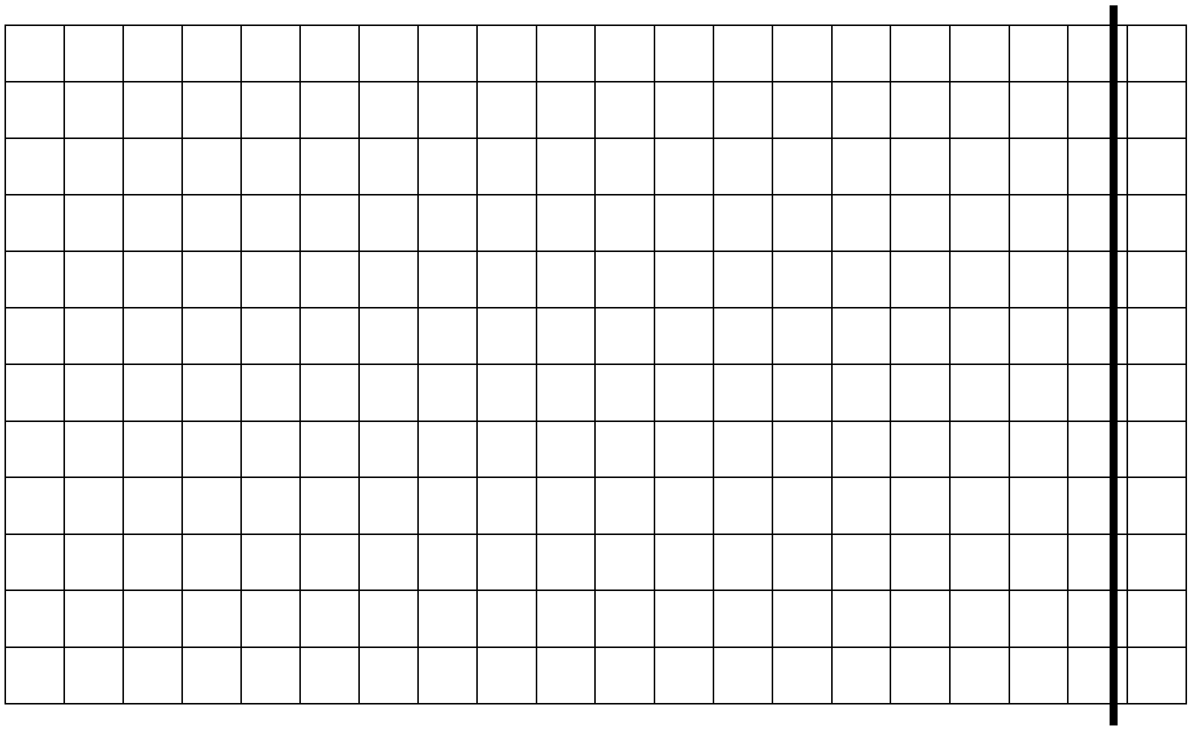


Figure 6. Student worksheet for lesson about reflection

1. Put the mirror on the thick line of the worksheet (grid paper).
2. Put a dice on the grid paper in front of the mirror, and look at the shadow in the mirror! What about the shape and size of the shadow?
3. How far is the distance of dice to the mirror and how far is the distance of the shadow to the mirror?
4. Look at the side of the dice in front of the mirror and the dice side in the shadow. What about the direction of the dice through the shadow? Turn the dice that the opposite side faces the mirror. What about the side of the dice shadow?
5. Do the same things for other dices. Is the result the same?
6. Write down your conclusion about the characteristics of reflection based on the experiment you have done.

IN RETROSPECT

The overall goal of the PMRI movement is to improve the learning results in mathematics of school age children in Indonesia. All children should acquire a reasonable amount of knowledge and skills in mathematics during their elementary school years and first years of secondary education. The learning of mathematics must be an inspiring and meaningful activity for all children, must be taught at each child's own level, and must lead all children to a practical knowledge base that will help them cope with quantitative situations in the world around them. For some children, learning mathematics at a young age must also function as on introduction to the more formal world of science and academic mathematics ahead of them. (Sembiring, Hadi, Zulkardi, Hoogland, 2010, p. 189).

PMRI has been proven to be an approach that can accomplish this. It works. However, what worked in the selected pilot schools is not automatically implementable on a large scale. The implementation and institutionalization of PMRI all over Indonesia is still an enourmous endeavour. It can only be accomplished with the hard and enduring efforts of many: teachers, parents, principals, teacher educators, mathematicians, publishers, journalists, policy makers, politicians, and many more. (Sembiring, Hadi, Zulkardi, Hoogland, 2010, p. 189).

For the coming years the following concrete issues will be addressed and work upon (Sembiring, Hadi, Zulkardi, Hoogland, 2010, p. 189):

- Expanding a school based system of professional development of teachers on the subject of PMRI. Mathematics and language are the key subjects for further development.
- Increasing the capacity of universities to educate prospective teachers with a conceptual and practical base of PMRI. Teachers are among the most crucial factors in the improvement of mathematics education.
- Creating a research agenda on PMRI and conducting design research in the classrooms, PMRI must become an instruction theory with a sound scientific basis in order to make evidence informed choices.
- Creating assessment materials that reflect the concept of PMRI. These concepts are in line with worldwide developments in mathematics education. See, for instance, PISA (OECD, 2006).
- Working on the public relations of PMRI through bulletins, newspaper articles, TV, etc.
- Creating a text book series of PMRI learning materials from Grades 1 to 6, as an example of PMRI practice and as a starting point for further local adaptation and development.
- Through the accomplishment of the above items, reaching an increasing number of schools in an increasing number of regions and cities in Indonesia, by striking a balance between bottom-up conceptual development and top-down facilitation and support.

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