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APPLYING THE PRINCIPLES OF REALISTIC MATHEMATICS EDUCATION (RME) IN TEACHING FOURTH-GRADE MATHEMATICS IN VIETNAM

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Abstract. This article highlights the importance of applying Realistic Mathematics Education (RME) in teaching mathematics at primary schools. It serves as a tool to cultivate a deeper, more intuitive understanding of mathematics among primary students, aligning with educational trends and specific educational objectives delineated in the 2018 Mathematics curriculum in Vietnam**.** The teaching of mathematics at the elementary level in Vietnam is undergoing significant changes with the application of RME theory. The aim is to make mathematics more meaningful and engaging for students by incorporating RME principles into the design of problems that are connected to everyday experiences.

***Keywords**:* RME, teaching mathematics, primary schools.

1. Introduction

RME is recognized as an instructional theory developed within and for mathematics education [1]-[3]. It provides a didactical philosophy for the teaching, learning, and design of mathematical instructional materials. This theory was developed in 1971 by a group of mathematics educators from the Freudenthal Institute at Utrecht University in the Netherlands. Utrecht University hosts a research institute that has consistently strived to innovate mathematics learning since the 1970s. It can be said that RME originates from Freudenthal's perspective on mathematics. His supportive view in RME is that learning mathematics should begin with realistic situations that students need to solve. In much of his research, Freudenthal H. [4] argued that "teaching mathematics needs to be connected to situations related to daily life and society in general to have value for the learner." (Freudenthal H. passed away in 1990, and the book was published one year after his death). Gravemeijer [5] offers a comprehensive development of RME theory, with critical insights into its application in mathematics curricula. Van den Heuvel-Panhuizen [6] provides an overview of mathematics education practices in the Netherlands, with a specific focus on the principles and implementation of Realistic Mathematics Education (RME). In another work, Van den Heuvel-Panhuizen [7] discusses the pedagogical use of models in RME, illustrated through a longitudinal study on teaching percentages.

Following the success of RME in the Netherlands, this instructional theory was applied in the 1990s in Wisconsin, USA, in a project called Mathematics in Context (MiC). In 2003, researchers from Manchester Metropolitan University (MMU) purchased a set of MiC materials, intending to train teachers to use them in a project based in local schools. Essential to the project's success was that teachers understand the philosophy of RME theory and its foundational basis on how children learn mathematics.

Over time, along with its development and refinement, the theory of RME has significantly influenced the advancement of mathematics education in many countries worldwide. Additionally, it is argued that learning mathematics becomes more meaningful and rational when employing the RME approach (Heriyadi & Prahmana, 2020). This is because RME consistently presents and integrates all mathematical problems within authentic contexts, ensuring that students' learning processes are closely linked to their everyday experiences (Hough S, Gough S, & Solomon Y, 2019; Purwitaningrum R, & Prahmana RCI, 2021).

Despite most research on RME originating from the Netherlands, there is evidence of its impact from other countries. Studies on international publications about RME indicate that it aims to enhance mathematical competencies [8] and critical thinking skills [9]. A study in Greece demonstrated that RME could contribute to the development of mathematical capabilities in children aged 4 and 6 [10]. Moreover, several studies on the application of RME in mathematics education in Vietnam have been discussed in the works and articles of notable authors such as *Understanding the theory of RME and applying it to create practical exercises in teaching mathematics* [11]; *Applying the theory of RME in teaching - Some challenges, principles, and recommendations* [12]; *Approaching and proposing some measures for applying RME theory in teaching and learning mathematics in Vietnam* [13]; *Some fundamental methodological issues relating to teaching the multiplication of two natural numbers to primary students* [14]; Subsequent studies have applied RME in various educational contexts, such as *Developing primary students' understanding of mathematics through mathematization: A case of teaching the multiplication of two natural numbers* [15]; *The development of Realistic Mathematics Education (RME) for Primary Schools' prospective teachers* [16]; *Reforming mathematics learning in Indonesia classrooms through RME* [17]; *Using RME to teach plane geometry in grade 7* [18]. Generally, these studies focus on clarifying the methods of applying RME in practical mathematics teaching while also providing suggestions for the potential application of this theory in teaching mathematics in Vietnam.

The aforementioned studies have discussed the application of RME theory in teaching mathematics at the primary, secondary, and high school levels; however, there has been limited research on the application of RME theory in teaching mathematics in the fourth-grade curriculum. This highlights a research gap that needs to be filled to better understand the effectiveness of RME at the primary school level.

2. Content

2.1. State of applying RME principles in primary school mathematics teaching in Vietnam

RME theory was established and developed based on three propositions put forward by Hans Freudenthal (mathematics as a human activity, guided reinvention, and didactical phenomenology) and five principles (use of contexts, use of models, students' construction and products, interaction, and integration of knowledge strands) [13]. Accordingly, students need to solve a problem associated with a context and interact with each other to explore knowledge using a model with different levels (finding solutions, ways to solve the initial problem, generalizing for other problems, discovering mathematical knowledge). Students' learning tasks are often not isolated within individual knowledge strands but typically integrate multiple knowledge strands; the products and constructions from earlier stages are used to continue exploration in subsequent stages. This integration is also reflected in encouraging students to use knowledge from different strands to solve problems.

There are also alternative approaches to the core principles in teaching RME theory. Van den Heuvel-Panhuizen M and Drijvers P [19] refer to six principles: the activity principle, the reality principle, the level principle, the intertwinement principle, the interaction principle, and the guidance principle.

Some studies in Vietnam rarely address the didactical phenomenology principle in teaching, often failing to reflect the principle of using models in RME theory [13], and frequently do not incorporate the level principle and the second aspect of the reality principle [19]. Document [13] explicitly presents the concept of didactical phenomenology and its application in teaching, but it does not provide specific examples of using these concepts in teaching mathematics in primary school. Didactical phenomenology in teaching can be understood as using the relationship between a mathematical object and the phenomenon from which it arises or is created in the context of teaching mathematics.

An OECD survey [20] highlights the inflexibility of the curriculum, which hinders creativity and the development of independent thinking skills. A World Bank study [21] underscores the persistent disparities in education quality across regions, affecting learning opportunities in different areas. Currently, in Vietnam, the approach to RME in teaching mathematics at the elementary level remains quite limited. Many teachers and schools have yet to widely adopt this method due to a lack of resources, support, and in-depth training. Materials and textbooks designed with the RME approach are still limited. Many teachers do not have access to a rich array of resources to implement lessons following this method. Although some teachers have received training in the RME approach, many still do not fully understand it and lack confidence in applying it.

Given these limitations, the application of RME theory in teaching elementary mathematics is essential to improve the quality of education. RME helps students develop problem-solving skills and apply mathematics to real-life situations, creating a more solid and profound foundation for learning mathematics. Therefore, concrete and robust steps are needed to adopt RME, including enhancing teacher training, providing comprehensive teaching materials, and creating a supportive educational environment.

2.2. Reasons for choosing RME theory in teaching primary mathematics in Vietnam

Teachers have the critical responsibility of fostering students' critical thinking and engaging them in active learning processes. Students' school experiences must be connected to their everyday life experiences outside of school. This shift marks a departure from the bookish approach that continues to dominate many educational systems, creating a gap between schooling, working, and living in modern society. Therefore, students need to be holistically developed in both knowledge and skills.

There are four essential higher-order skills: (a) critical thinking and problem-solving, (b) communication, (c) collaboration, and (d) creativity and innovation, also known as 21st-century skills (see http://www.p21.org/); all four are necessary as part of a comprehensive education. To prepare students for the future, schools should provide opportunities for them to engage in real-world problem-solving activities and develop thinking skills through practical learning experiences. Additionally, schools must nurture an environment that fosters creativity, independent thinking, and teamwork to ready students for the complex challenges they will face in their personal and professional lives.

RME is actually a theoretical framework proposed by mathematicians and mathematics education researchers and thus can be regarded as a theory of mathematics education. It is seen as a theoretical approach to understanding mathematical concepts through students' everyday experiences. The focus of RME is that students can rediscover mathematics but still under the guidance of adults (teachers). Accordingly, carrying out context-based problem-solving activities enables students to rediscover mathematics. Mathematics should not be seen as a finished product but as an activity or process. Thus, mathematics is delivered to students not as a final product but as a dynamic and exploratory activity in constructing mathematical concepts. RME includes views on mathematics, how students should learn mathematics, and how mathematics should be taught. Instead of being passive recipients of ready-made mathematics, students should be active participants, guided to use contexts to rediscover mathematics using different strategies they have. Implementing RME theory will make learning mathematics an engaging and meaningful experience for students by providing context-based problems.

2.3. Applying the principles of RME in teaching mathematics to Grade 4 students in Vietnam

RME relates to several core principles for teaching mathematics. Most of these core teaching principles were initially clearly presented by Treffers A (1978) but have been adjusted over the years, including by Treffers himself. Based on their research, Van den Heuvel-Panhuizen M, and Drijvers P (2014) identified six core principles of teaching according to RME theory:

2.3.1. Activity principle

The activity principle means that in RME, students are viewed as active participants in the learning process. This principle emphasizes that mathematics is best learned by doing mathematics, strongly reflected in Freudenthal's view of mathematics as a human activity, as well as Treffers' idea of horizontal and vertical mathematization. According to this principle, students learn mathematics through doing mathematics, giving them opportunities to perform both horizontal and vertical mathematization [22].

Exercise 1. When teaching the lesson "Commutative and Associative Properties of Addition" [23], the teacher organizes an experiential activity called “Smart Shopper” for the students. The teacher divides the class into groups of six. Each group is given plastic toys representing common food items along with their prices (e.g., vegetables: 16,000 VND, green onions: 4,000 VND, chicken: 220,000 VND, pork: 80,000 VND, etc.). In each round, the teacher announces, for example, “I have 100,000 VND,” and the students must quickly choose the food items that fit within that budget. The team that makes the correct choices the fastest and most accurately wins.

Horizontal Mathematization: In this example, students engage in horizontal mathematization by applying basic mathematical concepts (arithmetic) to solve real-life problems (selecting groceries within a budget). This process involves using mathematics to interpret and solve everyday situations, helping students see the connection between mathematics and real life.

Vertical Mathematization: Vertical mathematization is demonstrated as students develop and consolidate their understanding of fundamental mathematical properties, such as the commutative and associative properties of addition. This process involves not only applying these concepts but also deepening their understanding and ability to think mathematically, from theoretical learning to practical application.

Through this example, both horizontal and vertical mathematization processes are employed, aiding students in gaining a deeper understanding and flexible application of mathematical knowledge.

2.3.2. The reality principle

The reality principle can be acknowledged in RME in two ways. First, it highlights the importance of connecting the goals of mathematics education with the ability of students to apply mathematics to solve real-life problems. Second, it means that mathematics education should start with meaningful, problem-based situations for students, creating opportunities for them to find significance in mathematical structures while solving problems. Instead of beginning with abstract instruction or definitions to be applied later, in RME, teaching starts with context-based problems that have the potential to organize mathematics, allowing students to engage with informal contexts [22].

Exercise 2. When teaching the lesson "Parallel Lines" [23], the teacher organizes an observation activity of railroad tracks. Railroad tracks always run parallel and never intersect. Today, we will help engineers build new railroad tracks by learning about parallel lines and their properties. Parallel lines are two lines that never intersect. The teacher guides the students to draw two parallel lines in their notebooks. The teacher divides the class into groups to find pairs of parallel lines within the classroom (edges of the blackboard, edges of the window frame or the main door, etc.), in the schoolyard (lines on the basketball or volleyball court, lane markings on the sports field, etc.), and in everyday objects (shelves on the bookshelf, edges of a bookcase, etc.).

The importance linked to the objectives of mathematics education: This meaning is demonstrated through the teacher connecting the concept of parallel lines to a real-world situation with significance: the construction of railway tracks. This practical approach makes the mathematical concept more meaningful to students. By using a real-world context, students can see the application of mathematical knowledge in life and professions, specifically in the field of railway track engineering. In this way, students can appreciate the importance of understanding and applying the concept of parallel lines in practical situations.

Mathematics education starts with situations that are meaningful to students: This meaning is reflected in the teacher organizing activities where students observe and analyze pairs of parallel lines in their surroundings (in the classroom, playground, and everyday objects). By starting from specific and practical situations, students are encouraged to explore and identify parallel lines in familiar contexts, helping them gain a deeper understanding of the concept and its application. Learning from concrete and real-life examples allows students to build mathematical knowledge based on practical and relevant situations in their daily lives.

Thus, this example not only illustrates the reality principle in linking the goals of mathematics education with practical applications but also reflects the approach of starting mathematics education from meaningful real-life problems for students.

Exercise 3. When teaching the lesson "Obtuse Angles, Acute Angles, and Straight Angles" [23], the teacher organizes an activity for pairs to apply and experience. Each pair is given a real clock. The teacher instructs the students to set the clock according to the time shown on a slide (or as instructed by the teacher). After setting the clock, students will state the name of the angle by the hour hand and minute hand when the clock shows that time (or write it on paper and hold it up). The teacher instructs a pair of students to set the clock to 2 o'clock. After the students have set the clock, they will shout, "The real clock at 2 o'clock forms an acute angle", or write the answer "Acute angle" on paper and hold up their results.

The importance linked to the objectives of mathematics education: In this example, the use of the clock serves as a means to connect the concept of angles with a real-world object that students frequently encounter in daily life. The clock is a familiar tool that helps students identify and classify different types of angles (acute, obtuse, and right) in a tangible and practical manner. By doing so, students can understand the real-world application of the concept of angles in reading time on the clock and recognize the relevance of mathematics to real-life situations.

Mathematics education starts with situations that are meaningful to students: This activity begins with a specific situation, namely adjusting the clock and determining the type of angle formed. Engaging with the clock allows students to experience and explore different types of angles in a practical context. Rather than merely learning theoretical definitions of angles, students participate in a practical activity, which helps them visualize and comprehend the concepts more effectively. They not only learn about acute, obtuse, and right angles but also connect these concepts with different times on the clock, creating a meaningful and contextually relevant learning experience.

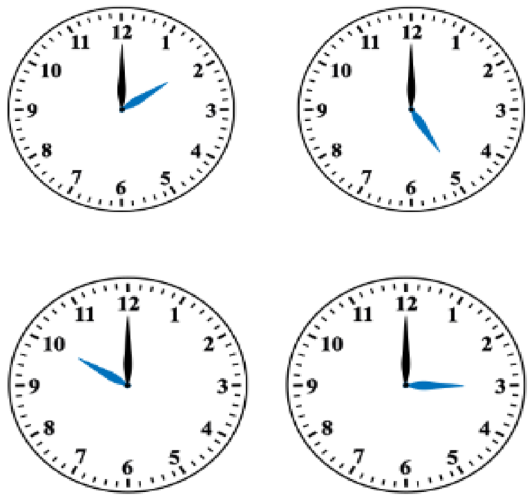


Figure 1. (Source: Internet)

In this way, the example integrates the teaching of mathematics with a practical tool and provides students with opportunities to work with real-world situations, enhancing their understanding and application of mathematical concepts.

2.3.3. The level principle

This principle emphasizes that, in learning mathematics, students progress through various levels of understanding: from solutions related to informal contexts to performing operations like symbols, diagrams, and mathematical representations to gain a deeper understanding of related concepts and strategies. Models are crucial in bridging the gap between "informal mathematics" related to context and "formal mathematics" [22].

Exercise 4. (Exercise 4, [23], p.28) There is a broken wooden wheel (see Figure 2). A woodworm is gnawing one of the two red spokes. Knowing that the spoke is being gnawed and a green spoke from an obtuse angle, identify the spoke being gnawed by the woodworm. The teacher guides students to solve the problem.

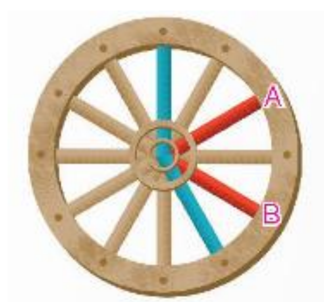


Figure 2. (Source: Grade 4 Mathematics Textbook)

- Understanding the problem:

+ What information is given? (The problem states that a woodworm is gnawing one of the two red spokes; the red spoke and the green spoke form an obtuse angle).

+ What does the problem ask for? (The problem asks to identify the spoke being gnawed by the woodworm).

- Building a system of guiding questions:

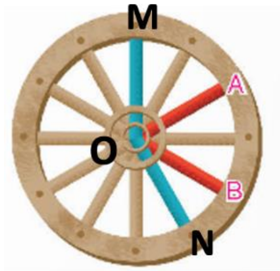


Figure 3.

+ Let the wheel vertex be O, the first green spoke be M, and the second green spoke be N (see Figure 3).

+ The woodworm gnaws a red spoke, knowing that the spoke forms an obtuse angle with a green spoke. How do we find out which red-spoke the woodworm is gnawing? (Consider the angles formed by red spoke A with each of its green spokes being M and N; the angles formed by red spoke B with each of its green spokes being M and N).

+ How do we determine what types these angles are? (Observe or use a protractor).

+ Examine the angles formed by red spoke A with each of its green spokes being M and N. What types of angles are they? (The angle at vertex O with sides OA, OM is acute and the angle at vertex O with sides OA, ON is right).

+ Examine the angles formed by red spoke B with each of its green spokes being M and N. What types of angles are they? (The angle at vertex O with sides OB, OM is obtuse and the angle at vertex O with sides OB, ON is acute).

+ Which red spoke is the woodworm gnawing? (Red spoke B).

2.3.4. The intertwinement principle

According to this principle, fields with mathematical content such as arithmetic, geometry, measurement, and data handling are not considered separate programs but are integrated with each other. Therefore, students need to mobilize their diverse mathematical understanding and knowledge. By applying this principle, the teaching of mathematics can be made more engaging and meaningful for students, aligning with the RME approach [22].

Exercise 5. When teaching the lesson "Numbers within the Million Range" [23], the teacher shows images of the national flags of several countries along with their population figures. The teacher asks the students to read the population of each country and write them as sums (according to danso.org in 2020): Japan: 126,476,461 people: one hundred twenty-six million, four hundred seventy-six thousand, four hundred sixty-one; Russia: 145,934,462 people; Germany: 83,783,942 people; France: 65,273,511 people; Vietnam: 97,338,579 people.

126,476,461 = 100,000,000 + 200,000,00 + 6,000,000 + 400,000 + 70,000 + 6,000 + 400 + 60 + 1.

This lesson demonstrates the RME principle of integrating various mathematical knowledge strands and themes. Firstly, students practice reading and writing large numbers, enhancing their numerical literacy by reading "126,476,461" as "one hundred twenty-six million, four hundred seventy-six thousand, four hundred sixty-one." Secondly, students break down large numbers into sums to reinforce their understanding of number structure, such as decomposing 126,476,461 into 100,000,000 + 20,000,000 + 6,000,000 + 400,000 + 70,000 + 6,000 + 400 + 60 + 1.

Furthermore, by relating population data to mathematical concepts, students see the practical applications of their learning, making it more relevant and engaging. This contextual approach illustrates how mathematics connects to real-life scenarios like demographics and geography. The lesson also seamlessly integrates geography and social studies with mathematics, as understanding population sizes helps students link their mathematical knowledge with geographical facts and socio-economic discussions.

In conclusion, this lesson exemplifies the RME principle by integrating various mathematical knowledge strands and topics. By using real-world data, it connects mathematical concepts to students' everyday experiences, thereby enhancing their understanding and interest in the subject.

2.3.5. Interaction principle

Mathematics learning is not only an individual activity but also a social activity. Therefore, RME encourages whole-class discussions or group work, providing opportunities for students to share their strategies and products with others.

Exercise 6. When teaching the lesson "Acute, Obtuse, and Straight Angles" [23], students can discuss in pairs using a situation where each group is given a paper fan. The teacher asks each student to open the fan to different angles for his/ her partner to see (acute, obtuse, straight, right angles). While observing their partners, students mark a check next to the angle their partners have opened. (Alternatively, the teacher can replace opening the paper fan with opening a notebook).

Figure 4. Student Observation Table (Source: Internet)

2.3.6. Guidance principle

In RME, this principle refers to Freudenthal's idea of "guided reinvention" in mathematics. Specifically, the teacher provides active guidance in students' learning processes, and the educational program must include situations that can act as levers for changes in students' understanding.

Exercise 7. When teaching the lesson "Find Two Numbers Given Their Sum and Difference" [23], the introductory problem is: Mai has 25 candies. Mai divides the candies into two parts: Mai gets one part, and My gets a part that is 5 candies more than Mai's part. How many candies does each have?

- The teacher guides students to draw a diagram to analyze the problem:

+ To find a solution, we will represent the problem through a diagram. Mai has one part of the candies, and My has a part that is 5 candies. Thus, Mai's number of candies is less than My's, and we will represent Mai's candies with a shorter line than My's. Mai has 25 candies and divides them between herself and My, so the total number of candies is 25. We represent the total with a bracket encompassing both lines.

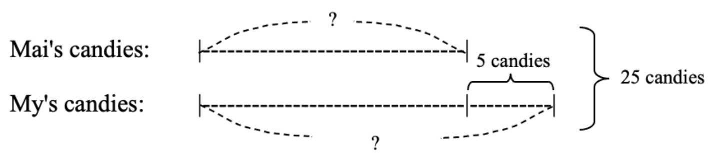
+ The line representing My's candies is longer than Mai's by a segment. The difference between the two lines is the extra candies My has compared to Mai. Since My has 5 more candies than Mai, we mark 5 in the difference between the two lines.

+ My's candies minus Mai's candies equals 5 candies, making 5 the difference between their amounts, and 25 the total. The numbers of candies are the two numbers we need to find, represented by question marks.

+ Thus, we have completed the diagram for the problem with the two numbers to find, knowing the given sum and difference of those numbers. (The teacher explains while pointing to the illustrative diagram)

- The teacher guides students on how to solve the problem based on the diagram:

+ Observing the diagram, we see that My has 5 more candies than Mai (5 is the difference). If we remove the difference segment (the difference between the two numbers), we get two equal segments, each equal to Mai's number of candies. We have the total number of candies as 25. If we subtract the difference segment corresponding to 5 candies from My's candies, we get two equal segments equal to twice Mai's candies. From there, we can calculate the number of candies Mai has. Steps to calculate:



+ Twice the number of Mai's candies is: $25 - 5 = 20$ (candies).

+ Mai's number of candies is: $20 : 2 = 10$ (candies).

+ Teacher: To simplify the two calculations, how can we combine them?

(Calculation: $(25 - 5) : 2 = 10$).

+ Teacher: After finding Mai's number of candies, how can we calculate My's number of candies? (Subtract Mai's number of candies from the total or add 5 to Mai's number of candies).

+ My's number of candies is: $10 + 5 = 15$ (candies).

Or: My's number of candies is: $25 - 10 = 15$ (candies).

+ The teacher summarizes the complete solution or invites a student to perform it.

- The teacher shows the students the complete solution and asks them questions:

+ Is Mai's number of candies the larger or smaller number? (Smaller number).

+ What does 25 represent? (The total of the two numbers).

+ What does 5 represent? (The difference between the two numbers).

+ Based on the complete solution and the roles of the numbers, deduce the method to find the smaller number when given the sum and the difference.

Students deduce the method to find the smaller number to determine the smaller number given the sum and the difference between two numbers:

$$Smaller\ number = (Sum - Difference) : 2$$

3. Conclusions

The theory of RME has been formed, developed, and implemented for about 70 years, achieving many accomplishments and still sparking debates. This theory has contributed to the development of mathematics curricula in many countries, serving as the fundamental theoretical basis for many textbooks and learning materials.

The RME theory can and needs to be further researched and implemented to advance the development of problem sets for elementary school students in Vietnam. Implementing a mathematics education program according to RME will aim to achieve the objectives of Vietnam's general mathematics education presented in the 2018 Mathematics General Education Program. Furthermore, although the 2018 Mathematics General Education Program has been announced, the implementation of the subject program (mathematics) into textbooks, school programs, and classroom programs is still a long journey, requiring a multidisciplinary approach and consideration of the current national context, including international integration.

This study provides fundamental introductory information about RME to assist educators in considering the integration of RME principles when designing school or classroom curricula. Applying RME in primary mathematics instruction can offer numerous benefits, as its principles promote contextual learning and guided reinvention, thereby enhancing students' understanding and critical thinking skills. However, developing a comprehensive educational program based on RME requires collaboration among numerous scholars and further in-depth research.

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