Practices of Mathematization by Basic Level Mathematics Teachers of Nepal

Nara Hari Acharya[1]
Tika Ram Pokhrel[2*]
Rajendra Kunwar[3]

[1]**Faculty Member**
Sanothimi Campus, Bhaktapur, Nepal
[2]**Teaching Assistant**
Institute for Innovative Learning
[3]**Associate Professor**
Research Center for Educational Innovation and Development, Kathmandu, Nepal
[1, 3,] **Tribhuvan University, Nepal**
[2,] **Mahidol University, Thailand**

Email:
nara.acharya@sac.tu.edu.np
rajendrailam@gmail.com
*Corresponding author
tikarampokhrel@gmail.com

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Abstract

The study on the process of mathematization practices applied to teaching mathematics by basic level teachers aimed to explore how the basic level mathematics teachers have been using and practicing mathematization in problem-solving. Twenty-five mathematics teachers of the basic level who had taken teachers' professional development training were the participants of the study. Five story-based problems at the basic level were distributed, and their solutions were collected after half an hour. The data were sorted and different solutions to the same problem were considered. It was observed that most of the teachers have been using mathematization in solving problems though they were unknown about it. Some of them were not aware of the visualization of the problems and solving the problem by using the formula directly. The study shows that while teachers are using both vertical and horizontal mathematization, many teachers lack a clear understanding of when and how to apply these methods appropriately. Providing professional development opportunities to mathematics teachers and incorporating mathematization concepts and skills into the curriculum can enhance mathematical thinking skills.

Keywords: Mathematization, problem solving, real-world, realistic mathematics education

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Background

Real-world problems or problem-situations are considered the key to the mathematical process. Mathematization is a process of transferring real-world problems into mathematical models and concepts (Almuna Salgado, 2017). This indicates that mathematization is essential for bridging the gap between the real-life situation and mathematical systems.

The teaching-learning of mathematics in Nepal is not enough to link real-life situations (Pokhrel et al., 2024). In order to minimize the gap between real-world scenarios and mathematics in the school mathematics curriculum, the government agency of Nepal has been implementing the competency-based curriculum (Curriculum Development Center [CDC], 2018) in the basic level education. The curriculum not only includes mathematical contents but is also expected to facilitate students to acquire soft skills along with 21st-century skills. The basic level curriculum has been divided into three steps; namely integrated curriculum for grades 1 to 3, the basic level curriculum for grades 4 and 5, and the basic level curriculum for grades 6-8 (CDC, 2018). The basic level curriculum is based on the contexts as well as the problems from real life, which are included in the textbook writing as well as the evaluation of the students. The contextual problems as well as the realistic problems of mathematics are included and have to be solved by the students. The students have to solve the problems by transforming the given problem into mathematical form. The teachers should know the mathematical relations of routine and non-routine problems. To this date, the majority of mathematics teachers have been adopting the method of teaching mathematics with emphasis on memorization and presenting the subject abstractly or symbolically (Zakaria & Syamaun, 2017). A mathematics teacher should be able to translate abstract mathematical concepts into tangible, understandable things [and vice-versa] for pupils so that they feel as though the lessons they have learned have application to their everyday lives (Valero et al., 2002).

Mathematization is an approach to the realistic mathematics education movement. Thus, a short introduction to the realistic mathematics education program is discussed herewith before dealing with mathematization.

Realistic Mathematics Education

The history of realistic mathematics education (RME) is relatively short. It was first introduced in the Netherlands by the mathematician Hans Freudenthal in the late 1960s focusing his criticism on rote memorization and the use of formulas in solving mathematical problems without understanding (Van den Heuvel-Panhuizen & Drijvers, 2020). His criticism was on the intuitionist philosophy of mathematics. It was advocated that the context or real-life situations should be implemented from the initial phase of learning mathematics. It is now an approach to teaching mathematics in which students develop deep knowledge and long-term understanding of the subject matter by starting from context and relating it to mathematics (Laurens et al., 2017). Nowadays, RME is being adopted and reflected on a deeper understanding and reflection of mathematical concepts. Mathematics learning should reinvent mathematical ideas in a meaningful way by processing the contextual situation of mathematics (Ariati & Juandi, 2022). According to Wittmann (2005), mathematics is an educational task integrated into our culture and context. Mathematical knowledge includes structural relationships along with the real-world situation.

RME is based on the constructivist learning theory with the teaching-learning principles of activity, reality, levels, interrelationship, interaction and guidance. Furthermore, concentration and creation, levels and models, deep thinking and special assignment, contextual interaction and collaborative processing are the key principles of RME (Julie et al., 2014). Thus, RME believes that there should be a meaningful context for learning mathematics. Mathematics as a human activity and its formalization is to follow progressively from context-based informal activities to more abstract activities. Models and representations are useful tools for bridging the gap between informal strategies to formal mathematical concepts. Accordingly, mathematics should be made relevant, understandable, and discoverable by students through engaging with the world around them.

Mathematization

As already discussed, mathematization is a process of converting an informal mathematical context which is seen in real-world scenarios to the formal mathematical systems. RME highlights two types of mathematization, namely, horizontal and vertical mathematizations. Horizontal mathematization is the process of converting the real-life context to mathematical texts. Converting common language issues into mathematical language would serve as an example. In horizontal mathematization, the learners connect prior knowledge and intuition to solve real-world situations. In vertical mathematization, the level of mathematical usage is enhanced. An example would be a mathematical process that transforms symbols into a more abstract representation. In this stage, problems in exercises are necessary for learners to properly investigate and comprehend mathematical subjects, making horizontal mathematization inadequate on its own (Menon, 2013).

Daily human activities are inextricably linked to the usage and application of mathematical concepts, as demonstrated by the ability to reason by drawing connections between formal mathematics and real-world issues (Nuraida et al., 2019). When students go through the mathematization process, they establish the bridge between formal and informal knowledge by addressing contextual problems and generating schema in their minds (Inci et al., 2023). The informal knowledge stored in students' mindsets gradually transformed into formal knowledge by a cognitive process (Eraut, 2000). Mathematization as an RME learning approach enables an interactive process of instruction and learning, allowing students to give their full attention to all classroom activities while providing genuine situations in developing their skills (Iskandar & Juandi, 2022; Zakaria & Syamaun, 2017). Furthermore, the RME approach's occurrence of the didactic principle indicates that learning activities begin with contextual difficulties and eventually lead to mathematical notions (Arnellis et al., 2023). It can be concluded that RME plays a vital role in the development of deep understanding in students by contextualizing the problem, mathematizing the problem, and solving them.

The existing curriculum of mathematics at the basic level incorporates different projects and practical tasks for evaluation. The prescribed methods of teaching are also student-centered. The teaching and learning of mathematics need to be shifted from the chalk-talk method to the student-centered inclined to developing deep understanding and different cognitive skills. The teachers have to link the mathematical content with the context. In the Nepalese context, it is rarely heard about the realistic mathematics education approach. The main objective of this study is to explore basic-level mathematics teachers' knowledge and skills in the mathematization process as mentioned in RME.

Methods

This study used a qualitative explorative research design with basic-level mathematics teachers the participants. A group of 25 teachers who participated in a 10-day basic-level mathematics teacher training program organized by the Government of Nepal from September 23 to October 02, 2024, were the research participants. They were asked to solve the problems of basic-level mathematics based on their understanding of realistic mathematics education. One of the following five questions was provided randomly for each participant who was asked to solve the question.

Q1. Goma gave 18 rubber bands to her friend Gita out of 20 bands. If her mother added 16 rubber bands to her, how many bands does she have now?

Q2. 340 trees are planted in the outer boundary of a square ground. Find the number of trees on one of the sides.

Q3. The perimeter of a square ground is 8 m. Then find the length and area of that ground.

Q4. There are two groups of parrots in a tree. The first group said if you send a bird, we will be twice, and the second group said if one of you comes, we will be equal. How many parrots are there in each group?

Q5. 125 mangos, 150 apples, and 225 pears are distributed among the students equally. How many fruits of each type does each student get?

After around half an hour, the answers from each of them were collected and then analyzed on the basis of the methods and strategies for solving these problems.

Analysis and Interpretation

The analysis was made by generating themes: real-life problem solving, representation strategy to solve problems, spatial reasoning, riddle-type problems, and practical-based concept development. Samples of answers provided by the teachers are presented to each question as evidence for data analysis and interpretation. These sample answers served as the main idea about how teachers deal with the classroom.

Real-Life Problem-Solving

Real-life problem-solving involves translating the problem into a mathematical structure. The learners are engaged with the contextual problem and reflect their knowledge and understanding related to the topic in the mathematical structure (Freudenthal, 2005). The real-life problems not only bridge the learners with their prior knowledge of the variables and operations of problems but also develop mathematical understanding. These types of problems orient learners to horizontal mathematization. The mathematization process in solving real-life problems can be analyzed from the work shown in Figure 1.

Q1. *Goma gave 18 rubber bands to her friend Gita out of 20 bands. If her mother added 16 rubber bands to her how many bands does she have now?*

Solution I *Solution II* *Solution III*

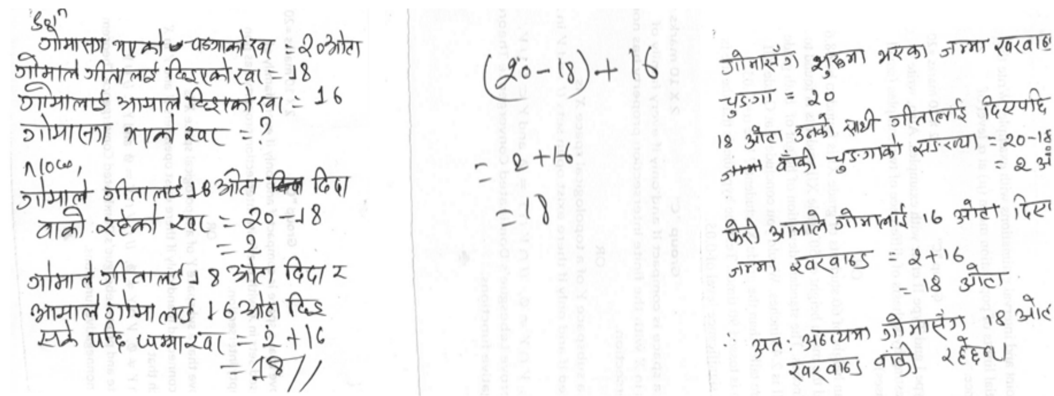

Figure 1 Solutions of Q1

Regarding the solution to question no. 1 which belongs to the basic operation, the first and the third solutions show that the problems are solved in a basic inductive way by using the basic mathematical concepts step by step and that the second one shows that the problems are directly written in mathematical statement and solved by the rules of simplification. The first and the third solutions use the context of solving mathematical problems by using horizontal mathematization in which the story was first listed as the given and has to be found and then solved inductively. The second teacher vertically mathematized the context into mathematical statements and solved the problem.

Representational Strategy in Solving Problems

Learners express their thinking in different ways, such as through visuals, symbols, or other forms of models during mathematical problem-solving in RME. In both horizontal and vertical mathematization, these strategies play central roles. RME encourages learners to create different forms of representations like drawings, number lines, sketches, bar models. These support the progressive formalization through student-centered guided strategies (Fauzan et al., 2023). The mathematization process in solving problems with representational strategies can be analyzed from the work shown in Figure 2.

Q2. *340 trees are planted in the outer boundary of square ground. Find the number of trees in its length.*

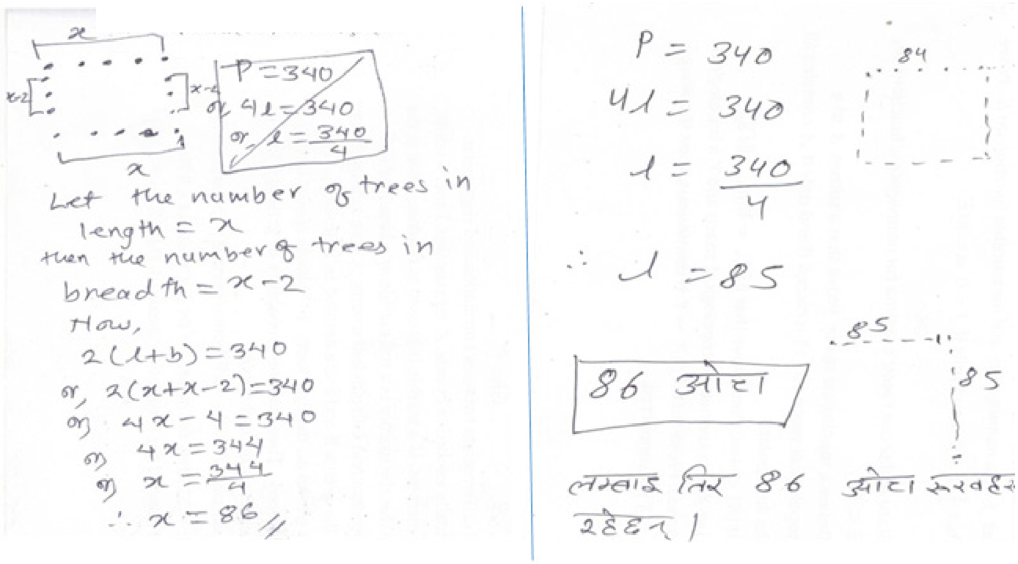

Figure 2 Solution of Q2

Q_2 is an application type of mensuration. The first solution is inductive, started with the rectangle and calculated through algebraic expressions. The second solution directly applies the formula of squares and calculates the required number. The mathematization of the context of the problem is properly implemented by the teachers in these solutions. These two solutions show that the first one has the idea of horizontal mathematization while the second has vertical mathematization and are alternative conceptions of mathematical problem solving (Barnes, 2004). Since the RME is a teaching theory, and constructivism focuses on the process of knowledge creation, so RME is compatible with the constructivist theory (Inci et al., 2023), the teachers construct different ideas and knowledge and solve the given contextual problem differently.

Spatial Reasoning

The abilities of visualizing, manipulating, and reasoning about the geometric shapes and their transformation helps developing spatial reasoning. Spatial reasoning includes reasoning, pattern identification, and mathematical thinking. The sketching and designing layouts on the problems with configuration help in developing the conceptual understanding of mathematics with mathematical reasoning and successful learning (Nugraha et al., 2024). The mathematization process in solving problems with spatial reasoning can be analyzed from the works of teachers as shown in Figure 3.

Q3. *The perimeter of a square ground is 8 m. Then find the length and area of that ground.*

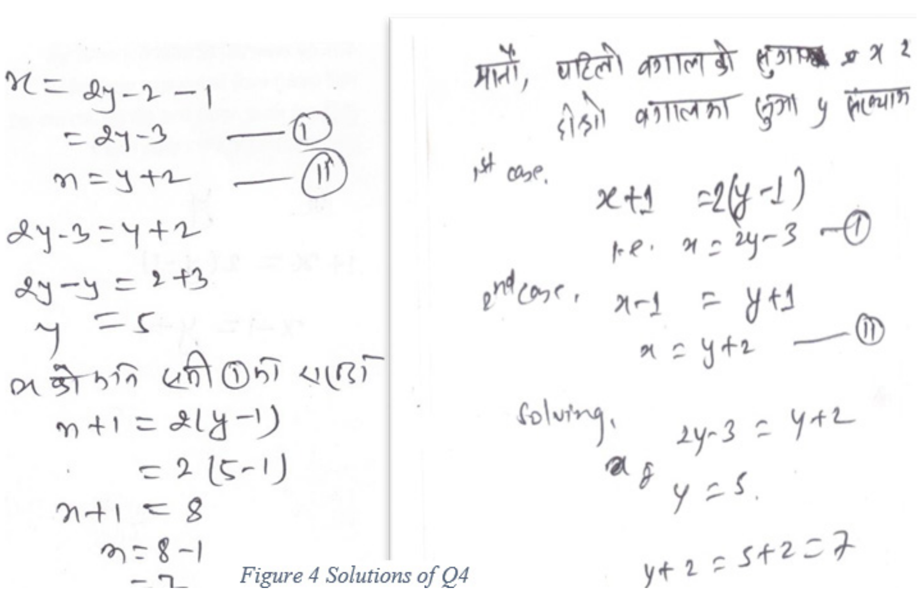

Figure 4 Solutions of Q4

This question belongs to the mensuration area of basic-level mathematics. This includes the area and perimeter in a connected form. The teachers solved them in different ways. In the first and second solutions, the teachers visualized the problem with the figure and then used the formula for finding the length of the side of the square and then the area of the square for the solution. In the third solution, the teacher not only visualized the mathematical concept but also solved the problem. In the way Inci et al. (2023) suggest, during the process of solving the mathematical story problem, the teacher employed the horizontal form of mathematization, in which the relationship between the problem and its context is explored and then translated into mathematical form.

Riddle-Based Problem Solving

The riddle types of problem-solving help the learners with vertical mathematization in which learners formalize and gear up different strategies into more abstract mathematical forms through active engagement. The mathematization process in solving riddle-based problems can be analyzed the work shown in Figure 4.

Q4. *There are two groups of parrots in a tree. The first group said if you send a bird we will be twice, and the second group said if one of you came we will be equal. How many parrots are there in each group?*

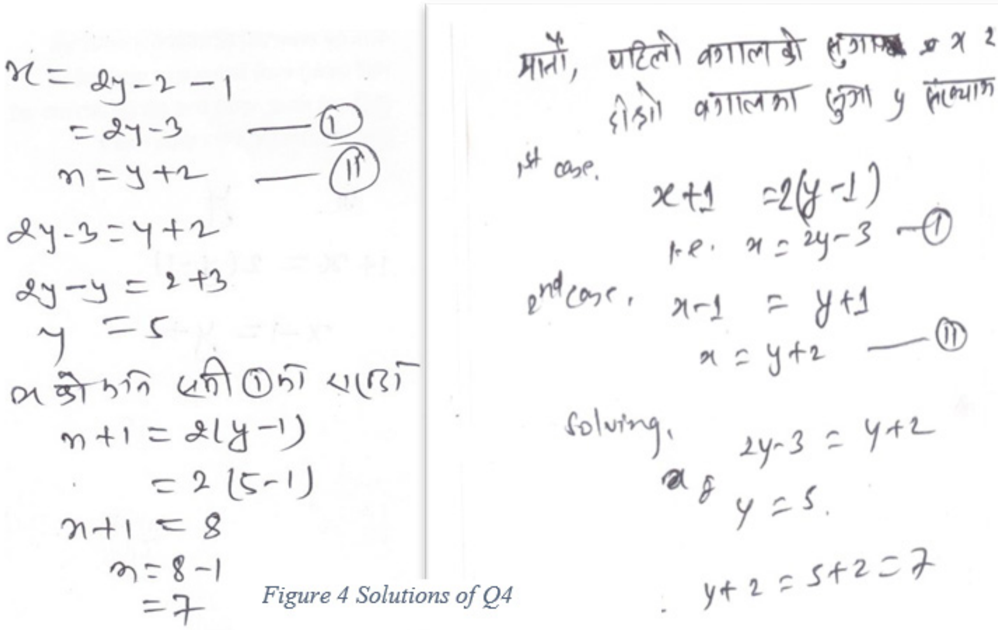

Figure 4 Solutions of Q4

Q4 is the translated version of a problem from a mathematics textbook written in Sanskrit in the earlier history of mathematics in Nepal. While solving it, teachers focused on turning the given information into equations, as it involves solving simultaneous equations in a practical context. In both the solutions the teachers have translated the given context in the mathematical equation by using the variables x and y. After that both the teachers solve by the substitution method of solving the simultaneous equation. Hence, the teacher first uses horizontal mathematization and then further vertical mathematization to solve the given contextual problem of mathematics.

Practical-Based Concept Development

The conceptual development in mathematics through practical and hands-on activities allows students to develop their understanding with activities. Practical-based concept development enables learners to interact with hands-on materials with both types of mathematization. As the learner constructs the knowledge in the constructivist approach, the practical-based concept development also interacts with the physical world and helps to internalize abstract ideas with mathematical relevancy (Van Den Heuvel-Panhuizen, 2005). The mathematization process in solving real-life problems that requires practical-based concept development can be analyzed from the work shown in Figure 5.

Q5. *125 mangos, 150 apples, and 225 pears are distributed among the students equally. How many fruits of each type do each student get?*

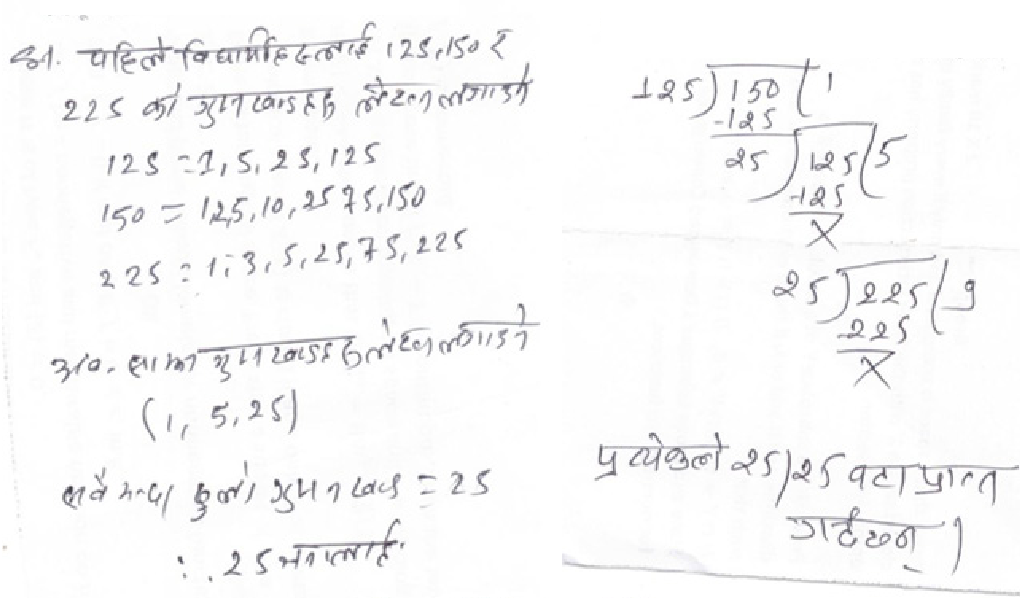

Figure 5 Solutions of Q5

Q5 is related to the problem of arithmetic and, particularly finding the highest common factor of three numbers. Two different solutions to the problem are applied by the teachers.

Although all processes and the methods of solving are distinct, the result is the same in both cases. According to Van den Heuvel-Panhuizen and Drijvers (2020) realistic mathematics education is a technique of mathematical problem solving by mathematization of the context and then solving the problem by using mathematical ideas and knowledge that the problem solver has previously acquired. Acharya (2018) explained that the textbooks have been using such problems. The contextual problems in textbooks not only link learning with society and culture but also the learners can apply the mathematical concepts they have learned to the routine and non-routine problems. The contextual problems connect different subject matters with mathematics and mathematize the different disciplines (Pratiwi & Widjajanti, 2020). The school level textbooks of both basic and secondary levels have included the different areas and topics. Nowadays the Curriculum Development Center has implemented the context-based multiple items model to test for summative evaluation for basic and secondary levels (CDC, 2019).

Conclusion

Teaching and learning mathematics primarily focused on repetitive procedures and formula memorization before the introduction of mathematization. Mathematics instruction often neglected the importance of real-world relevance and deep conceptual understanding. Against this backdrop came mathematization as a paradigm. The concept of mathematization has transformed mathematics education by promoting the interpretation and modeling of everyday situations through mathematical thinking, fostering analytical reasoning, relational understanding, and meaningful engagement with problems in context. The story problems are those which are integrated and implemented in mathematics to consolidate learning. To develop the skill of mathematization in students, the teachers should be well-informed about it. In the context of Nepal, mathematics teachers have been more or less familiar with the process of mathematization. They are less aware of the visualization and mathematization of the problems before solving them. Some of them use vertical mathematization and some of them use the horizontal kind without any logical and authentic reason. Also, it is better to provide refresher trainings on RME, thus familiarizing the with the different techniques for solving routine or daily life problems for mathematics teachers. From the policy level, it is better to integrate the different concepts as well as the methods in the curriculum as well as the curricular materials.

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