**International Journal of Educational Management and Development Studies**
**Volume 4 Issue 2 June 2023**
**DOI: https://doi.org/10.53378/352980**

# Effectiveness of Realistic Mathematics Education Approach on Problem-Solving Skills of Students

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## Abstract

Mathematics is concerned with the method used in the teaching and learning process in addition to issues encountered in the cognitive domain. The Philippines' education system is still dominated by traditional mathematics teaching, which frequently overlooks the goal of mathematics education—to prepare students to deal successfully with real-life situations. This affects the declining performance of the students in their overall mathematical ability, especially in problem-solving. Hence, this study utilized a pre-experimental design to measure the effectiveness of the Realistic Mathematics Education (RME) approach in the problem-solving skills of the students in terms of understanding the problem, devising a plan, carrying out the plan, and looking back. Furthermore, the cluster sampling technique was used in choosing thirty-five grade 9 students and evaluated their problem-solving ability using a pre-test and post-test assessments. Based on the result, there is a highly significant difference in the mean pre-test and post-test performance of the respondent before and after using the RME approach in all the four phases of problem-solving (p-value=0.000). This implies that the RME is an effective teaching approach that successfully improved the mathematical proficiency of the students, especially in all aspects of problem-solving skills. The findings verify that educators can use the RME approach to expose their students to more collaborative teaching-learning processes that incorporate real-world scenarios. Future researchers may also conduct a similar study in face-to-face learning to comprehensively use the RME approach.

**Keywords:** *Didactical Phenomenology, Emergent Model, Guided Reinvention, Problem-solving Skills, Realistic Mathematics Education Approach*

**Article History:**

***Received***: *January 31, 2023* ***Revised***: *March 31, 2023*
***Accepted***: *April 1, 2023* ***Published online***: *April 7, 2023*

**Suggested Citation**:
Dinglasan, J.L., Caraan, D.C. & Ching, D.A. (2023). Effectiveness of Realistic Mathematics Education Approach on Problem-Solving Skills of Students. *International Journal of Educational Management and Development Studies*, 4 (2), 64-87. https://doi.org/10.53378/352980

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**This paper is a finalist in the International Research Competition Category 2 Undergraduate.*

## 1. Introduction

Mathematics is expected to provide high-quality education that emphasizes problem-solving and makes the learners globally competitive. As stated in the third edition of the World Economic Forum (2020), problem-solving is one of the top abilities most in-demand in the next five years. Furthermore, the Department of Education (DepEd) developed a curriculum that emphasizes the twin goals of mathematics, problem-solving skills and critical thinking. This curriculum satisfies the need to get Filipino pupils ready for the demands of the twenty-first century.

Despite the innovations made by the international and local education system, students still considered mathematics the most challenging subject (Escarez & Ching, 2022) specifically problem-solving (Nurjamaludin et al., 2021). This problem is evident in the Program for International Student Assessment (PISA) 2018, where the Philippines came in last place out of 79 countries in mathematics (OECD, 2019). The Philippines did not reach the average score of 489 and got only 353. In relation with this, according to the study of Roman (2019) from the result of national assessments and research from the Philippines over the past 15 years, students show poor Mathematical performance that is noticeable from basic education to higher education levels. It is supported by the study of Imam (2016) that the country's mathematics performance is still considered poor, and affirm that the initial result of current efforts of the government by adopting K-12 curriculum did not do much to change the status quo. Additionally, from the findings of Pentang (2021), Filipino learners with an unsatisfactory performance in numbers, measurement, and statistics while alarmingly poor in geometry and algebra. Based on the National Achievement Test (NAT) 2018, students got a low mean percentage score of 35.34% in the Mathematical Ability subtest (Penaso & Gaylo, 2019). In this assessment, problem-solving skills are acknowledged as the core of mathematics education (OECD, 2013).

Meanwhile, Laurens et al. (2018) highlighted that using ineffective teaching tactics and learning approaches has an impact on students' capacity to learn mathematics. Moreover, in 1970 a new approach in mathematics teaching was introduced in the Netherlands by Freudenthal Institute popularly known as the Realistic Mathematics Education (RME) approach. Plenty of the past international studies showed that the RME approach is an effective strategy in enhancing the cognitive and mathematics achievement level of the students (Laurens et al. 2018; Zakaria & Syamaun, 2017). However, in comparison to the traditional lecture with problem-solving skills activities, this teaching style is not widely used in the Philippines. In reviewing related literature and studies, the study was unable to locate any study conducted in the Philippines to consider the RME approach as a teaching strategy for improving students' mathematical skills, to the best of the researchers' knowledge. To fill up the gaps left by previous studies, this study adapted the RME approach to the Philippine educational system and test its effectiveness on problem-solving skills of the students.

With the characteristics of the RME approach, learners can easily relate to the problem and be able to imagine the situations present in it. In solving a problem, they reflect and rely upon their previous knowledge and experiences to understand more. And for systematic problem-solving, this study incorporated the four phases of problem-solving by George Polya. This study was conducted to determine the pre-test performance of the student on problem-solving skills before the use of the RME approach in terms of understanding the problem, devising a plan, carrying out the plan, and looking back. It also determined the post-test performance of the students on problem-solving skills after the use of RME approach and find out significant difference between the pre-test and post-test performances before and after using the RME approach.

## 2. Literature review

### *2.1. Realistic Mathematics Education Approach*

The RME approach is a development of research strategy and pedagogical theory on mathematics based on the idea of Hans Freudenthal (Dickinson & Hough, 2012). It is a teaching method that uses students' everyday experiences as a starting point for their learning (Kosim & Tirta, 2020). It establishes adequate mathematical comprehension, including the actual use of mathematics. Additionally, RME approach includes three core heuristic principles such as didactical phenomenology, self-developed or emergent models, and guided reinvention (Bray & Tangney, 2016).

*Guided Reinvention.* Guided reinvention is a procedure in which the students' learning experiences should be aligned to the process in which mathematics was developed by the mathematician (Anwar et al., 2012). It plays distinct roles in the instructional design of this study, where students let to reinvent mathematical concepts that they relate to in the mathematical statements. The use of guided reinvention promotes the students' work and responses as the main topic of the discussion, and teachers act as facilitators.

*Didactical Phenomenology.* It is a process that takes place in instructional design, where students should expose to the teaching-learning process that is experientially real to them. Students are more engaged in discussions when they have activities that are personally relevant to them (Stephan et al., 2014). Thus, this process depends on every classroom, the situation of the students, and their level of thinking and experience, where contextualization and indigenization in mathematics education take place (Dickinson & Hough, 2012).

*Emergent Model.* According to Stephan et al. (2014), educators should support student modelling by introducing new or existing tools, as well as a student-created tool to use for understanding and explaining mathematical reasoning. Additionally, emergent modelling plays a fundamental role in shifting the students' knowledge and reasoning from the informal level into a more formal mathematical concept (Anwar et al., 2012). Furthermore, incorporating various modelling into mathematics learning improves learners' analytical and problem-solving skills significantly (Erbas et al., 2014).

### *2.2. Problem-solving Skills*

A lot of experts believe that the heart of education is to teach students how to think and become problem-solver (Khoiriyah & Husamah, 2018). One of the goals in the development of 21st-century education is acquiring problem-solving skills to be able to prepare the students in facing the demands of life. However, challenges in problem-solving take place and are always evident. Students frequently struggle with problem-solving because they lack a thorough knowledge of the problem-solving process and its application in real-life contexts (Yu et al., 2015). Thus, students should be taught using real-world scenarios to develop their problem-solving skills that cater them with opportunities to become real problem-solvers (Saygılı, 2017). Moreover, the four principles of problem solving includes understand the problem, devise a plan, carry out the plan, and look back, introduced by George Polya (1949).

*Understand the Problem.* According to Krawec et al. (2013), understanding is one of the variables that contribute to math problem-solving being one of the most difficult areas of the curriculum. Is a complicated talent that not only calculates the answer, but also interprets and integrates the problem information, forms and retains an image of the problem, and develops a feasible solution, which requires sophisticated thinking and strategic methods. Moreover, the burdensome part of solving a word problem is understanding the problem, especially the words it contains. Thus, a learner's capability to understand and comprehend different terms and expressions in mathematics leads to developing their ability to solve word problems (Vula & Kurshunmlia, 2015).

*Devise a plan.* According to Ersoy and Güner (2014), one of the most important factors in solving a problem is deciding on the right strategy. The use of a heuristic method, without a doubt, improves pupils' capacity to think while solving arithmetic problems. Furthermore, by drawing diagrams, investigating exceptional situations, specializing answers, and generalizing solutions, a heuristic method promotes the transfer of mathematical reasoning (Hoon et al., 2013). Hence, it fosters critical thinking and creativity, as well as the capacity to establish and implement projects and strategies (Szabo et al., 2020).

*Carry out the plan.* In the study of Hoon et al. (2013), in the process of finding the solutions of the learners, they pondered further. These methods of thought resulted in the development of creativity by acting it out or going backward to examine the solutions. Additionally, it develops managerial skills and the ability to achieve goals collectively, as well as productivity and the ability to complete tasks in a reasonable amount of time. It teaches pupils how to make the most of previous experiences (Szabo et al. 2020).

*Look Back.* Looking back, according to Liljedahl et al. (2016), "in memory to previously acquired knowledge [...] and further develops knowledge in long-term memory that may be extended in later problem-solving encounters." In summary, reflecting on the past is a good investment in future experiences with problem-solving situations, since it establishes the connections required later. Additionally, according to Szabo et al. (2020), this final step demonstrates to the learner the advantages of working together to capture the problem, discuss the solution, evaluate it, and find the best solution.

### *2.3. Theoretical Framework*

This research was based on John Dewey's Constructivism Theory (1986). Constructivism theory states that learners can build and develop new information through real-world experiences and ideas. They draw on previous knowledge and apply it to new information. Dewey claimed that students that learn using real-world activities and interventions display a high level of knowledge and skills in critical thinking and collaboration (Brau, 2020).

The RME approach is a constructivist-based teaching style that encourages students to investigate and collaborate on their learning in relation to real-world concerns (Freudenthal, 1991). Based on Hans Freudenthal's concept, the RME approach is a development of research methodology and mathematical pedagogy (Dickinson & Hough, 2012). In 1970, the Freudenthal Institute in the Netherlands developed this strategy. Guided reinvention, didactical phenomenology, and emergent model are three core heuristic principles of RME in teaching process design, according to Gravemeijer (1994) and Freudenthal (1991).

Meanwhile, problem-solving is guided by the view of George Polya for easier understanding and a more systematic process in solving a problem (Liljedahl et al., 2016). Understand the problem, devise a plan, carry out the plan, and look back are the four phases of problem-solving. Moreover, Dewey believed that the ideas and processes produced by the learners are easily gained from the experiences that have importance to them. The reason why the study saw the potential to the adapted RME approach in increasing problem-solving skills of the learners.

## 3. Methodology

### *3.1. Research design*

The study utilized a pre-experimental research design as research method. Specifically, one-group pre-test and post-test design. The RME approach is used as the treatment in this study, and the group observed was the students' problem-solving skills, such as understanding, strategizing, applying, and reflecting.

### *3.2. Respondents of the Study*

Junior high school students enrolled in one of the schools in the Province of Batangas in the Philippines during the academic year 2021-2022 comprised the study's population. The sampling technique utilized in this research is clustered sampling— from the two clusters or section of the Grade 9 in the school, random sampling was used to select the study’s respondents with 35 Grade 9 students.

### *3.3. Instrumentation*

*Lesson Exemplars.* The researchers developed lesson exemplars that were parallel with the K-12 most essential learning competencies (MELC) guidelines for Mathematics grade 9 for the current academic year. It was focused on various topics of trigonometry.

*Pre-test and Post-test Assessments*. An eight-item test that require the four-step problem-solving method, used to evaluate the students' problem-solving abilities. Moreover, it was assessed by a modified rubric adapted from Putra et al. (2020).

### *3.4. Data Collection Procedure*

*Implementation*. After receiving clearance from the appropriate offices, the researchers began formally applying the teaching technique and collecting data. Following it, the researchers collaborated with the subject instructor to gain a background on the students and the mathematics lesson where the RME approach can be used. With the assistance of the teacher, the assessment was administered using Google Meet. The RME approach was then incorporated, guided by its three core heuristic principles.

The researchers used guided reinvention by providing them with activities that encourage investigation and observation in order for them to make meaning on their own. For didactical phenomenology, real-life experiences were not only used as examples and parts of the discussion, but the researchers let the students experience the discussion by giving them activities that connect the topic in trigonometry to the real world. In the self-emergent model, models or graphs were provided to support their learning and after giving some examples, students were allowed to draw the situation on their own to familiarize and make it a routine in every problem solving that they will encounter. Furthermore, as part of the self-emergent model, the researchers used various online platforms and websites to incorporate tools that will aid their learning. After utilizing the RME approach, the researcher disseminated the post-test with the same level of questioning as the pre-test but not identical. After gathering the data, the results were treated statistically for interpretation.

### *3.5. Ethical Considerations*

The study observed utmost confidentiality in dealing with respondents' test results and personal information. Only the researcher and thesis adviser have access to the results of the individual data in the test questionnaires. The names of the respondents are omitted from this study.

### *3.6. Statistical Treatment*

The study used descriptive and inferential statistics to give the raw data collected in this study significant meaning. The frequency and percentages were used to present descriptive data on pre-test and post-test outcomes. Paired t-tests, on the other hand, were used to examine the effectiveness of the RME approach on students' problem-solving skills in Mathematics.

## 4. Findings and Discussion

**Table 1**

*Pre-test Performance of the Students in Problem-solving Skill*

| Score | Understand the problem | | Devise a plan | | Carry out the plan | | Look back | | Interpretation |
|---|---|---|---|---|---|---|---|---|---|
| | f | % | f | % | f | % | f | % | |
| 25-32 | 7 | 20.00 | - | - | - | - | - | - | Exemplary |
| 17-24 | 13 | 37.14 | 1 | 2.86 | - | - | - | - | Proficient |
| 9-16 | 15 | 42.86 | 18 | 51.43 | 10 | 28.57 | 1 | 2.86 | Developing |
| 0-8 | - | - | 16 | 45.71 | 25 | 71.43 | 34 | 97.14 | Emerging |
| Total | 35 | 100 | 35 | 100 | 35 | 100 | 35 | 100 | |

*Legend: 25-32 Exemplary; 17-24 Proficient; 9-16: Developing; 0-8: Emerging*

Table 1 shows the test scores of the respondents in mathematical problem-solving skills before exposure to the RME approach. On the result of the pre-test examinations in understanding the problem, most of the students fall on the developing level with a total frequency of fifteen (15) students. They can understand the various terminology and phrases that are present in the problem, but more than two values are missing or incorrect on their answer. This shows that most of the respondents are not familiar on the topic the reason why they have difficulty on identifying important concept in the problem. This is supported by the study of Vula and Kurshunmlia (2015), that if students have foreknowledge about the meaning of the terms in a word problem, they can learn mathematical concepts and enhance necessary mathematical understanding without obstructions.

Moreover, seven students got an exemplary level of performance even though the topic has not yet been discussed, because they have prior knowledge about trigonometric identities since it was already discussed before the implementation of the study. It portrays that they have the mastery on the basic knowledge about the topic, such as the mnemonics SOH-CAH-TOA, which is the foundation of the succeeding MELCs in the fourth quarter of grade 9.

Furthermore, it can be distinguished from the table that when it comes to devising a plan, more than half (51.43%) of the students are prominently under the developing level. It implies that the majority of the students are having difficulty discerning excellent plans that aid in their strategies, which encompasses representations of possible illustrations and recognizing suitable methods or techniques that will direct them to the correct answer. This is consistent with the findings of the study of Phonapichat et al. (2014), which found that students lack organization of problem-solving processes when it comes to formula writing, wherein they are unable to write orderly processes.

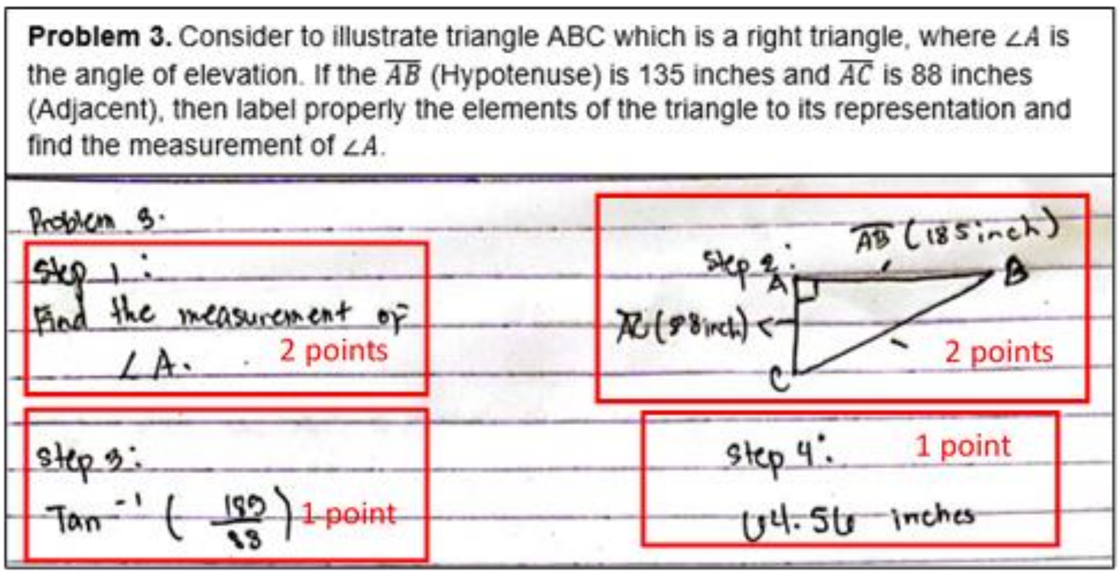
In carrying out the plan, the uttermost frequencies of the respondents are in the emerging level, with a total of twenty-five (25) students representing 71.43% out of thirty-five (35). It connotes that most students could not identify several strategies required to solve a given problem, and they cease to elaborate on the processes and outcomes. They also do not demonstrate well-reasoning in utilizing the plan. Moreover, students frequently fail in the third step because they obviously have no clue of (or misapply) problem-solving procedures, notably those required for problem representation. This is parallel to the findings of Dhlamini et al. (2016) states that students who were not proficient or had a low level of proficiency in trigonometry were those who left blank spaces and used incorrect mathematical procedures, resulting in mathematically incorrect responses.

On a final note, almost all of the respondents, 97.14%, fall under the emerging level of performance on looking back. It imposes that the students are either trying or unable to check and reflect on their answers. They are experiencing difficulties examining their solutions. This also means that most of the respondents have not been able to succeed in the antecedent steps. It is consistent with Annizar et al. (2020)'s study, which found that some learners made mistakes during the planning and implementation stages but did not go through the process of looking back. This finding suggests that the step of looking back is foreign to the majority of pupils because so few subjects actually conduct it.

Figure 5 shows the sample answer of student no. 05 on problem number 3 of the eight-item post-test assessment. It represents how most respondents answered the pre-test assessment indicating a low-performance range from emerging to developing levels in each step of the problem-solving process.

**Figure 1**

*Sample Answer of Student No. 5 in Pre-test Assessment*




The figure depicts how most learners perform at the developing level during understanding the problem. It is clear from student no. 05's response that she was able to identify what was asked in the problem but was unable to provide the given data in the problem. It implies that the respondent lacks a thorough understanding of the problem and is most likely unaware of the subject. In devising a plan, students were in the emerging to developing level. This means that they were able to draw an illustration but were having trouble labelling the appropriate values. In this case, they were unable to identify the appropriate formula, which is part of the planning stage and will aid the next step.

Meanwhile, in the third phase, Student no. 5 used the wrong formula in answering the problem. It implies that they are familiar with the concept but are impotent to apply the right one. As a result, even though they try answering the problem, they fail to get the correct answer. Finally, regarding the final step, most of the students did not check to see if they had gotten the right answer. Thus, they are unlikely to have any idea of how they can reflect and draw formal conclusions on their response, which is why they only write their answers in the previous step to avoid leaving them blank.

**Table 2**

*Post-test Performance of the Students in Problem-solving Skills*

| Score | Understand the problem | | Devise a plan | | Carry out the plan | | Look back | | Interpretation |
|---|---|---|---|---|---|---|---|---|---|
| | f | % | f | % | f | % | f | % | |
| 25-32 | 32 | 91.43 | 24 | 68.57 | 7 | 20.0 | 10 | 28.57 | Exemplary |
| 17-24 | 3 | 8.57 | 9 | 25.71 | 15 | 42.86 | 10 | 28.57 | Proficient |
| 9-16 | - | - | 2 | 5.72 | 9 | 25.71 | 6 | 17.15 | Developing |
| 0-8 | - | - | - | - | 4 | 11.43 | 9 | 25.71 | Emerging |
| Total | 35 | 100 | 35 | 100 | 35 | 100 | 35 | 100 | |

*Legend: 25-32 Exemplary; 17-24 Proficient;9-16 Developing; 0-8 Emerging*

The table 2 highlights the great outcome of the students on their overall post-test assessment after the treatment. On the first principle of mathematical problem-solving, out of thirty-five (35) respondents, thirty-two have exemplary performance with a percent of 91.43%. It shows that most students exhibit a clear and comprehensive understanding of the problem, wherein students carefully analyzed each question in preparation for solving it and easily determined all the given values and variables being asked. They have a broad understanding of the topic, which explains the students' familiarity with many concepts, such as trigonometric ratios, special angles, angle of elevation and depression, and oblique triangles. Knowing a lot of ideas about a specific topic broadens students' reading comprehension. Consequently, they can recognize all the factors involved in approaching the problem, which improves their mathematical problem-solving skills. It is in line with the study of Simpol et al. (2017), who claim that accuracy of a problem's final answer is determined by the students' ability to grasp and extract keywords.

In devising a plan, twenty-four students corresponding to more than 2/3 of the class (68.57%) shows an exemplary level of skill. It means that employing the RME approach increased the respondents' performance in creating a concrete outline of strategies for solving a problem. Students with this prominent outcome are well-learned in strategizing phase, which includes illustrations of a possible diagram and recognizing appropriate methods or techniques that will lead to the correct answer.

Majority of the students in strategizing used correct, comprehensive, and appropriate mathematical concepts as part of their problem-solving process. It indicates that high-performing students take a different perspective to solve the given problem, displaying multiple plans and connecting the illustrations they created to various formulas they have encountered. Accordant with the discovery of the study of In'am (2014), enhanced strategizing roots from the students' experiences, as this step can be possible by making an analogy with relatively similar problems that the students encountered.

Concerning the third phase of the problem-solving process, the majority obtained the proficiency level with 15 respondents, representing 42.86 %. It demonstrates that the students are skilled in executing the strategies and methods thoroughly, coming from the former step to solve the problem. Students who perform at the proficient level can frequently recognize multiple ways to implement the plan and have strong reasoning skills. They get the accurate answer, but with a few steps and solutions. Students at a high level learn about trigonometry not only by knowing the six trigonometric ratios to be used but also by executing these formulas to find the missing value in the problem.

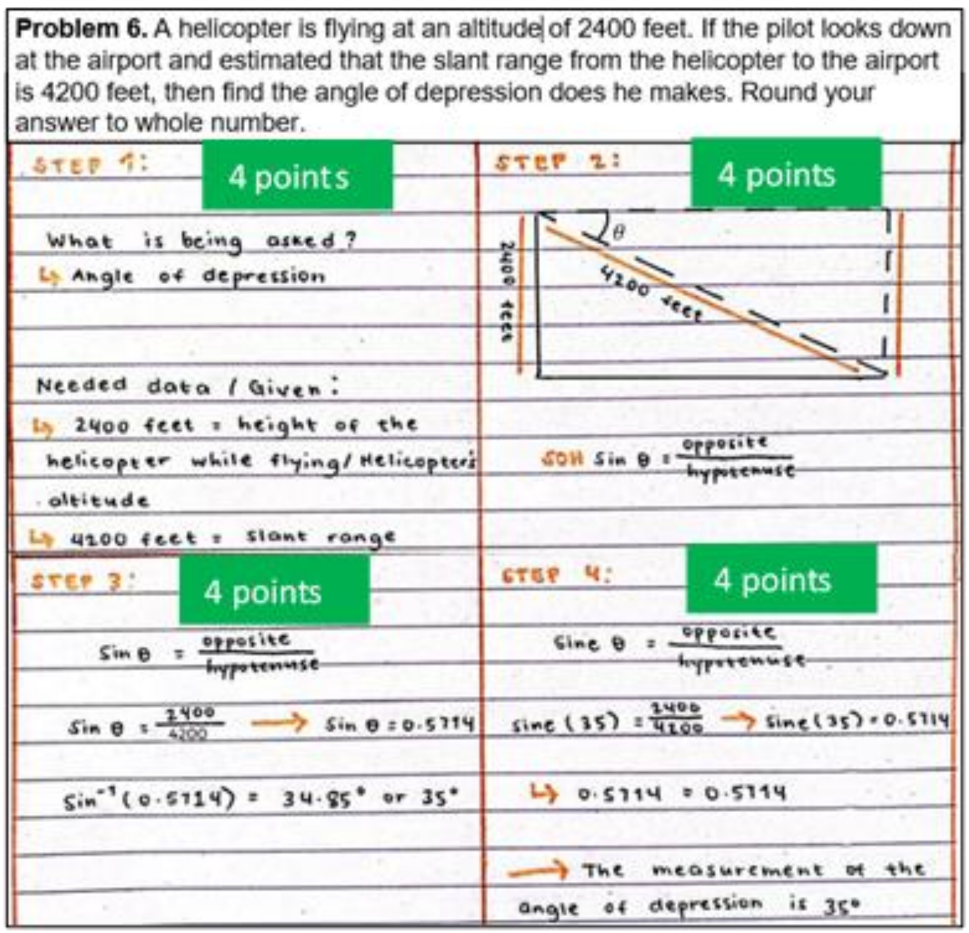
In terms of the looking back process, students demonstrate a mastery level with ten students accounting for 28.57% performing at an exemplary level and ten students also performing at a proficient level. These large frequency and percentage of students, implies that they successfully interpret and conclude their final answer as part of the last step. They did this step in a clear, focused, and logical manner. In addition, reflecting on their overall solution to getting the final answer is an essential task to identifies which part of the step they overlooked that caused incorrect answer, allowing them to return to some of the previous phases. It explains why the majority of the respondents that have mastery of looking back got their final answers in every problem accurate. This is parallel to the study of Thomson et al. (2021), revealed that students compare and analyze the formula and illustrations used in word problems involving right triangles and generate alternative solving strategies among the six trigonometric ratios.

Figure 6 shows the sample answer of student no. 10 on problem number six of the eight-item post-test assessment. It displays how most of the students answer the post-test with a high-performance range from proficient to exemplary level in all phases of problem-solving.

The figure displays how most of the students that perform at an exemplary level respond to understanding the problem. It can observe that the majority of the respondents copy their answers directly from the problem. Moreover, the sample problem contains unfamiliar terms such as altitude, slant range, and angle of depression, which are only found in this area of trigonometry. Even so, they were able to make sense of these terms. As seen in student no. 10's answer, she identifies the word *altitude* as synonymous with the term *height* for easier understanding.

**Figure 2**

*Sample Answer of Student No. 10 in Post-test Assessment*




Furthermore, more than 2/3 of the respondents fall under the exemplary level of strategizing. This kind of planning provided in the figure is broad and straightforward but accurate. Almost all students at an exemplary level have this kind of plan before solving the problem. From this, she successfully identified the accurate formula.

The majority of respondents demonstrated proficient level in the computing step. Students with excellent result exhibit well-developed thought in carrying out the plans from step 2. From the sample, due to the student's skills and knowledge of trigonometric ratio, students easily determined the formula and how to perform it to obtain the final answer. Thus, by grasping all of the discussed strategies and formulas for determining the missing value, they improved and became more motivated to handle this type of trigonometric problem. At the last phase of problem-solving, students fall from proficient to an exemplary level of performance. This indicates that students checked their answers carefully using the strategies they used and correctly concluded the final answer. As seen in the figure, student no. 10 presented the formula she used and went back to her process of calculating the angle of depression. She confirmed that the answer was correct after determining that both sides were equal. Finally, she finished the answer with a complete sentence that included the phrase on what was asked and the computed value with the appropriate unit.

**Table 3**

*Test of Difference Between the Mean Pre-test and Post-test Performance of the Students in Mathematical Problem-Solving Skills.*

| Mathematical Problem-solving Skills | Pre-test | | Post-test | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | | | |
| Understanding the problem | 20.89 | 6.09 | 30.23 | 3.19 | 8.350 | 34 | .000 |
| Devising a plan | 8.74 | 4.01 | 26.31 | 5.52 | 16.433 | 34 | .000 |
| Carrying out the plan | 5.40 | 5.00 | 18.66 | 7.89 | 9.186 | 34 | .000 |
| Looking back | 2.03 | 2.91 | 17.57 | 8.93 | 10.402 | 34 | .000 |

*Legend: p-value (Sig.) < 0.05 – significant, p-value (Sig.) >0.05 – Not significant.*

Table 3 displays the significant difference in the respondents' mean pre-test and post-test performance. It demonstrates that the students' mathematical problem-solving skills are highly significant in all the four-phases of problem-solving with a computed p-value= 0.000 for all four phases. This implies that after the exposure of the RME approach, students exhibited an improved academic outcome in problem-solving. This is in parallel with the study of Taufina et al. (2019), who discovered that pupils taught using conventional methods performed significantly less in problem-solving than those exposed to the RME approach.

Based on the given table, it can be gleaned that there is a highly significant difference (p-value= 0.000) between the pre and post-test performance of the students in understanding the problem. It depicts a notable improvement in their mathematical learning from a developing level with a 20.89 mean to an exemplary level with a mean of 30.23. The students' poor performance before treatment was caused by their confusion about the topic's specific wordings. But through the RME approach, the discussion of every topic was more collaborative and engaging, which improved their self-confidence. The students became more deeply involved in each lesson, sharing their ideas in class, which increased their mathematical skills. It resulted in their mastery of trigonometric concepts and ideas such as trigonometric ratios, special right angles, angle of elevation and depression, and oblique triangles, allowing them to have a more comprehensive understanding of the problem. It is parallel to the findings of Nurjamaludin et al. (2021), which asserted that the RME approach boosts students' confidence, which leads to the success of mathematical problem-solving.

Besides, students enhanced their reading comprehension because of the RME that facilitates self-exploration. They investigate and explore mathematical concepts, where they are introduced to a variety of unfamiliar terms and ideas, they eventually give meaning on their own before the discussion begins. This explains the RME strategy's outstanding accomplishment in the first step of problem-solving, when the respondents' understanding of trigonometry was increased. As resonates with Afthina and Pramudya (2017), when applied to learning models, the RME method increases students' engagement and understanding of geometry instruction.

In terms of devising a plan, the students' mean pre-test performance (8.74) was classified as an emerging level, whereas the mean post-test result showed a notable increase (26.31), demonstrating an exemplary level. It also reveals the computed p-value of 0.000, indicating a highly significant difference in the outcome before and after using the RME approach. This essentially denotes that the utilization of the RME approach has a significant impact on improving the strategizing skills of the learners in problem-solving. Making connections with the students' good work towards the second phase of problem-solving and the RME approach can exhibit different implications. First, students' prior experiences, according to In'am (2014), play a significant role in their problem-solving method. This approach incorporates the students' realities in the discussions and assessment, notably improving the overall performance in Mathematics. Considering problem situations were factually based on their imagination and experiences, students became more interested in the whole teaching and learning process, especially in solving a problem. Using contextualized problems makes the strategizing step easier for them. They get a hint on how to approach the problem since they relate the problem scenarios to their level of thinking and experiences. It also explains the decreased difficulty for the students to illustrate the situation provided by the problem as part of strategizing. This is in line with Bray and Tangney's (2016) results that RME intervention with contextualized problems or incorporating the didactical phenomenology, one core principle of the RME, significantly improved the skills in mathematical problem-solving of the students, which strategizing belongs.

Second, exposing students to the treatment allows them to see the problem from a different perspective, demonstrate several plans, and connect the illustrations they created to various formulas they have encountered. Thus, mastery of devising a plan subject to high creativity and critical thinking (Szabo et al., 2020). As part of the RME intervention, teachers act as a facilitator while the students' ideas are the center of the discussion. Students not only shared their insights but also discovered new viewpoints in a math class from one another and learned by analyzing each presentation and response. Thus, the RME awakens the students to be open to different possibilities for solving a problem through various plans and strategies. Chairil et al. (2020), who demonstrate that instructional materials based on RME principles develop students' critical thinking skills in problem training and evaluation, support this conclusion.

Lastly, students are required to illustrate the problem situation based on their level of thinking and label it, as part of self-emergent model, allowing them to determine the best formula to use. For this reason, strategizing became routine in every problem-solving task, which leads to a more convenient illustration of the question and connecting it with the method to use. Thus, the RME approach develops students' strategizing and planning because of the repeated and consistent practice. In connection with the study of Julie et al. (2013), they operated the RME in teaching materials for the students and highlighted the principle of the emergent model. They concluded that this technique helps students strengthen their problem-solving skills, primarily in their capacity to plan and strategize effectively before solving problems.

Moreover, the table shows the highly significant difference in the students' pre and post-test mean scores (p-value= 0.000) in carrying out the plan. This implies that after the RME approach, students exhibited improved academic performance in Mathematics- specifically from emerging (5.40) to exemplary level (18.66) on the third phase of problem-solving. The guided reinvention, promotes the students' work and responses as the main topic of the discussion. Hence, RME produces a student-focused classroom. This explains the improvement in the students' communication skills. Students can express themselves, give explanations, and listen, leading to a deeper comprehension of mathematics. The students' participation is visible in the form of explaining the various answers, which allows them to get familiar with and comfortable with solving other problems. Thus, RME enhanced the communication skills of the students that take part in the improvement of their computational skills. A similar result was discovered by Palinussa et al. (2021), where the RME approach strengthens the students' mathematical reasoning and communication skill that helps in executing a formula for a problem.

Furthermore, didactical phenomenology has a significant impact on the problem-solving process' third phase. According to Liljedahl et al. (2016), one of the reasons students masters the computational step is the high reliance on prior knowledge and previous experiences when solving a problem, and this is where didactical phenomenology takes place in instructional design. Students felt they belonged in the discussion using the RME, which made them more engaged in the conversation. It also brought their eagerness to execute and perform the planned strategy to get the correct answer. As a result, didactical phenomenology helps students improve their computing skills. This is also consistent with the findings of Stephan et al. (2014), stated that when students participate in activities that are personally meaningful to them, they become more engaged in discussions and improve their skills in carrying out the plan.

Moreover, according to Vroom (2020), the emergent model has four stages: situational, referential, generic, and formal. This stages bridges the students' knowledge and reasoning from the informal level into a more formal mathematical concept. Thus, the RME principle has a positive impact on increasing learners' problem-solving ability in terms of executing the strategy. This result is parallel with the study of Anwar et al. (2012), who concluded that emergent modelling enhanced the students' learning process and developed their computational skills, especially in solving contextual problems.

In regards to the looking back process, the students' pre-test performance was the lowest, at 2.03, falling below the emerging level, whereas their post-test performance was remarkable, with a mean of 17.57, corresponding to proficient to exemplary. The table also shows the highly significant difference (p-value= 0.000) in students' performance in the last step in problem-solving before and after exposure to the RME approach. Some literature indicates that most students rarely reflect or look back once they get their answer since this phase is often omitted which is why it is new for the students (Thomson et al., 2021; Simpol et al., 2017; In'am, 2014). Students that were exposed to the RME strategy, on the other hand, excelled at this procedure and used it as a routine in every problem-solving task they encountered. The strategy equipped the students with all of the knowledge they would need to solve a trigonometric problem. They acquired enough skills in finding different plans and formulas to solve a problem, increased their activeness, and became aware of different perspectives in solving a problem. In other words, RME allows learners to employ their critical thinking skills by reflecting on the problem. This is corroborated by Wulandari's (2020) study, which found that the RME technique increased students' problem-solving abilities, especially in concluding and reflecting on the final answer, through the enhancement of the critical thinking skills as described as the ability that prompts pupils to choose the best conclusion.

Moreover, looking back process can be associated with reflective thinking where the students should look back on their work not only for mathematical accuracy and completeness but also for rationality and applicability. The principle of self-emergent models improves the reflecting skills of the student because it is used to bridge the informal knowledge to formal ones using models. This principle of the RME approach unquestionably developed the students’ reflecting skills considering their successful performance. In connection with the study of Junaedi and Wahyudin (2020), they revealed that the final achievement and improvement of the the looking back process of the students is significantly better in using the RME approach.

Lastly, students have acquired mastery of the first three steps of the problem-solving process using the RME approach, which explains their proficiency in the looking back process. This is in line with the result of Nurkaeti (2018), who discovered that the difficulty in looking at the solution won't exist if the learner correctly understands the problem, appropriately plans the solution, and successfully solves it.

## 5. Conclusion

The following are the significant findings of this study based on the data analyzed and interpreted. The overall pre-test performance of the respondents in problem-solving skills falls under the emerging to developing level. In understanding the problem and devising a plan, students got developing level, while in carrying out the plan and looking back, students have the emerging level of performance. This implies that familiarity in the topic really much impacted the performance of the students in problem-solving. Outstanding improvement is reflected in the post-test performance of the students after the exposure to the RME approach. Students performed exemplary levels of performance in understanding the problem and devising a plan. In carrying out the plan, students got the proficient level of performance. While in looking back process, students fall under proficient and exemplary levels. This shows that they gained enough learning that enable them to develop different skills and mastered the topic, which contributed to the development of their problem-solving abilities. Moreover, results showed that there is a highly significant difference between the mean pre-test and post-test performance of the students in problem-solving, which all the four phases of problem-solving got a computed p-value of 0.000. This revealed that the use of the RME approach increases the level of problem-solving skills of the students, in all the four-phases.

From the obtained results, RME significantly increased the performance of the students. This helps learners enhance and master the problem-solving ability; thus, the school and its organization may encourage teachers to explore the RME approach to improve the teaching-learning process. Findings also manifest that the use of RME approach is highly interactive, and can provide the best learning experiences for the learners, therefore, teachers may utilize it to expose their students to more engaging and collaborative learning experience with the incorporation of real-world scenarios. They may be encouraged to use this strategy to create learning that is more innovative and creative.

Since the study was conducted through online set-up due to the pandemic, future researchers may conduct a similar study in a face-to-face mode of learning to comprehensively use the RME approach. Also, it is advised to increase the number of respondents and use two classes to have a detailed comparison between the controlled and experimental groups, which falls under the quasi-experimental research design. Moreover, to test the usefulness of the RME approach in other aspects, they may use this parallel approach to the various disciplines of mathematics as well as other subjects like Science and English. In addition, the future researcher may explore each principle and characteristic uniquely found in the RME approach and thoroughly focus on it for designing their learning exemplars. All in all, this study serves as the foundation for future studies to extend the use of the RME approach from the local to the global educational system.

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