

Mathematical Literacy: Connecting the Real World and Mathematics

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Introduction

The society today needs not only those who can understand science but also those who are beyond it. As we know with the evolution of the viewpoint that mathematics is not only the ability to calculate but also the capacity to associate applied mathematics with the real world. It's so necessary to solve a very complex problem. One that supports that ability is education.

Through education one can enhance and develop the creative, flexible, problem-solving, collaborative, and innovative thinking skills needed to lead life. Education is expected to equip a person to apply knowledge to everyday life. These abilities should be fostered in education through the subjects that are taught in classrooms. These expectations are reflected in the core competencies of the Curriculum Contents Standard 2013 (Permendikbud No 68 Tahun 2013, 2013).

The core competence (KI) of the cognitive domain for each subject is to equip the student with factual, conceptual, and procedural knowledge based on the student's curiosity about science, technology, cultural arts related to phenomena and apparent events. The core competence domain of the skills for each subject is to process, present, and plunge into concrete fields (using, deforming, scaling, modifying, and making) and abstract fields(writing, reading, counting, drawing, and writing), according to what is learned in school and other similar sources in the perspective/theory.

Based on the Content Standard, mathematics as one of the compulsory subjects is expected not only to equip students with the ability to use calculations or formulas in the work on the test, but also to involve their skillful and analytical skills in solving everyday problems. This is in line with the National Council of Teaching Mathematics (NCTM) view that makes problem solving, reasoning, and proof, communication and representation, the standard processes in mathematical learning (NCTM, 2000).

Mathematics requires students not only to have the ability to calculate, but also to have a logical and critical ability to solve problems. Problem solving is not just a routine problem but more to the problems faced on a daily basis. Such a mathematical ability is known as mathematics literacy.

According to a survey conducted by the Programme for International Student Assessment (PISA), the mathematical literacy from students in Indonesia is still low (OECD, 2014). Indonesia is below the international average (Kementerian Pendidikan dan Kebudayaan, 2023). Not only that, the majority of students can solve problems only below level 2. Given the facts mentioned, the mathematical literacy of students in Indonesia still needs to be improved. How examples of issues and some efforts in improving mathematical literacy are expressed in this article.

Literature studies are research activities that gather data from libraries, read and record and manage the literature obtained. As for the focus of the question to be discussed in this article is

1. What is mathematical literacy?
2. How is the process of mathematization understood by PISA?
3. What are competences required to undertake the Process of Mathematical Literacy?
4. How is mathematical literacy urgent in life?
5. How does the process analyze the ability to literate mathematically?

In this study, data collection is carried out by gathering shared sources, whether journals, books, or supporting reports to answer the proposed problem. Journals are obtained from various articles from journals that are indexed from sinta 1 to sinta 6. Books / reports from google scholar. The keywords for the journals and books collected are mathematical literacy, PISA and mathematics literacy in life. Procedures for writing articles of this literary study are: (a) searching for various literature, (b) choosing relevant literature with abstract reading, (c) writing important things to find the concepts studied, (d) conceptualization, (e) data analysis in the form of analysis of the content of the journal, (f) results and discussion (g) conclusions.

Mathematical Literacy

Mathematical literacy is popularized by the OECD/PISA.

“Mathematical literacy is an individual’s capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena. It assists individuals to recognizes the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive, engaged and reflective citizens”.

The definition by PISA shows that mathematical literacy relates to the use of reasoning, concepts, facts, and mathematic tools in finding solutions to solving everyday problems so that it is not just the ability to master mathematics itself.

The phrase "mathematical literacy" was first established by (NCTM, 2000) as part of the goal of mathematics education to become a mathematician, before it was

introduced through PISA. According to this definition, mathematical literacy is "the capacity of an individual to investigate, to hypothesize, and to reason logically as well as to effectively use a variety of mathematical methods to solve problems." Their capacity for mathematics should increase as they become literate. The four primary components of mathematical literacy in problem solving—exploring, linking, and logically solving—as well as the use of various mathematical techniques, are covered in this comprehension. This key element helps him solve problems on a daily basis while also advancing his mathematics skills.

Said another way, (Ojose, 2011) contends that mathematical literacy is the ability to understand and apply the principles of mathematics in daily situations. In this way, someone with strong mathematical literacy is sensitive to the mathematical principles that apply to the issue or situation they are dealing with. Following this sensitivity, problem solving using mathematical ideas was carried out.

According to this perspective, literacy in the context of mathematics was defined by (NCTM, 2020) as the ability to apply mathematical reasoning to solve difficulties in daily life in order to better prepare oneself for life's challenges. The goal of mathematical thinking is to be able to reason logically, solve problems, communicate, and explain (OECD, 2014). This way of thinking is established using methods, ideas, and quantitative information pertinent to the issue at hand.

(Ojose, 2011) added the word "effective" in the sense of mathematical literacy to support the earlier opinion. The capacity to apply mathematical knowledge and comprehension to successfully navigate the difficulties of daily life is known as mathematical literacy (Kirsner et al., 1993). A mathematically literate person must be able to apply their knowledge and comprehension efficiently in addition to being able to use it.

Five aforementioned viewpoints all highlight the same idea, which is how to apply mathematical knowledge to solve problems in daily life more successfully. A mathematically literate person will identify or comprehend which mathematical concepts are pertinent to the problem they are tackling as they work through this challenge. The ability to articulate the issue into its mathematical form so that it can subsequently be solved developed from this consciousness. Investigating, linking, formulating, defining, developing, and other mathematical thinking processes are all part of this process. The three primary stages of this thought process are formulating, using, and interpreting. Therefore, the ability to formulate, use, and interpret mathematics in a variety of contexts to solve problems in daily life can be characterized as mathematical literacy. Which can be represented as follows (OECD, 2013) :

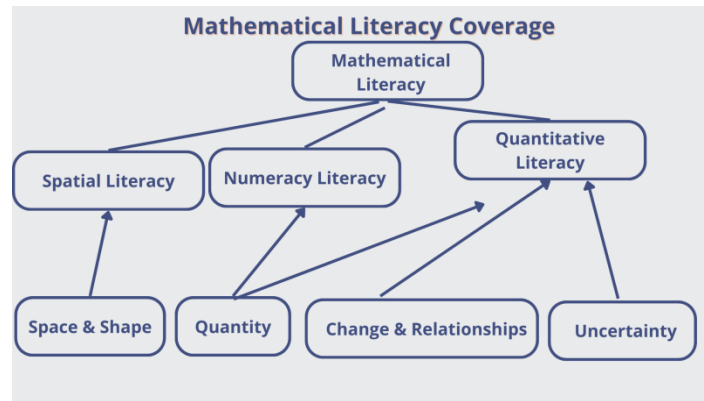


Figure 1. *Mathematical Literacy Coverage*

Mathematical literacy encompasses spatial literacy, numeracy and quantitative. Spatial literacy refers to our awareness of space. This ability requires an understanding of the nature of objects, relative positions and other things associated with the reservoir.

Additionally, Traffer's defines numeracy as the capacity to handle data and numbers as well as assess claims based on circumstances and facts requiring estimates and mental processes in practical settings. This skill involves the recognition, comprehension, and application of numerical statements in a range of real-world situations. The capacity to answer practical problems with numbers is known as numeracy. Quantitative literacy, which is broader than numeracy, is the capacity to recognize, comprehend, and apply quantity statements in everyday situations. This ability's primary component is the capacity to modify quantitative claims in situations that are known or unknown.

Mathematics as the Key to Literacy

Mathematical literacy is about dealing with 'real' problems (real world problem). Which means that the problem that exists is not pure mathematics, but is placed in some sort of 'situation'. In short, students must 'solve' real-world problems that require the skills and competences students acquire through school and life experience. The process of solving such problems by PISA is called the process of 'matematisation'.

Mathematization can simply be described as the process of triggering a phenomenon. Mathematizing itself is the process of modeling a phenomenon mathematically. The process of mathematization understood by PISA is not merely the creation of a mathematical model or representation of an issue, but a process involving the translation of a real problem into mathematics until the process of solving the problem. The stages of the mathematical process according to PISA are as follows:

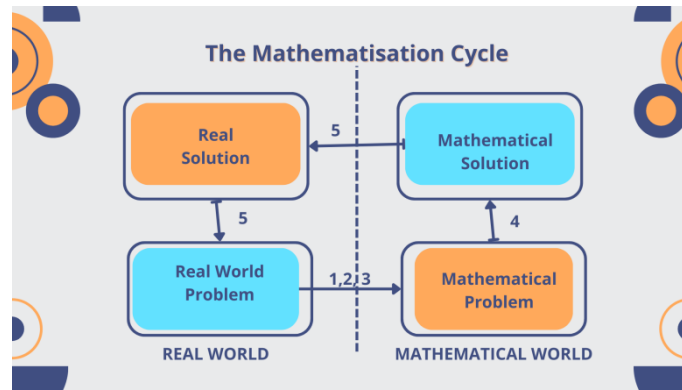


Figure 2. *The Mathematisation Cycle*

1. The process of mathematization begins with a problem that exists in the real world. This process of formulation includes the process of constructing, simplifying, and compiling a mathematical model of a given problem. This stage requires the ability to understand information and mathematical concepts that are relevant to the problem.
2. Then the problem solver tries to identify a mathematical step or form that is relevant and suitable for the situation and rearrange the problem according to the mathematics concept identified.
3. Then followed by a gradual cutting-down of things from reality or sorting out what is needed to solve existing problems. These three steps lead us from real-world problems to mathematical problems.
4. The fourth step is to solve the mathematical problem identified in three previous steps.
5. In this fifth step, questions will arise. What does that mathematical solution mean in the real world? So this is the process of interpreting answers into language in the real world.

To understand this cycle better by giving examples. The following items have been tested in the field for PISA but were rejected due to high difficulty levels. The item was previously released by the OECD. To make the mathematical process clear we have changed the question:

HEARTBEAT

For health reason people should limit their efforts, for instance during sports, in order not to exceed a certain heartbeat frequency.

For years the relationship between a person's recommended maximum heart rate and the person's age was describe by the following formula:

$$\text{Recommended maximum heart rate} = 220 - \text{age}$$

Recent research showed that this formula should be modified slightly. The new formula is as follows:

$$\text{Recommended maximum heart rate} = 208 - (0.7 \times \text{age})$$

QUESTION 1. HEARTBEAT

What is the main difference between the two formulas and how do they affect the maximum allowable heart rate?

Figure 3. *The example question for PISA*

1. The process of mathematization begins with a problem that exists in the real world. Clearly from this item, the realty in this case is physical fitness. An important rule when doing exercise is that one should not force oneself to

exercise in order to be fit, as this may cause health problems. We can jump to this conclusion because of the maximum heart rate text.

2. Then the problem solver tries to identify mathematically relevant, and rearrange the problem according to the mathematical concept identified. It seems clear that we have two words formulas that need to be understood, and indeed so asked to compare these two formulas, and what the real meaning of the formula gives the relationship between the recommended maximum heart rate and a person's age.
3. Next we gradually sort from reality to what to use. There are various interpretations of mathematical difficulties that can be made. One way is to change the formula into formal mathematics to:

$$y = 220 - x$$

$$y = 208 - 0.7x$$

Of course we have learned that y expresses maximum heart rate in b/m and x age in years. Another way to define a problem into mathematics is to draw a graph from a given formula. The three steps above take us from real-world problems to mathematical problems.

4. The fourth step is to solve the mathematical problem that exists. The mathematics problem that is faced is to compare two formulas or graphs, and to see the differences from people of a particular age. A good way to start is to find out where both formulas give the same result or where both graphs cut. So we can solve this by solving the equation:

$$220 - x = 208 - 0.7x$$

From these equations we get $x = 40$ and $y = 180$. So two charts cut at points $(40, 180)$. And the first equation gradient is -1 , and the second -0.7 so, we know that the second chart is 'less sharp' than the first. Or the $y = 220 - x$ chart lies 'on top' of the $y = 208 - 0.7x$ chart for x values smaller than 40, and below for x value greater than 40.

5. What this mathematical solution actually means in the real world is the question that now arises. In other words, if we understand that x is a person's age and maximal heart rate, it shouldn't be too difficult. The two algorithms get the same conclusion when a person is 40 years old: a maximum heart rate of 180. In extreme terms, if the age is zero, the maximum heart rate attained using the previous method was 220, however under the new formula it is only 208. This indicates that the old formula permits a higher heart rate for younger people. But modern insights allow for larger maximal heart rates for the older ones, in this case for individuals over 40. For example, and once again extreme: for the age of 100 years we see that the old formula gives us a maximum of 120 and the new 138.

Competence Required for Mathematical Literacy

Some competences are required to undertake the process of mathematical literacy.

1. Mathematical thinking and reasoning. Ask questions that match the mathematical characteristics, know what kinds of answers are obtained using mathematics, differentiate the questions given, and know the limits of the concepts used.
2. Mathematical argumentation. Knowing how to prove something, knowing other proofs using mathematical reasoning, having a desire to look further into a proof, and being able to create and express arguments mathematically.

3. Mathematical communication is the ability to express answers in a variety of ways, whether orally, in writing, or in other visual forms, and to understand the answers of others.
4. Modelling. Able to organize plans in the press looking for answers, translate reality into mathematical forms, both context and the real world, do several ways to solve a problem, analyze the steps taken, can give credentials or find solutions to a modeling process.
5. Problem posing and solving. Can define and solve problems in a variety of ways.
6. Representaion. Able to represent mathematical objects in various forms.
7. Symbols. Using symbols both formally and technically in the use of language and also in mathematical operations.
8. Tools and technology. Using a tool or technology that feels appropriate to what is needed.

To be mathematically "mathematically literate" one has to master the above competence to find variable answers. Besides, one also needs confidence in their own ability to use mathematics and comfort in using ideas quantitatively. Appreciation of mathematics from a philosophical and social historical point of view is also needed. So from that one can conclude that a mathematician is also an expert in literature. But today's school curricula rarely emphasize insight and still not many actively support learning that emphasizes litigation. It is unfortunate that the development of insights in mathematics is better supported even from the pre-school level. Many countries have begun to respond seriously to students' mathematical literacy. For example, Singapore, which has grown rapidly for PISA scores, could be proof that there is still a lot to be improved in the availability of increased mathematical literacy.

The Competencies Cluster

When doing real mathematics, then requires simultaneously in the use of many skills. To operate this mathematical competence, it would be very helpful if the skills were divided into three groups (Rosa & Orey, 2023). The Competence Cluster according to PISA is:

Cluster 1. Reproduction

These clusters are closely related to definition and computation, knowledge of facts, representation, recognition of equivalents, remembering mathematical objects and properties, performing routine procedures, applying standard algorithms, and developing technical skills. Handles and operates with statements and expressions containing symbols and formulas in the 'standard' forms associated with this level. Items in cluster 1 are often in double selection, empty content, match, or (limited) open question format.

Cluster 2. Connections

In this cluster, we start to draw links between many mathematical domains and strands, as well as integrate data to answer basic issues where students have choices about how to approach problems and how to apply mathematical tools. They still need to use mathematics to solve the problem, even though it shouldn't be one of those repetitive ones. According to the circumstance and goal, students at this level are also asked to handle a variety of representational formats. Students must be able

to differentiate between and connect various assertions, including definitions, claims, examples, conditioned statements, and supporting data, in order to complete the connection component.

From the point of view of mathematical languages, another aspect of this cluster is the definition and interpretation of symbolic and formal languages as well as the understanding of languages and their relationship with real-world languages. Items in these clusters are often placed in context and involve students in mathematical decision-making.

Cluster 3. Reflection

Related to mathematical tinging, generalization, and insight. In cluster 3, students are asked to mathematize situations (recognize and filter the mathematics that exist on the subject and use the math to solve problems). They have to analyze, interpret, develop their own models and strategies, and make mathematical arguments including evidence and generalizations. This competence includes critical components and model analysis and reflection on processes. Students should not only be capable of solving problems but also be able to make questions that match the material they master.

This competence works well only if the student can communicate properly in a variety of ways (misalnya, secara lisan, dalam bentuk tertulis, menggunakan visualisasi). Communication is meant to make a two-way process that the student must also be able to understand communication with mathematical components by others. Competence on cluster 3 quite often combines skills and competences usually associated with the other two groups.

Cluster 3, which goes into the heart of mathematics and mathematical literacy, is difficult to test. Double selection is clearly not the format of the choice in cluster 3. Contextual questions with several answers (with or without increased levels of complexity) are more likely to be promising formats. However, both the design and evaluation of students' answers are very difficult to make. It can be said that we can describe eight competencies that match the three on the competence cluster. The actual PISA framework does this in detail (meaning eight competencies when they play in the reproductive cluster, in the conjunctival cluster in the reflexive cluster.

The Urgency of Mathematical Literacy in Life

Based on the understanding described above, mathematical literacy is the ability of a person to formulate, use and interpret mathematics in various contexts of solving problems in everyday life effectively. It will encourage one to perceive and understand the use of math in daily life. Sensitivity to the usefulness of mathematic will help one to think numerically and spatially in order to interpret and analyze critically everyday situations with greater confidence. In politics, for example, a society with good mathematical literacy can turn statistical data into quantitative facts and effective information to choose legislative candidates more wisely. Thus, it is expected to create a critical and democratic society (De Lange, 2016).

In the world of work, for example, methematic literacy also has a vital housing role. Although at present our performance has been greatly assisted by computers, we need to have mathematical literacy skills. The current job demands are no longer on

how to use mathematical calculations but more on how we understand a system and how to develop it. This ability is essential for level officers to prevent upwards. By understanding the system, they can develop the system dynamically as needed (OECD, 2014).

Other examples, when shopping, we are often faced with a selection of goods. Some of them may get discounts or bonuses in the form of vouchers or something. With mathematical literacy, we can determine the goods to be chosen by considering the more economical price. In addition to mentioned examples, there are many problems of everyday life that require literacy skills. From simple things to more complex things. From defining effective routes to policymaking in the business world, both require literacy.

Mathematical Literacy Analysis

For a deeper look at how the differences and variations in mathematical abilities are, the author gives two details about mathematics literacy taken from the PISA issue and then friends from Grade A Mathematics Education in 2019 to answer the question .

In the hope of an understanding of the mathematical ability to solve the problem. But this is definitely just an illustration because the mathematical literacy of graduate students must be different from that of high school and senior high school students. The question given is as follows:

TASK 1. LIGHTHOUSE
Lighthouses are towers with a light beacon on top. Lighthouses assist sea ships in finding their way at night when they are sailing close to the shore.
A lighthouse beacon sends out light flashes with a regular fixed pattern. Every lighthouse has its own pattern.
In the diagram below you see the pattern of certain lighthouse. The light flashes alternate with dark periods.

Light														
Dark														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13

It is a regular pattern. After some time the pattern repeats itself. The same taken by one complete cycle of a pattern, before it starts to repeat. Is called the period. When you find the period of a pattern. It is easy to extend the diagram for the next second or minutes or even hours.

Item type: Multiple-choice
Competency Cluster: Connections
Overarching idea: Change and relationships
Situation: Public

TASK 1. LIGHTHOUSE
Which of the following could be the period of the pattern of this lighthouse?
a. 2 seconds b. 3 seconds c. 5 seconds d. 12 seconds

For how many seconds does the lighthouse send out light flashes in 1 minute?
a. 4 b. 12 c. 20 d. 24

Figure 4. The example question for PISA

Here's the answers and the mathematical steps.

Table 1. Scoring Mathematics Steps

No	Mathematic steps	Discussions	Score
1	Starts with a problem situated in reality	On the question of known patterns on the flashlight, "dark-light", asked how many seconds the pattern was formed on a flashlight.	3
2	Identify the relevant mathematics, and reorganizes the problem according to the mathematical concepts identified	There's a pattern that we can understand. There is a relationship between light and time. We can turn that pattern into a mathematical formula.	5
3	Followed by gradually trimming away the reality. These three steps take us from real world problems to mathematical problems	Make a pattern on the outer light 1-2 dark 2-3 bright 3-4 dark 4-5 bright 5-7 dark 7-8 bright 8-9 dark 9-10 bright	5
4	Solving the mathematical problem	From patterns we've created we know that the pattern of the mercury changes every 5 seconds which means that in one period there are 4 light changes that are dark-light-dark.	5
5	Describe what is the meaning of this strictly mathematical solution in terms of the real world	Which means every 5 seconds the spark will return to the same pattern.	3

No	Mathematic steps	Discussions	Score
1	Starts with a problem situated in reality	The problem is how many times space craft emits rays in 1minutes	3
2	Identify the relevant mathematics, and reorganizes the problem according to the mathematical concepts identified	The length of time affects how many times the lightning flashes. These relationships can be attributed to comparison formulas	5
3	Followed by gradually trimming away the reality. These three steps take us from real world problems to mathematical problems	There are several strategies that can be used as follows. 1. When each period is 5 seconds, there will be 12 periods per minute. 2. Or we can use the 5 times per 10 seconds multiple approach, then in one minute we will multiply by 6.	5
4	Solving the mathematical problem	1. 5 seconds = 1 period 1 period = 2 patterns of light So, in 1 minute = $12 \times 2 = 24$	5

		2. 2. 10 seconds = 2 periods 2 periods = 4 pattern of light Then, in one minute = $6 \times 4 = 24$	
5	Describe what is the meaning of this strictly mathematical solution in terms of the real world	In 1 minute the spacecraft will emit 24 rays	3

Item type: open constructed-response

Competency Cluster: Connections

Overarching idea: Quantity

Situation: Public

TASK 2.

There are three apartments in the buildings. The largest, apartment 1, has a total area $95m^2$. Apartments 2 and 3 have areas of $85m^2$ and $70m^2$ respectively. The selling price for the building is 300.000 zeds. how much should the owner of apartment 2 pay? Show your work

Figure 5. The example question for PISA

Table 2. Scoring Mathematics Steps

No	Mathematics steps	Discussions	Score
1	Starts with a problem situated in reality	The problem is that the price of apartments is different.	3
2	Identify the relevant mathematics, and reorganizes the problem according to the mathematical concepts identified	The total price of the apartment is known, we are asked to find out the price of a second apartment. To find the price of the second apartment can by making the equation.	5
3	Followed by gradually trimming away the reality. These three steps take us from real world problems to mathematical problems	Making the form of the equation as follows: $95x + 85x + 70x = 30000 \text{ zeds}$ With x is the price of the square perimeter of the apartment from the Equation we can obtain the entire area of apartment $95m^2 + 85m^2 + 70m^2 = 250m^2$	5
4	Solving the mathematical problem	So the price of the second apartment is $\frac{85}{250} \times 300000 \text{ zeds} = 102000 \text{ zeds}$ Which means $\frac{85}{250} = 1200 \text{ zeds}$ for each m^2 , so the price for apartment 2	5

5	Describe what is the meaning of this strictly mathematical solution in terms of the real world	is 102000 Zeds Means the price for the 2nd apartment is 102000 zeds	3
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Here are some of the answers from the two tasks.

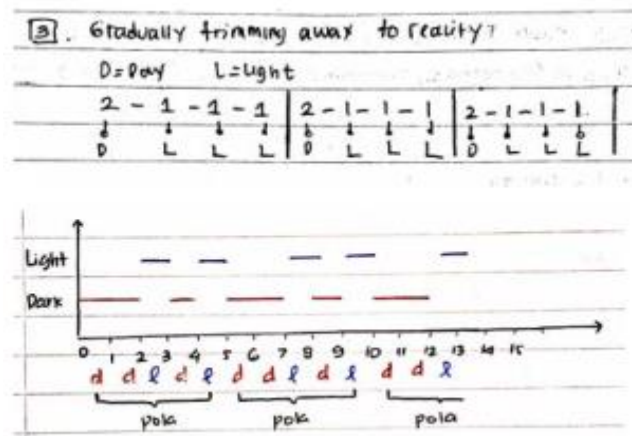


Figure 6. The example question for PISA

Above is an example of a third mathematical process where the process is to bring real-world questions into mathematics. From the two answers above we can get that to the same answer each individual is able to give different interpretations. So we can conclude that the process of mathematics can depend on how the experience and ability of a person understand their mathematical material.

Development of Mathematical Literacy

The process of mathematization is a crucial component of mathematical literacy, as has already been discussed. The process involves creating, applying, analyzing, and assessing mathematical concepts in a variety of settings. In actuality, the scenario or context of the problem that needs to be solved plays a major role in the method or representation that is used. It requires the skill of the student to apply his knowledge in a variety of contexts.

In fact, there are still a lot of students who have trouble doing it. Students who have been able to apply their knowledge to a problem do not necessarily apply it to different problems. Students need to experience problem-solving processes in different situations and contexts in order to be able to use their skills effectively. This experience can be facilitated through learning methods that give students the experience.

This can be facilitated by a variety of learning strategies or approaches. Several of them include problem-based learning, problem solving, contextual teaching and learning, and realistic approaches to mathematics. At this point, students will transform real-world issues into mathematical problems using their literary skills, answer them, and then interpret the results in authentic settings. They utilise and develop their mathematical literacy in this way.

Learning challenges are more than just problems. Four requirements should be met by the problem to be used: it must be real, complex, compelling, and powerful (OECD, 2022). The problem actually describes the actual problem as well as the broader context, which is the real point. Additionally, the challenge is meant to be so difficult that pupils must figure out the correct questions. Furthermore, the topics raised shouldn't be limited to commonplace narratives. The issues raised may be overly familiar or unfamiliar. And next need an Interventions aimed at enhancing academic numeracy will be more successful if they address language development in addition to mathematical competency (Prince & Frith, 2020) and than the pursuit of social justice and peace, think about decentralizing global mathematical knowledge and placing local mathematical practice, or margin, at the center of the mathematics education process (Rosa & Orey, 2023).

Conclusion

The capacity to effectively formulate, apply, and comprehend mathematics in a range of situations including difficulties from daily life is known as mathematical literacy. From the perspective of computations, numbers, and spaces, mathematics includes all ideas, methods, facts, and mathematical instruments. Process-wise, this skill encompasses not just computation but also thinking, communicating, and other mathematical thought processes. Mathematical processes provide a summary of these procedures.

To put it simply, mathematics is the process of translating and resolving real-world issues. All mathematical objects are involved in this process of issue solution. After a solution is found, it is applied to a real-world scenario or environment. A procedure like this will make someone more aware of how mathematics is used to solve difficulties in daily life. His sensitivity will enable him to tackle the issue quickly and successfully. This is applicable to everyday issues as well as complicated work-related issues.

Given the importance of mathematical literacy, efforts are needed to develop such skills. Education in this respect mathematical education has an important role to play in realizing it. As described earlier, learning mathematics should provide an opportunity or experience for students to solve problems in various situations. Through this way students will activate their literacy skills while developing them.

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Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of paper titled “**Mathematical literacy: Connecting the real world and mathematics**” belongs to the authors.

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