The Role Of Mathematical Literacy To Improve High Order Thinking Skills

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Abstract. Mathematical literacy is the ability of individuals to formulate, use, and interpret mathematics in various contexts. NCTM has formulated 5 competencies in mathematics learning, namely mathematical problem solving, mathematical communication, mathematical reasoning, mathematical connection, and mathematical representation. These five abilities are included in mathematics literacy abilities and must be possessed by all students. High-level thinking is a thought activity that includes aspects of problem solving, critical, creative, metacognitive to achieve certain goals, which in the domain of Bloom's Taxonomy conducts the analysis, synthesis and evaluation of a problem. The ability of mathematical literacy will encourage students to be able to think at a high level because in mathematics literacy students will be required to use all critical and creative thinking to be able to formulate and interpret mathematics in various contexts so that the highest level of mathematical skills (level 6) can be achieved.

1. Introduction

The role of mathematics in life is so important because the mastery of mathematics is needed by students as a provision in facing the rapid development of science. Students are not only required to understand mathematics but are also required to make optimal use of their knowledge to solve more and more complex problems. Mathematics studied and developed in order to equip students with the ability to think logically, analytical, systematic, critical, and creative. [1]

Education has a vital role to face challenges [2]. Education is the most important thing to form personality. Based on this, it is hoped that through education can improve and develop students' abilities to think critically, creatively, flexibly, solve problems and be innovative. Students can apply science in school to solve everyday problems.

The development of students' abilities can be done through subjects taught at school. The government has formulated core competencies that students must achieve in the 2013 Curriculum content standards. The formulation of the content standards in K13 on the cognitive aspects of each subject is to equip students with factual, conceptual, and procedural, metacognitive knowledge at specific technical levels, detail and complex based on students' curiosity about science, technology, art and culture related to phenomena and eye-sighting events. Core Competencies in the aspects of skills for each subject are skilled in reasoning, processing, and presenting in an effective, creative, productive, critical, independent, collaborative, communicative and solutive manner. These skills are in the realm of concrete and abstract using methods in accordance with scientific principles.
NCTM (National Council of Teaching Mathematics) which is the largest organization in the world concerned with mathematics education has set 5 basic mathematical abilities namely problem solving, reasoning and proof, communication, connection and representation. The five standards are in line with the content standards in K13 which want students to reason, analyze, think critically etc. to solve the problems. Mathematical literacy is an individual's ability to formulate, use and interpret mathematics in various contexts. Mathematical literacy will lead students to communicate and explain the phenomena they face with mathematical concepts. In South Africa, the pursuit of mathematical literacy has motivated the introduction of a new stand-alone school mathematics subject area available for learners in grades 10–12, which aims at allowing “individuals to make sense of, participate in and contribute to the twenty-first century world – a world characterized by numbers, numerically based arguments and data represented and misrepresented in a number of different ways. Such competencies include the ability to reason, make decisions, solve problems, manage resources, interpret information, schedule events and use and apply technology”.

Mathematical literacy is said to be good if one is able to analyze, reason, and communicate knowledge and mathematical skills effectively, and be able to solve and interpret mathematical solutions. A student who is able to solve mathematical problems by applying previously owned knowledge to new and unknown situations, is said to have high-level thinking skills. Higher Order thinking Skills (HOTS) refers to the ability to apply knowledge, skills and values in reasoning, reflection, problem solving, decision making, innovating and creating something new [3]. Higher order thinking skills are grounded in lower order skills such as discriminations, simple application and analysis, and cognitive strategies and are linked to prior knowledge of subject matter content. Higher-order thinking skills are the ability to connect, manipulate, and transform the knowledge and experience they have to think critically and creatively in an effort to make decisions and solve problems in new situations. According to (Resnick 1987) cited by (Fisher 1999) that the characteristics of HOTs can be observed through learning practices in the classroom. Higher order thinking is using the thinking widely to find new challenge [4]. Higher order thinking demands someone to apply new information or knowledge that he has got and manipulates the information to reach possibility of answer in new situation. [5]

The following are some learning differences that expect HOTs and routine learning:

| Learning HOTs                                      | Regular learning                                      |
|----------------------------------------------------|--------------------------------------------------------|
| Learning is not routine, some are unpredictable in the direction of disbursement | Routine learning, the results are planned              |
| Involving a meaningful process                      | The process only works and has little meaning         |
| The learning is complex                             | The aims and objectives are clear                      |
| Generate many solutions from several points of view | The solution is limited and convergent                 |
| Trying hard, requires mental work                   | Assessed based on results not effort                   |

PISA (Program for International Student Assessment) initiated by the OECD (Organization for Economic Cooperation and Development) monitors literacy reading, math skills and science skills for students aged 15 years. Indonesia has been taking this test since 2000. An assessment by PISA is carried out every three years. In 2015, Indonesia's position that followed the assessment by PISA was 69 out of 76 countries. The increase in PISA assessment in 2015 occurred in the scientific assessment from 382 to 403, the mathematics competition also increased from 375 to 386. In the reading competition also increased slightly from 396 to 397 [7]. The survey shows that the literacy ability of Indonesian students based on international studies has not been satisfactory and is still relatively low. Some research conducted on students in Indonesia shows the ability to solve problems that demand high-level thinking or HOTS (High Order Thinking Skills) are classified as low. In the next section, it will be discussed whether there is a relationship between mathematical literacy skills and higher order thinking skills (HOTS), how to improve.
2. Discussion

2.1 Mathematical Literacy

Understanding mathematical literacy according to PISA is: "Mathematical literacy is an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes mathematical reasoning and using mathematical concepts, procedures, facts, and tools to describe, explain, and predict phenomena. It assists individuals to recognize the role that mathematics plays in the world and to make the well-founded judgments and decisions needed by constructive engaged and reflective citizens" [6]. Mathematical literacy is the capacity of individuals to formulate, use, and interpret mathematics in various contexts. This includes mathematical reasoning and uses mathematical concepts, procedures, facts, and tools to describe, explain, and predict phenomena. This helps individuals to recognize the role mathematics plays in the world and to make judgments and decisions needed by constructive and reflective societies.

The definition of literacy implies mastery of mathematical material not only has the ability to count alone, but the ability to reason logically and critically in solving real problems. Solving this problem is not just a problem in the form of routine problems but rather the problems faced daily. Besides mathematics literacy requires students to communicate and explain the phenomena they face with mathematical concepts. The process of solving real problems becomes the main component in mathematical literacy. This kind of thought process is called by PISA as mathematical thinking.

Mathematical thinking is the whole way of looking at things, from revealing their numerical, structural, or logical importance, and analyzing the underlying patterns [7]. Mathematical thinking is more than procedure even mathematical thinking is the goal of mathematics education. Mathematical thinking activities are more emphasized to: 1) modeling, 2) ordination and structuring, 3) analytic thinking and problem solving, 4) manipulating formulas, 4) abstracting, 5) reasoning and proof. The most important thing from mathematical literacy is mathematical thinking.

2.2 High Order Thinking Skill

According [5] high level thinking uses thinking widely to find new challenges. High-level thinking requires a person to apply the new information or knowledge he has and manipulate information to reach possible answers in new situations. Brookhart states that high-level thinking is understood as the end of Bloom's cognitive taxonomic theory. According to King, higher-order thinking skills include critical, logical, reflective, metacognitive, and creative thinking, while according to Newman and Wehlage in [8] by high-level thinking students can distinguish ideas or ideas clearly, argue with good, able to solve problems, able to construct explanations, able to hypothesize and understand complex things become clearer. According to Vui in [9] high level thinking will occur if someone associates new information with information already stored in his memory and relates it and / or rearranges and develops the information to achieve a goal or find a solution to a situation that difficult to solve.

High-level thinking includes aspects of problem solving ability, creative thinking, critical thinking, ability to reason, metacognitive, and decision-making abilities so that students are able to associate new information with information already in their head and then develop the information to find a difficult problem solving. According to Facione in [10] critical thinking is the ability of interpretation, analysis, evaluation, conclusions, explanations and self-regulation. Critical thinking skills by Onosko and Newmann in [11] can challenge students to interpret, analyze or manipulate information. Therefore, critical thinking skills are needed when we try to understand something information that will be used to trigger ideas [12]. Likewise critical thinking requires students to use new information or manipulate existing knowledge and information so as to obtain a reasonable response to new situations. Ennis argues that critical thinking is reflective thinking that focuses on making decision patterns about what to believe and what to do.

In the context of solving mathematical problems, Krulik and Rudnick in [13] state that critical thinking is analytical thinking and reflection involves the activity of testing, questioning, connecting and evaluating all aspects of a situation or problem. Critical thinking skills are very important in learning mathematics, because these skills can improve the quality of mathematics learning better and
meaningfully, therefore it must be a systematic way to develop such skills through learning mathematics in schools.

Creative thinking is a way to generate new ideas using creative behavior. Through creative behavior, students can be active and creative in the classroom. They can use their creative thinking to solve problems in various ways. So, the problem is there must be some solutions. Schraw et al. in [5] classify bloom thinking skills into two categories namely Lower Order Thinking Skills which consist of knowledge, understanding and application. High-level Thinking Skills consisting of analysis, synthetics and evaluation.

High-level thinking is based on Bloom’s Taxonomy which categorizes the level of thinking in the cognitive domain from the lowest to the highest, namely 1) knowledge, 2) understanding, 3) application, 4) analysis, 5) synthesis and 6) evaluation. Bloom's concept in his book Taxonomy of Educational Objectives (1956) is a number of learning objectives that are divided into three areas, namely cognitive is mental skills (around knowledge), affective is the emotional side (about attitudes and feelings) and psychomotor related to physical abilities (skills).

The cognitive domain of Bloom’s Taxonomy was revised by Lorin Anderson and David Krathwohl in 2001, the order was changed to 1) remembering, 2) understanding, 3) applying, 4) analyzing, 5) evaluating, 6) creating. Levels 1 to 3 are called low order thinking skills (LOTS: Lower Order Thinking Skills) while levels 4 to 6 are called higher order thinking skills (HOTS: Higher Order Thinking Skills).

| Category                      | Keywords                                           | HOTS               | Description                |
|-------------------------------|----------------------------------------------------|--------------------|----------------------------|
| Remembering: Can students recall the information in their heads? | Mention definition, mimic pronunciation, state it structure, say, repeat, state | -                  | Low lorder thinking skills (LOTS: Lower Order Thinking Skills) |
| Understanding: Can students explain concepts, principles, rules or procedures? | Classify, describe, explain identification, place, report, translate, paraphrase | -                  | Lower Order Thinking Skil |
| Application: Can students apply their understanding to new situations | Choose, show, act, use, illustrate, interpret, arrange schedules, sketch, solve problems, write | -                  |                          |
| Analysis: can students classify the parts based on their differences and similarities? | Research, compare, compare, differentiate, do discrimination, separating, testing, experimenting, asking | Critical thinking Higher-order thinking skills (HOTS: Hot Order Thinking Skil) |
| Evaluation: can students state the good or bad bad for a particular phenomenon or object? | Giving argument, defending, stating, choosing, giving support, giving evaluation, evaluating | Creative thinking yinking Skil) |
| Creating: can students make something or opinion? | Assemble, change, make, design, formulate, write | • Solution to problem • Make decision |

2.3 The relationship between mathematical literacy skills and higher order thinking skills

Literacy is an ability to apply mathematics to everyday life. In other words, solving real problems becomes very important in mathematical literacy. The process of solving this real problem by PISA is called the mathematical process. Mathematics simply means to model a phenomenon metematically. So mathematical literacy activities involve the process of matematization. PISA views the process of matematization as the process of translating everyday real problems into mathematical models until
the process of solving those problems. The steps of the mathematical process according to PISA can be described as follows:

![Figure 1. Mathematical Process](image)

The picture explains the process of mathematical, that is if there is a real problem then the problem will be formulated into a mathematical problem in the form of a mathematical model. The model that has been formed is then solved using a mathematical formula and produces a solution or solving the mathematical problem earlier. The solution that has been found will be reinterpreted into a real problem to be evaluated for the solution that has been found.

All activities in the mathematical process in mathematical literacy involve higher-order thinking skills. When students formulate real problems into mathematical problems, critical thinking skills, logical and metacognitive skills are needed. Students must be able to determine the variables involved, objectives to be achieved etc. Creative thinking skills are needed by students when students look for solutions from models that have been made, where students must be fluent, flexible in using formulas that they have understood. At the stage of interpreting solutions to the context of real problems requires the ability to analyze, critical, logical, reflective and metacognitive. Based on the description there is clearly a link between mathematics literacy with higher-order thinking skills.

| Level 6 | Students can conceptualise, generalize and utilize information based on investigation and modeling of complex problem situations |
|---------|-----------------------------------------------------------------------------------------------------------------------------------|
|         | can use their knowledge in a relatively non-standard context                                                                       |
|         | They can link various sources of information and representation and translate flexibly between them                                |
|         | Students are able to think and reason in advanced mathematics                                                                       |
|         | Students can reflect on it actions, and can formulate and communicate their actions and reflections appropriately                       |
| Level 5 | students can develop and work with models for complex situations, identify obstacles and determine assumptions                         |
|         | Students can choose, compare and evaluate appropriate problem solving strategies if they encounter complex problems                  |
|         | Students at this level can work strategically broad thinking and reasoning skills, well-developed, appropriate related representations, symbolic and formal characterization, and insights related to this situation. |
|         | Students begin to reflect on their work and abilities formulate and communicate their interpretations and reasons                    |
| Level 4 | Students can work effectively with models and can choose as well integrate different representations, then connect it to the real world |
| Level 3 | Students can carry out procedures that are clearly explained                                                                       |
|         | Students at this level can interpret and use representation based at different sources of information                                |
| Level 2 | Students can interpret problems and solve them with formula                                                                       |
| Level 1 | Students can use their knowledge to solve problems routine, and can solve problems in a general context                           |
Ways to improve mathematical literacy skills [6] include:
1. Using the real world context when doing mathematics learning
2. Using everyday terminology when introducing mathematics
3. Improve mathematical communication skills and mathematical representation by involving literary values in mathematics learning
4. Doing learning that integrates mathematics with other sciences so that students are not isolated from any context

3. Conclusion
Mathematical literacy skills can be improved by bringing students closer to real problems through curriculum integration. Mathematical literacy can improve higher order thinking skills, reasoning abilities, representation skills and mathematical connection skills.

References
[1] Wardono, S. B. Waluya, S. Mariani, and S. D. Candra, “Mathematics Literacy on Problem Based Learning with Indonesian Realistic Mathematics Education Approach Assisted E-Learning Edmodo,” in *Journal of Physics: Conference Series*, 2016.
[2] R. Hera and N. Sari, “SEMINAR NASIONAL MATEMATIKA DAN PENDIDIKAN MATEMATIKA UNY 2015 713 Literasi Matematika: Apa, Mengapa dan Bagaimana?,” pp. 713–720, 2015.
[3] S. Tajularipin, V. Muniyan, M. Diwiyah, H. Raidah, and A. R. Suzieeleez Syrene, “Implementation of Higher Order Thinking Skills in Teaching Of Science: A Case Study in Malaysia,” *Int. Res. J. Educ. Sci.*, 2017.
[4] Y. M. Heong, W. B. Othman, J. B. M. Yunos, T. T. Kiong, R. Bin Hassan, and M. M. B. Mohamad, “The Level of Marzano Higher Order Thinking Skillsamong Technical Education Students,” *Int. J. Soc. Sci. Humanit.*, 2011.
[5] M. D. Kusuma, U. Rosidin, A. Abdurrahman, and A. Suyatna, “The Development of Higher Order Thinking Skill (Hots) Instrument Assessment In Physics Study,” *IOSR J. Res. Method Educ.*, 2017.
[6] OECD, *PISA 2015 Assessment and Analytical Framework: Science, Reading, Mathematic and Financial Literacy*, 2016.
[7] V. O. McBrien, “Introduction to Mathematical Thinking,” *New Scholasticism*, 1953.
[8] A. H. Abdullah, N. L. Z. Abidin, and M. Ali, “Analysis of students’ errors in solving Higher Order Thinking Skills (HOTS) problems for the topic of fraction,” *Asian Soc. Sci.*, 2015.
[9] M. Masnur and S. Syaparuddin, “The Effect of POGIL Learning Model on HOTS Students of Elementary School Teacher Education Program,” *Edumaspul J. Pendidik.*, 2019.
[10] P. A. Facione, “Critical Thinking: What It Is and Why It Counts Peter A. Facione The,” *Mol. Imaging Biol.*, 2016.
[11] M. Y. Kamarudin, N. M. R. N. Yusoff, H. Yamat, and K. Abdul Ghani, “Inculcation of Higher Order Thinking Skills (HOTS) in Arabic Language Teaching at Malaysian Primary Schools,” *Creat. Educ.*, 2016.
[12] R. H. Ennis, “The nature of critical thinking: An outline of critical thinking dispositions and abilities. Presentation at the Sixth International Conference on Thinking at MIT, Cambridge, MA, July, 1994,” *faculty.education.illinois.edu*, 2011.
[13] T. Y. E. Siswono, “Leveling students’ creative thinking in solving and posing mathematical problem,” *J. Math. Educ.*, 2010.