The 7th International Conference on Multidisciplinary Research (ICMR) 2024
Proceeding of ICMR 7(1), 74-83 DOI:https://doi.org/10.32672/picmr.v7i1.2749

Students' Mathematical Critical Thinking Ability in Solving Open-Ended Problems

Hanifa Dina Aulia Dewi Umbara[1*], Al Jupri[1]

[1]Mathematics Education Department, Universitas Pendidikan Indonesia, Indonesia

*Corresponding Author: Hanifadina@upi.edu

Abstract. *Students' mathematical critical thinking ability (MCTA) in Indonesia is still low, and one contributing factor is that students are not accustomed to solving non-routine problems, including open-ended problems. This research aimed to explore the mathematical critical thinking ability (MTCA) in solving open-ended problems using a qualitative approach with a case study method. This research involved 24 grade IX students from a junior high school in Bandung City, Jawa Barat Province, who had studied quadratic equations. Data collection included written tests for MCTA and interviews. The results reveal that students fail to meet the MCTA indicators due to their lack of practice in solving contextual problems on quadratic equations and open-ended problems. In addition, to gain a deeper understanding of critical thinking ability and the ability to solve open-ended problems, future researchers could use two separate instruments, as these abilities involve distinct cognitive processes: convergent thinking and divergent thinking.*

Keywords: *junior high school, mathematical critical thinking ability, open-ended problem*

1. Introduction

Mathematics has a crucial role in everyday life, and it is characterized by its support of various sectors of human life, including the development of science and technology. Therefore, mathematics is one of the subjects that must be studied at school. Mathematics is a science formed through human thought processes related to ideas, processes, and reasoning (Simangunsong et al., 2021). Mathematics is also often referred to as a way of thinking, so learning mathematics can help students improve their thinking skills.

According to Coffman (2013), there are two thinking skills: lower-order thinking skills (LOTS) and higher-order thinking skills (HOTS). LOTS requires students to answer factual questions with a single answer, which can be found directly in books or through memorization. Meanwhile, HOTS requires students to understand, interpret, analyze, and interpret information (Syaodih et al., 2022). In addition, according to Imran & Partikasari (2020), thinking ability consists of four levels: recall thinking, basic thinking, critical thinking, and creative thinking. Based on this, the ability to think critically is one of the abilities students must possess.

Critical thinking ability prepares students to think in various disciplines. According to Ennis (1991), critical thinking is a person's ability to analyze, evaluate, and conclude information or arguments objectively and rationally. Critical thinking is actively, consistently, and carefully considering a belief or knowledge, which involves evaluating the underlying reasons and anticipating further conclusions (Aiyub et al., 2021). Mathematical elements' distinctive and intricate nature necessitates that students engage in critical thinking during their learning process. Consequently, it is essential to foster critical thinking ability to address problems and derive conclusions from multiple possibilities (Agustina, 2019). A survey by the Association of American Colleges and Universities (AACU) found that 93% of respondents considered critical thinking and

Proceeding of ICMR 7(1), 74-83 DOI:https://doi.org/10.32672/picmr.v7i1.2749

problem-solving essential, with over 75% wanting greater emphasis on this ability (Su et al., 2016). However, facts in the field show that mathematical critical thinking ability (MCTA) still tends to be low.

The low level of MCTA is evidenced by the research conducted by Aston (2023), which states that students in the UK often experience difficulties in critical thinking because various factors often hinder them. This condition also happened in Indonesia. According to Agus and Purnama (2022), 94.4% of students had low critical thinking ability. Several other studies show that students' MCTA has not been optimally developed (Rahayu & Dewi, 2022; Budiwiguna et al., 2022). The results of various surveys also reinforce this. The results of the PISA survey 2022, which measured students' abilities based on the level of problems from simple to problems requiring higher-level thinking skills, Indonesia was ranked 70 out of 81 other participating countries with an average score of 366 (OECD, 2023). This condition indirectly shows that Indonesian students' MCTA is still lacking and needs improvement. In addition, the results of the Trends in International Mathematics and Science Study (TIMSS) survey in 2015, which assessed students' critical thinking ability through questions with high cognitive levels, showed that students' critical thinking ability in Indonesia was still low, ranking 44 out of 49 countries with an average score of 397. Students' MCTA in Indonesia is still low because mathematics learning in schools has not fully honed these abilities, and attention to their development is still lacking, so there is an opportunity to explore and develop them further.

Students' MCTA can be developed through learning at school. The results of research from Utami et al. (2022) state that improving critical thinking ability is prioritized in learning mathematics at school so that students can get used to solving non-routine problems requiring more profound and complex thinking. However, this is not in line with what happened. Widiastuti and Rahmah (2023) stated that students have difficulty solving problems that require critical thinking because students are rarely trained to solve non-routine problems. Thus, students must be accustomed to dealing with various mathematical problems through learning at school.

Mathematical problems are situations or problems that involve mathematical principles. According to Thamsir et al. (2019), mathematical problems are problems whose solutions cannot be found immediately because the solutions do not use routine procedures. Yee (2002) divides problems into closed or well-structured and open-ended or ill-structured problems. Closed problems are problems that are clearly formulated and always have one correct answer. In contrast, open-ended problems are problems that do not have a clear formulation and no fixed procedure guarantees the correct solution. In addition, Davidson and Sternberg (2003) classify problems based on the clarity of the solution set. Well-defined problems have clear goals, solution steps, and solution obstacles based on existing information. Meanwhile, ill-defined problems have a series of unclear solutions, so they require a systematic approach to finding a solution.

Currently, learning in schools only accustoms students to solving closed problems. This situation is supported by the results of research from Anggraeni (2021), which states that in the learning practices that have occurred so far, learning mathematics is accustomed to using closed mathematical problems without giving open-ended mathematical problems. This habit causes students to experience difficulties when faced with open mathematical problems. Meanwhile, according to the results of research from Udyani et al. (2018), students' MCTA is taught with the help of open-ended problems rather than closed problems. Thus, familiarizing students with solving open mathematical

Proceeding of ICMR 7(1), 74-83 DOI:https://doi.org/10.32672/picmr.v7i1.2749

problems is expected to improve their critical thinking ability. Based on the facts that have been presented, the researcher aims to explore students' MCTA when solving open-ended problems.

2. Method

This research explored the mathematical critical thinking ability (MTCA) in solving open-ended problems among ninth-grade students. Researchers employed a qualitative approach using a case study method to achieve this. This research was conducted at a junior high school in Bandung City, Jawa Barat Province, involving 24 students who had studied quadratic equations. Researchers selected three non-random students based on collected data to represent different mathematical critical thinking ability levels.

Data collection utilized both test and non-test techniques. The test involved a written test of students' MCTA. The non-test technique was interview guidelines. Several appropriate instruments were required to facilitate these data collection methods. The research employed two types of instruments: the researcher, as the primary instrument, who was directly engaged in data collection, and various supporting instruments. An expert validated a written test of MCTA consisting of six items representing an indicator of MCTA. The indicator of MCTA, according to Ennis (1991), can be seen in Table 1. The interview was semi-structured and informal. Three selected students representing mathematical critical thinking ability levels were the interview subjects.

Table 1. The Indicators of Mathematical Critical Thinking Ability (MCTA)

Question Number	Indicator
1	Focus (F): Identify the focus or central concern.
2	Reason (R): Identify and judge the acceptability of the reasons.
3	Inference (I): Judge the quality of the inference, assuming the reasons to be acceptable.
4	Situation (S): Pay close attention to the situation.
5	Clarity (C): Check to be sure that the language is clear.
6	Overview (O): Step back and look at it all as a whole.

After collecting the data, the researcher analyzed it by first reducing it. The researcher examined the students' work in solving the written test of MCTA to select subjects who could represent MCTA based on their levels. The criteria for selecting subjects at each level were students who had relatively similar ways of working on problems with the most ways of working on problems and suggestions from a mathematics teacher. The last data reduction was carried out on the interview transcript. If there was a mismatch between the MCTA test answers and the interview results, then the data were not used in data analysis. The results of data reduction were presented in descriptive form.

The data presented describe the MCTA of students with high, moderate, and low mathematical anxiety levels. The final stage of data analysis was to conclude. Conclusions in this research were in the form of descriptions.

3. Results and Discussions

All students' MCTA test results were categorized at high, moderate, and low levels. The percentage of the categorization can be seen in Table 2.

Proceeding of ICMR 7(1), 74-83 DOI:https://doi.org/10.32672/picmr.v7i1.2749

Table 2. Percentage level of MCTA of all students

No	Level Category	Percentage
1	High	8.3%
2	Moderate	79.2%
3	Low	12.5%

Next, three students were selected to represent each level of MCTA. Subject S1 represents a high level, S2 represents a moderate level and S3 represents a low level of MCTA. The results of the MCTA can be seen in Table 3.

Table 3. Achievement of subjects with high, moderate, and low levels of MCTA

Subject	1st Indicator	2nd Indicator	3rd Indicator	4th Indicator	5th Indicator	6th Indicator
S1	✓	✓	-	-	-	✓
S2	✓	-	-	-	-	✓
S3	-	-	-	-	-	-

Table 3 shows the outcomes of students' MCTA tests and interviews conducted for this research. A high level of MCTA subject S1 fulfilled three of the six indicators of MCTA. A moderate level of MCTA subject S2 fulfilled two of the six indicators of MCTA. Meanwhile, subjects with a low level of MCTA, such as subject S3, cannot fulfill all the indicators of MCTA. The figures provided have been translated into English for easier comprehension and to ensure accessibility for a broader reader. The question and an example answer of the first MCTA indicator can be seen in Figure 1 and Figure 2.

Margasana village has a field that resembles a rectangle. It is known that the length of the field is three times its width. The villagers plan to paint the entire surface of the field. On the outer edges of three sides of the field, a 1 m wide street is made, with a total area of 52 m^2. Margasana Village has 150 kg of paint in stock, and each kilogram of paint can be used to paint 1 m^2 of surface. The following illustrates the shape of the field in Margasana Village.
Is the paint supply enough to paint the entire surface of the field?

a. If yes, state your reasons!
b. If not, explain why and illustrate a painting pattern on the field so that the area painted is exactly 150 m^2!

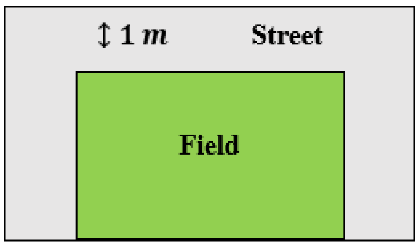


Figure 1. The question of the 1st MCTA indicator

Based on Figure 2, subject S2 fulfilled the first MCTA indicator. Subject S2 understood the problem by mentioning what was known and asked about the problem aligned with the research result by Susanto et al. (2023), which states that students with good critical thinking ability were able to analyze problems that arose and determine attitudes and views on problems that have been studied in learning. In addition, subject S2 made the right decision and argued that the available paint could not paint the entire field, which aligns with the research results by Winarti et al. (2018), which state that students with good critical thinking ability can understand the content of the problem. In

Proceeding of ICMR 7(1), 74-83 DOI:https://doi.org/10.32672/picmr.v7i1.2749

contrast to the other two subjects, subject S2 illustrated the painting pattern correctly by explaining through an interview that he would paint half of the field area as illustrated on the answer sheet, which aligns with the research result by Rachmantika and Wardono (2019) which state that students with good critical thinking ability were capable of solving problems by analyzing and generalizing ideas based on existing facts. This result means subject S2 can solve open-ended problems on the first MCTA indicator.

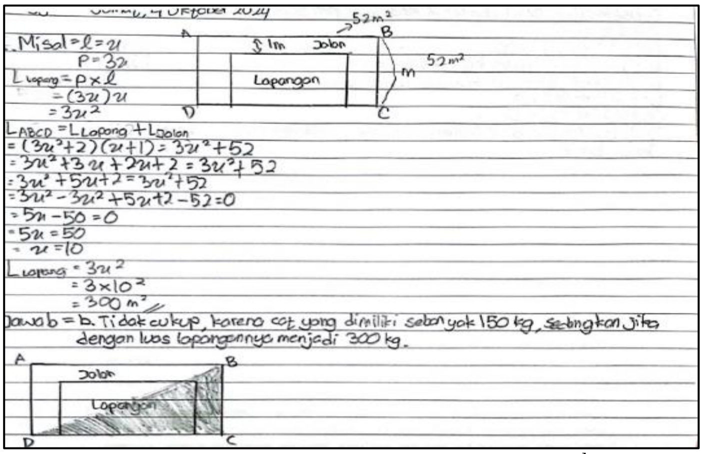

Misal = $l = x$
$p = 3x$
$L_{lapang} = p \times l$
$= (3x)x$
$= 3x^2$
$L_{ABCD} = L_{Lapang} + L_{Jalan}$
$= (3x^2+2)(x+1) = 3x^2+52$
$= 3x^3+3x+2x+2 = 3x^2+52$
$= 3x^2+5x+2 = 3x^2+52$
$= 3x^2-3x^2+5x+2-52=0$
$= 5x-50=0$
$= 5x=50$
$= x=10$
$L_{lapang} = 3x^2$
$= 3 \times 10^2$
$= 300\ m^2$
Jawab = b. Tidak cukup, karena cat yang dimiliki sebanyak 150 kg, sedangkan jika dengan luas lapangannya menjadi 300 kg.

Figure 2. The answer to subject S1 on the 2nd MCTA indicator

Next, the question and an example answer of the second MCTA indicator can be seen in Figure 3 and Figure 4.

Take a look at the problem and solution steps below.

PROBLEM

A factory makes two types of cardboard boxes that resemble cubes: cardboard box A and cardboard box B. The volume of cardboard A is $a\ m^3$ and the volume of cardboard B is $b\ m^3$. The factory wants to pack several boxes of both types in a new box with a volume of $100\ m^3$. You know that the volume of cardboard box A is $37\ m^3$ more than twice the volume of cardboard box B. What is the volume of boxes A and B respectively?

COMPLETION STEPS

For example:
x: number of cardboard types A
y: number of cardboard types B
Step 1.
The total volume equation:

$$xa + yb = 100$$

Step 2.
Equation the volume of cardboard box A is $37\ m^3$ more than twice the volume of cardboard box B.:

$$a = b^2 + 37$$

completion steps are still continuing…
Is there a wrong solution step?

a. If yes, at the start of which step was wrong, and what should they be?
b. If not, give your reason!

Figure 3. The question of the 2nd MCTA indicator

Based on Figure 4, subject S1 fulfilled the second MCTA indicator, namely correctly determining the wrong solution steps accompanied by appropriate reasons, even though it was not written in detail on the answer sheet. This situation is supported by Harlita and Ramli (2018), who state that students must express their arguments during

Proceeding of ICMR 7(1), 74-83 DOI:https://doi.org/10.32672/picmr.v7i1.2749

learning to develop their critical thinking ability. However, subject S1 could not solve the problem until the volume of type A and B cardboard was determined because it was confused about contextual problems. This result means subject S1 could not solve open-ended problems on the second MCTA indicator.

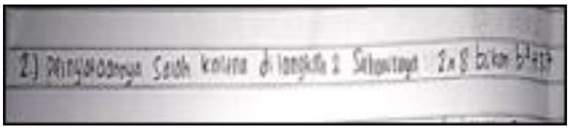


Figure 4. The answer to subject S1 on the 2nd MCTA indicator

Next, on the third MCTA indicator, subject S1 had difficulty determining the roots of the quadratic equation obtained. This occurred because subject S1 felt anxious about handling larger numbers, as they were only accustomed to working with smaller numbers, from units to tens, in school. The incomplete answer makes students unable to provide a conclusion about the value of x that under the context of the problem. Likewise, subject S3 could not understand the problem. This situation makes students unable to draw the correct conclusions from the context, so they cannot decide what to believe and do logically (Roviati & Widodo, 2019). Meanwhile, another subject did not understand the problem when the subject first read the problem and ran out of time when the subject wanted to try again to solve the problem. These results mean that all the subjects could not solve the open-ended problems on the third MCTA indicator.

Figures 5 show the question and an example answer for the fourth MCTA indicator.

A farmer has a rectangular piece of land with an area of 600 m^2. He plans to build a fence around the land. However, due to limited funds, the length of the fence he can build is limited to 120 m. The farmer wants to maximize the area of land that can be fenced with the available fence length. The farmer plans to increase the length and decrease the width of the land by a large size so that the total perimeter remains 120 m and the area remains 600 m^2. Is the farmer's plan possible?

a. If yes, find at least two different ways in which the farmer's plan can be carried out!
b. If not, give your reasons!

(a)

(b)

Figure 5. (a) The question and (b) answer to subject S2 on the 4th MCTA indicator

Based on Figure 5(b), subject S2 could not fulfill the fourth MCTA indicator. Subject S2 could not determine the key to the real problem because the subject did not understand the problem related to the farmer's plan to increase the length and reduce the width of the land. This failure aligns with the research result of Susanto et al. (2023), which states that no students could connect the discussed problem with relevant issues in the situation indicator. Subject S2 argued that the plan was carried out in the final step by mentioning methods one and two of the answer sheet. This result means subject S2 could not solve open-ended problems in the fourth MCTA indicator.

Proceeding of ICMR 7(1), 74-83 DOI:https://doi.org/10.32672/picmr.v7i1.2749

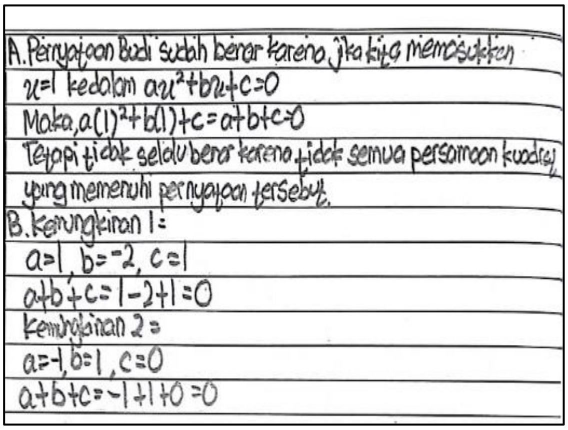
On the fifth MCTA indicator, all subjects could not find the information needed for the right solution. This situation indicates that all the subjects could not solve open-ended problems on the fifth MCTA indicator and the student does not yet possess adequate critical thinking ability. According to Firdaus et al. (2015), one of the key aspects of critical thinking in mathematics is the ability to analyze information. For example, subject S1 could explain the answer, but the explanation was incorrect, whereas students should be able to select and process information from appropriate information (Anisa et al., 2021).

Figure 6 show the last question and an example answer for the sixth MCTA indicator.

Johan and Mario worked together to paint the entire wall in 18 minutes. If Johan works alone, it will take him longer than Mario's time. How much time did Johan and Mario each take to paint the wall?
Is the information given in the problem enough to answer the question?

a. If yes, list all the information and calculate the time taken by Johan and Mario respectively!
b. If no, what information is needed and complete the information to calculate the time Johan and Mario each took!

(a)



(b)

Figure 6. (a) The question and (b) answer to subject S2 on the 6th MCTA indicator

Based on Figure 6(b), subject S2 fulfilled the sixth MCTA indicator, namely conducting a thorough re-examination to determine the decisions' accuracy. This result indicates that subjects have good critical thinking ability, as critical thinking requires effort to examine beliefs and knowledge based on existing evidence and their conclusions. Subject S2 also provided additional argumentation: not all quadratic equations have the root of the quadratic equation $x = 1$. In addition, subject S2 was also able to answer questions utterly related to the possible values of $a, b,$ and c that fulfill. This situation means subject S2 was able to solve open problems in the sixth MCTA indicator.

Their unfamiliarity with contextual problems causes students' failure to complete mathematical critical thinking ability tests. Meanwhile, mathematical contextual problems can present real situations that students have experienced, with contexts that are appropriate and related to the mathematical concepts being studied (Kurniasih, 2016). This condition leads to difficulties connecting mathematical concepts with real-life situations and solving problems relevant to everyday life. It also limits their mathematical critical thinking ability development. Additionally, the interview results revealed that students mentioned their teachers had never assigned open-ended problems during classroom lessons. As a result, the students felt confused when faced with such problems.

Overall, it appears that most students could not solve each problem fully. They could only complete the sections involving closed problems but not the open-ended ones. Critical thinking involves analyzing, evaluating, and reflecting on information or arguments, often requiring convergent thinking. Convergent thinking is an original and reflective thinking process that involves decision-making abilities. Additionally,

Proceeding of ICMR 7(1), 74-83 DOI:https://doi.org/10.32672/picmr.v7i1.2749

convergent thinking encourages individuals to find the correct solution to problems characterized by being vertical, focused, systematic, dependent, and applicable (Rosyid & Thoha, 2018). On the other hand, solving open-ended mathematical problems requires exploring various possibilities, generating new ideas, and finding innovative solutions. Therefore, it can be said that solving open-ended problems requires creative thinking ability. Creative thinking is closely related to divergent thinking, characterized by generating multiple ideas or solutions for a problem. Meanwhile, students are only accustomed to working on closed problems that do not allow for divergent thinking (Kurniasih, 2016). Divergent thinking is the ability to generate various ideas or solutions to a problem by directing thought differently (Guilford, 1959). This process involves creative exploration, allowing individuals to discover unconventional and innovative approaches.

Convergent and divergent thinking are two crucial cognitive abilities for solving problems. Both play distinct roles in problem-solving: convergent thinking focuses on finding the most appropriate solution from various possibilities. In contrast, divergent thinking involves generating multiple ideas or approaches to a problem. Both are necessary for producing effective and innovative solutions. Therefore, different assessment instruments are required to gain a deeper understanding of students' critical thinking ability and their ability to solve open-ended problems.

4. Conclusions

Based on the research results and overall discussion of students' critical thinking ability in solving open-ended problems, it is concluded that students fail to meet the MCTA indicators due to their lack of practice in solving contextual problems on quadratic equations and open-ended problems. The first MCTA indicator, most students can meet this indicator by focusing on a problem and making decisions, allowing them to solve open-ended problems. Some students can meet the second MCTA indicator by arguing about the given solution. However, most students could not fully solve the problem, indicating they could not complete the open-ended problems. Furthermore, no students could meet indicators 3, 4, and 5. Students' failure to meet the third MCTA indicator is due to a lack of understanding of the problem, making them unable to determine the steps to solve it and draw the correct conclusion. The failure to meet the fourth indicator is because students could not identify the key issue of the problem. Meanwhile, students failed to meet the fifth indicator because they could not correctly explain the solution based on the given information. Some students could meet the sixth indicator because they could conduct checks and make the right decisions, allowing them to solve open-ended problems. Future researchers could use separate instruments to understand critical thinking ability and the ability to solve open-ended problems better, as these abilities involve different cognitive processes: convergent thinking and divergent thinking.

5. References

Agus, I., & Purnama, A. N. (2022). Kemampuan berpikir kritis matematika siswa: studi pada siswa SMPN satu atap. *Jurnal Pendidikan Matematika Raflesia*, *07*(01), 65–74. https://ejournal.unib.ac.id/index.php/jpmr

Agustina, I. (2019). *Pentingnya berpikir kritis dalam pemebelajaran matematika di era revolusi industri 4.0*. Researchgate.Net. https://www.researchgate.net/publication/341788018

Proceeding of ICMR 7(1), 74-83 DOI:https://doi.org/10.32672/picmr.v7i1.2749

Aiyub, Suryadi, D., Fatimah, S., & Kusnandi. (2021). Investigation of watson-glaser critical thinking skills of junior high school students in solving mathematical problems. *Journal of Physics: Conference Series*, *1806*(012090). doi: 10.1088/1742-6596/1806/1/012090

Anggraeni, R. (2021). *Analisis kesulitan siswa SMP dalam memecahkan masalah matematika tertutup dan terbuka* [Universitas Pendidikan Indonesia]. http://ejournal.undiksha.ac.id/index.php/semnasmipa/article/view/10184

Anisa, A. R., Ipungkarti, A. A., & Saffanah, K. N. (2021). Pengaruh kurangnya literasi serta kemampuan dalam berpikir kritis yang masih rendah dalam pendidikan di Indonesia. *Conference Series Journal*, *1*(1), 1–12.

Aston, K. J. (2023). “Why is this hard , to have critical thinking ?” Exploring the factors affecting critical thinking with international higher education students. *SAGE Publications*. doi: 10.1177/14697874231168341

Budiwiguna, B. S., Winarti, E. R., & Harnantyawati, R. (2022). Analisis kemampuan berpikir kritis peserta didik SMP Negeri 19 Semarang kelas VIII ditinjau dari self-regulation. *PRISMA, Prosiding Seminar Nasional Matematika*, 311–319. https://journal.unnes.ac.id/sju/index.php/prisma/article/download/54193/21029

Coffman, D. M. (2013). *Thinking about thinking: An exploration of preservice teachers' views about higher order thinking skills*. University of Kansas.

Davidson, J. E., & Stenrberg, R. J. (2003). *The Psychology of problem solving*. Cambridge University Press.

Ennis, R. (1991). Critical thinking: A streamlined conception. In *Palgrave Handbook of Critical Thinking in Higher Education* (pp. 22–43). Palgrave Macmillan.

Firdaus, Kailani, I., Bakar, M. N. Bin, & Bakry, B. (2015). Developing critical thinking skills in students in mathematics learning. *Journal of Education and Learning*, *9*(3), 226–236. doi: 10.11591/edulearn.v9i3.1830

Guilford, J. P. (1959). Three faces of intellect. *The American Psychologist*, *14*, 469–479. doi: 10.4159/harvard.9780674864207.c5

Harlita, D. R. F., & Ramli, M. (2018). Meningkatkan Kemampuan argumentasi siswa melalui action research dengan fokus tindakan think pair share. *Proceeding Biology Education Conference*, *15*(1), 253–259.

Imran, R. F., & Partikasari, R. (2020). Pengembangan model pembelajaran sains dengan konsep keterampilan berpikir tingkat tinggi (HOTS) pada mahasiswa PAUD Universitas Dehasen Bengkulu. *Jurnal Ilmiah Potensia*, *5*(2), 173–179.

Kurniasih, A. W. (2016). *Budaya mengembangkan soal cerita kontekstual open-ended mahasiswa calon guru matematika untuk meningkatkan berpikir kritis*. Universitas Negeri Semarang.

OECD. (2023). PISA 2022 results (Volume I): The state of learning and equity in education. In *PISA, OECD Publishing: Vol. I*. doi: 10.1787/53f23881-en

Rachmantika, A. R., & Wardono. (2019). Peran kemampuan berpikir kritis siswa pada pembelajaran matematika dengan pemecahan masalah. *Prisma, Prosiding Seminar Nasional Matematika 2*, 439–443.

Proceeding of ICMR 7(1), 74-83 DOI:https://doi.org/10.32672/picmr.v7i1.2749

Rahayu, B. N. A., & Dewi, N. R. (2022). Kajian teori: Kemampuan berpikir kritis matematis ditinjau dari rasa ingin tahu pada model pembelajaran preprospec berbantu TIK. *Prisma, Prosiding Seminar Nasional Matematika*, 297–303.

Rosyid, M. Z., & Thoha, M. (2018). Model berpikir konvergen siswa dalam menyelesaikan soal matematika materi pengukuran waktu. *Elementary: Islamic Teacher Journal*, *6*(2), 291–300.

Roviati, E., & Widodo, A. (2019). Kontribusi argumentasi ilmiah dalam pengembangan keterampilan berpikir kritis. *Titian Ilmu: Jurnal Ilmiah Multi Sciences*, *11*(2), 56–66. doi: 10.30599/jti.v11i2.454

Simangunsong, V. H., Perangin-angin, R. B., Gultom, D. I., & Naibaho, D. T. (2021). Hubungan filsafat pendidikan dan filsafat matematika dengan pendidikan. *Sepren: Journal of Mathematics Education and Applied*, *2*(2), 14–25. doi: 10.36655/sepren.v2i2.513

Su, H. F. H., Ricci, F. A., & Mnatsakanian, M. (2016). Mathematical teaching strategies: pathways to critical thinking and metacognition. *International Journal of Research in Education and Science (IJRES)*, *2*(1), 190–200. doi: 10.21890/ijres.57796

Susanto, Ardi, M., Arfandi, A., Lopa, A. T., & Rahman, M. H. (2023). Analisis keterampilan berpikir kritis siswa dan faktor-faktor yang mempengaruhinya pada Sekolah Menengah Kejuruan Negeri 5 Makassar. *Seminar Nasional Hasil Penelitian 2023 "Penguatan Riset, Inovasi, Kreativitas Peneliti Di Era 5.0"*, 1042–1051.

Syaodih, E., Widaningsih, S., Suherman, F., & Budiman, A. (2022). Penyuluhan terhadap guru dalam mengimplementasikan konsep belajar berbasis Hots. *Abdimas Siliwangi*, *5*(2), 290–302.

Thamsir, T., Silalahi, D. W., & Soesanto, R. H. (2019). Upaya meningkatkan kemampuan pemecahan masalah soal non-rutin pada materi persamaan dan pertidaksamaan linear satu variabel dengan penerapan metode peer tutoring [efforts in improving mathematical problem-solving skills of non-routine problems of one-vari. *JOHME: Journal of Holistic Mathematics Education*, *3*(1), 96–107. doi: 10.19166/johme.v3i1.927

Udyani, K. R., Gita, I. N., & Suryawan, I. P. P. (2018). Pengaruh penerapan model pembelajaran core berbantuan masalah terbuka terhadap keterampilan berpikir kritis matematis siswa. *Jurnal Pendidikan Matematika Undiksha*, *9*(1), 54–62. doi: 10.23887/jjpm.v9i1.19886

Utami, H. B., Salsabila, E., & Wiraningsih, E. D. (2022). Pentingnya kemampuan berpikir kritis dalam dunia pendidikan matematika. *J-PiMat : Jurnal Pendidikan Matematika*, *4*(2), 529–538. doi: 10.31932/j-pimat.v4i2.2025

Widiastuti, F., & Rahmah, S. (2023). Matematika dan berpikir kritis di era global. *Gunung Djati Conference Series*, *32*, 52–60. https://conferences.uinsgd.ac.id/index.php/gdcs/article/view/1993/1420

Yee, F. P. (2002). The Role of problems to enhance pedagogical practices in the singapore mathematics classroom. *The Mathematics Educator*, *6*(2), 15–31.