ISSN 2355-4185(p), 2548-8546(e)
DOI: https://doi.org/10.24815/jdm.v11i1.36721

Student's Collaboration and Creative Mathematical Thinking Skills in Problem-Based Learning Using Numeracy Problems

Nora Nurhalita[1], Meryansumayeka[1*], Scristia[1], Muhammad Yusup[1]

[1]Mathematics Education Department, Sriwijaya University, Indonesia
*Email: meryansumayeka@fkip.unsri.ac.id

Received: 9 January 2024; Revised: 14 April 2024; Accepted: 28 April 2024

Abstract. *Collaboration and creative mathematical thinking are important for students. However, students' collaboration and creative mathematical thinking skills are still low because students are not used to collaborating or investigating the problem-solving process. This research aims to determine students' collaboration and creative mathematical thinking skills in the 10th grade in Problem-Based Learning using numeracy problems. This research was carried out on 25 vocational school students majoring in accounting in Palembang, Indonesia. The research method used was a mixed method. The results of research on students' collaboration skills show that most of the students are in the excellent category. Students can fulfill respect for others and commitment indicators, but the indicators of deliberation and participation are rarely fulfilled. The research results on students' creative mathematical thinking skills show that 80% are in the very good category, 16% are in the good category, and others are in the pretty good category. Students can fulfill three indicators, fluency, originality, and elaboration, but flexibility is rarely fulfilled. Creative thinking skills of students need to improve.*

Keywords*: collaboration skills, mathematical creative thinking, problem-based learning, numeracy problems*

How to cite: Nurhalita, N., Meryansumayeka, Scristia, & Yusup, M. (2024). Student's collaboration and creative mathematical thinking skills in problem-based learning using numeracy problems. *Jurnal Didaktik Matematika*, 11(1), 120-138. DOI: https://doi.org/10.24815/jdm.v11i1.36721

Introduction

Sequences and series are one of the mathematical topics studied by students in high school, which aims to develop students' abilities in arithmetic or geometric sequences and series to solve contextual problems (Amsari, Arnawa, & Yerizon, 2022). Usually, arithmetic series material is used in academic potential tests, so it is important to study mathematics learning (Prafianti, Novitasari, Albab, & Ambarwati, 2023). Learning mathematics at school can equip students to think critically, logically, systematically, analytically, creatively, and collaboratively (Siregar & Narpila, 2023). Collaboration skills are a person's skills to work effectively and responsibly to make the commitments needed to achieve common goals (Hidayati, 2019). Collaboration skills involve working together to generate ideas and solve problems towards a shared vision (Yu, Liu, Hsieh, Lee, Simpkins, & Pantano, 2022). Collaboration skills are important for students because they can be used when they experience real life in society or when they are in the world of work (Hidayati, 2019).

Collaboration skills are related to creative thinking skills, which can create creative thinking skills and vice versa. Creative thinking is not always created from individual thoughts but requires collaborative activities (Amrianto, Dharmawan, & Sari, 2023). Creative mathematical thinking is important for students to master and process the information provided to solve a problem (Fauzi, Amin, Dirgeyase, & Priyatno, 2019). Creative mathematical thinking skills are a person's skills to create new ideas and solutions to solve problems (Yayuk, Purwanto, As'Ari, & Subanji, 2020). Creative mathematical thinking is a student's skill in understanding a problem and finding a solution using various strategies or methods (Kardoyo, Nurkhin, Muhsin, & Pramusinto, 2020).

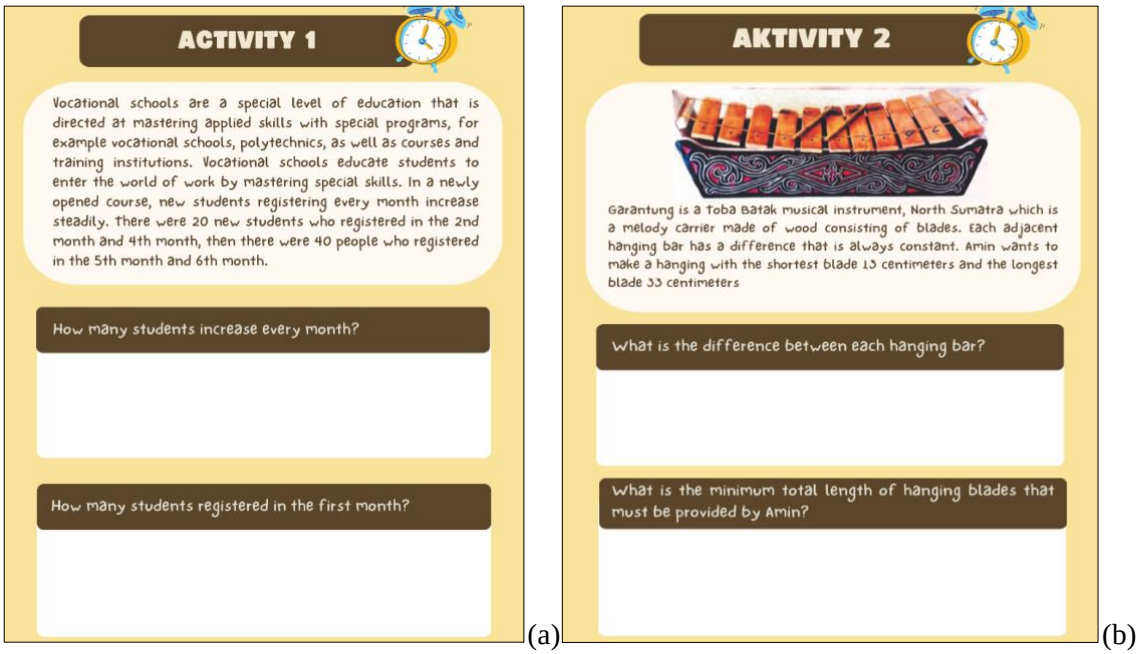
Some previous research reported students' creative mathematical thinking skills are still low (Selvy, Ikhsan, Johar, & Saminan, 2020). One of the reasons is that teachers rarely teach a learning topic connected to real-life problems and do not conduct further investigations in a problem-solving process (Simanjuntak, Hutahaean, Marpaung, & Ramadhani, 2021). Like creative mathematical thinking skills, students' collaboration skills are still low (Amran, Perkasa, Satriawan, Jasin, & Irwansyah, 2019). The low collaboration skills of students in schools are characterized by low students' skills in collaborating to carry out group learning and low mutual respect for differences of opinion; students have thoughts that are not open and not accommodating to each other, students don't want to share roles and don't responsibilities in working together (Nahar, 2022).

The solution to overcoming students' collaboration skills problems is to apply problem-based learning because it can improve students' collaboration skills and help them solve problems together (Hidayati, Zubaidah, & Amnah, 2023). Problem Based-Learning focuses on a problem; then students find a solution to the problem (Nurlaily, Soegiyanto, & Usodo, 2019). Problem-based learning also improves students' mathematical and creative thinking skills (Nurkhin & Pramusinto, 2020). Research by Maskur, Sumarno, Rahmawati, Pradana, Syazali, Septian, and Palupi (2020) states that the effectiveness of Problem-Based Learning and interaction with Aptitude Treatment can improve creative mathematical thinking skills in the 2013 curriculum. Ramadhani, Farid, Lestari, and Machmud (2020) used Problem-Based Learning with a local culture based on student gender and previous mathematical abilities to improve creative thinking. However, previous research still used the 2013 curriculum. The novelty of this research is that the researchers used a Merdeka curriculum, which is more oriented toward numeracy problems. Thus, this research aims to know the collaboration skills and creative mathematical thinking of students in the 10th grade in Problem-Based Learning for arithmetic sequences and series material using numeracy problems.

Method

This study uses a mixed method that describes students' collaboration and creative thinking skills. The quantitative approach is used to show the achievement of indicators of each ability, and the qualitative approach describes more specific student behaviors related to collaboration and creative thinking skills.

This research was carried out on 25 vocational school students majoring in accounting in Palembang, Indonesia. They were 10th-grade students who were approximately 16 years old. Students learn sequences and arithmetic series topics for two meetings. In the first meeting, students learn about arithmetic sequences. The teacher asks students to discuss the solution to the problem, as shown in Figure 1(a). In the second meeting, students learn about arithmetic sequences. The teacher asks students to discuss the solution to the problem, as shown in Figure 1(b). They learn in group discussions with five people.



(a) (b)

Figure 1. (a) Arithmetic sequence problems; (b) Arithmetic series problems

Data on the student's creative mathematical thinking was collected through tests. The creative thinking problems are validated by experts before data collection so that the instruments used in this research are valid. Figure 2 shows the creative thinking problems.

The instrument of creative mathematical thinking skills is retrieved from Suripah and Retnawati (2019), as in Table 1.

Table 1. Indicators of creative mathematical thinking skills

Number	Indicator	Descriptor
1.	Fluency	Ability to produce an idea smoothly and precisely.
2.	Flexibility	Ability to produce more than one solution method.
3.	Originality	Ability to solve problems using language, ideas, or their methods.
4.	Elaboration	Ability to detail an idea.

The percentage of creative mathematical thinking skill indicator was calculated using the following formula:

$$TS = \frac{P}{Q} \times 100$$

TS = Total Score
P = Total score obtained by students
Q = Maximum score

The results of the calculation of creative thinking skill values are grouped into several categories, namely very good (81-100), good (61-80), pretty good (41-60), not good (21-40), very not good (0-20) (Nehru, Ananda, & Navalyyan, 2022).

1. Bird migration is the movement of bird populations that occurs every year at a certain time, from breeding places to foraging places, as long as the climate in the breeding places does not allow it. No less than 60 types of raptors migrate to Southeast Asia every year. Andi is a researcher who records bird migration. It was recorded that migratory birds entered into a formation consisting of 12 rows, increasing steadily with each row. In the first row, there are 6 birds, and in the last row, there are 50 birds.
   a. Write various methods to determine the increase in bird migration in each row.
   b. How many birds in total migrate in? (Use various strategies or methods that you can)
   c. After 3 months, the birds will migrate out to form a formation consisting of 12 rows, namely the 1st row consisting of 8 birds, the 2nd row consisting of 12 birds, the 3rd row consisting of 16 birds, and so on until the row the 12th. What strategies can you use to determine the percentage increase in the number of birds migrating out compared to the number of birds migrating in? (Use more than one strategy or method as you can)

2. Andi took an academic writing course to practice his writing skills. Academic writing is the ability to write scientific work in English using good and correct rules so that Andi gets used to writing well and correctly; the teacher asks Andi to write a text every week. In week 4, the teacher asked Andi to write a text consisting of 160 words. Next, in the seventh week, Andi had to write a text consisting of 220 words. What week will allow Andi to write exactly 300 words of text? (Use various strategies or methods that you can)

Figure 2. Creative thinking problems

Collaboration skill data were collected through observation. Interviews are used to confirm student activities when collaborating in group discussions. The collaboration skills are measured by indicators adapted from Hidayati (2019) and Nahar (2022), as in Table 2.

Table 2. Indicators of collaboration skills

Number	Indicator	Descriptor
1.	Committed	• Try to solve the problems given • Don't separate yourself from your group of friends • Responsible for resolving problems promptly
2.	Respect for others	• Respect the opinions of group friends • Don't scoff at group friends who can't solve problems
3.	Deliberate	• Discuss with group friends to solve problems • Use joint decisions to solve problems
4.	Participate	• Share tasks in solving the problems given • Look for various references to solve the problems given • Give feedback in group discussions

Collaboration skills are assessed using a rubric as presented in Table 3.

Table 3. Collaboration skills rubric

Indicator	Descriptor	Rubric	Score (1-4)
Committed	Try to solve the problems given	Students do not try to solve the problems given	1
		Students sometimes try to solve the problems given	2
		Students often try to solve the problems given	3
		Students always try to solve the problems given	4
	Don't separate yourself from your group of friends	Students always separate themselves from their group of friends	1
		Students often separate themselves from their group of friends	2
		Students sometimes separate themselves from their group of friends	3
		Students never separate themselves from their group of friends	4
	Responsible for resolving problems promptly	Students are irresponsible, so they cannot solve problems promptly	1
		Students are sometimes responsible but cannot solve problems promptly	2
		Students are often responsible but cannot solve problems promptly	3
		Students are always responsible so they can solve problems promptly	4
Respect for others	Respect the opinions of friends in the group	Students never respect the opinions of their friends in the group	1
		Students sometimes respect the opinions of their friends in the group	2
		Students often respect the opinions of their friends in the group	3
		Students always respect the opinions of their friends in the group	4
	Don't make fun of friends in the group who can't solve problems	Students always make fun of friends in the group who cannot solve problems	1
		Students often make fun of friends in the group who cannot solve problems	2
		Students sometimes make fun of friends in the group who cannot solve problems	3
		Students never make fun of friends in the group who cannot solve problems	4
Deliberate	Discuss with friends in the group to solve problems	Students never discuss with friends to solve problems	1
		Students sometimes participate in discussions with friends in the group to solve problems	2
		Students often participate in discussions with friends in the group to solve problems	3
		Students always discuss with friends in the group to solve problems	4
	Using joint decisions to solve problems	Students never use joint decisions to solve problems	1
		Students sometimes use joint decisions to solve problems	2
		Students often use joint decisions to solve problems	3
		Students always use joint decisions in solving problems	4
Participate	Share tasks in solving the problems given	Students never share tasks in solving the problems given	1
		Students sometimes share tasks in solving the problems given	2
		Students often share tasks in solving given problems	3
		Students always share tasks in solving the problems given	4
	Look for various references to solve the problems given	Students do not participate in looking for various references to solve the problems given	1
		Students sometimes participate in looking for various references to solve the problems given	2
		Students often participate in looking for various references to solve the problems given	3
		Students always participate in looking for various references to solve the problems given	4
	Provide feedback in group discussions	Students do not participate in responding to group discussions	1
		Students sometimes respond to group discussions	2
		Students often respond to group discussions	3
		Students always respond to group discussions	4

Based on the score of the rubric, the percentage of collaboration skill indicators was calculated using the following formula:

$$TS = \frac{SC}{SM} \times 100$$

TS = Total Score
SC = Accessed score
SM = Maximum score

The results of the calculation of collaboration skill values are grouped into several categories: excellent (80-100), good (60-79), sufficient (40-59), poor (20-39), and very low (0-19) (Hidayati, 2019).

Results and Discussion

Collaboration Skills

Students' collaboration skills are explored through observations when students work in groups for two meetings, meeting 1 (M-1) and Meeting 2 (M-2). The score of students' collaboration skills for each indicator is presented in Table 4.

Table 4. The score of students' collaboration skills for each indicator

No	Students	Committed	Respect for others	Deliberate	Participate	Total	Category
		Average	Average	Average	Average		
1	FA	12	8	8	12	100	Excellent
2	SIS	10	8	4	7	72.5	Good
3	MF	6.5	8	2	3	48.75	Sufficient
4	VSR	11	8	8	12	97.5	Excellent
5	IS	9	8	6	9	80	Excellent
6	AFN	12	8	8	12	100	Excellent
7	NAP	11	8	8	11	95	Excellent
8	EDR	10	8	7	11	90	Excellent
9	MYA	6.5	8	2	3	48.75	Sufficient
10	WA	10	8	4	6	70	Good
11	EM	5.5	8	2	3	46.25	Sufficient
12	IDK	10	8	7	11	90	Excellent
13	LWJ	11.5	8	8	12	98.75	Excellent
14	FAS	12	8	8	12	100	Excellent
15	AR	5	8	2	3	45	Sufficient
16	A	12	8	8	12	100	Excellent
17	BRA	10	8	7	11	90	Excellent
18	MRA	12	8	8	12	100	Excellent
19	DK	9	8	4	6	67.5	Good
20	SZ	11.5	8	8	12	98.75	Excellent
21	M	9	8	4	6	67.5	Good
22	AM	5.5	8	2	3	46.25	Sufficient
23	RS	9.5	8	4	6	68.75	Good
24	MS	10	8	6	9	82.5	Excellent
25	N	11	8	8	11	95	Excellent
Total		241.5	200	143	215		
Percentage		80.5 %	100.0%	71.5%	71.7%		

Based on Table 4, the percentage of student's collaboration skills for each category is then calculated as presented in Table 5.

Table 5. The percentage of student's collaboration skills for each category

Total Score (TS)	Frequency	Category	Percentage
80-100	15	Excellent	60%
60-79	5	Good	20%
40-59	5	Sufficient	20%
20-39	0	Poor	0%
0-19	0	Very Low	0%
Total	25		

Based on Table 5, most students are in excellent category. However, there are some students whose collaboration skills are not good. The appearance of each indicator of students' collaboration skills is supported by the following interactions in a group discussion during the learning process and an interview after the learning process.

Committed

Based on the results of observations, the commitment indicator fulfilled by students has a percentage of 80.5%. Student conversations in groups show the emergence of commitment indicators as follows.

FA : *Come on, let's start working on the students' worksheets. We are only given 45 minutes.*
AFN : *Come on, I'll start reading the questions*
FA : *OK, after that, we write down what we know, ask about the question, and then look for the answer. (For approximately 40 minutes, they tried to solve the students' worksheet problems)*
MRA : *There are only 5 minutes left; we have to write the answers on the students' worksheets.*

This statement is also supported by the results of an interview conducted by the researchers and one of the students. FA became the interview subject representing students who fulfilled the committed indicators.

R : *While working on the Student Worksheet, did you and your friends remain in the group and not separate from the group?*
FA : *We did not separate ourselves from the group; we worked on the Student Worksheets together.*
R : *Can you and your group of friends complete the Student Worksheets on time?*
FA : *Yes, it's just that the answer to the problem hasn't been written on the Student Worksheet.*
R : *Why do you and your group of friends keep trying to solve the problems on the Student Worksheet even though the problems are considered difficult?*
FA : *Because we like to work on challenging math problems*

Based on the interview results, while working on the Student Worksheet, students did not separate themselves from their group friends. They were responsible for solving problems on the

Student Worksheet using the time given. It can be seen that students are still trying to solve the problems on the Student Worksheet even though the questions given are difficult.

Respect for others

Based on the results of observations, the respect for other indicators fulfilled by students has a percentage of 100%. Student conversations in groups show the emergence of respect for others, as shown in the following indicators.

AFN : *In my opinion, what is known in activity question 1 is that 20 people is the total number of students in the second month and fourth month, or* $U_2 + U_4 = 20$.
MRA : *Sorry, but I have another opinion.*
FA : *OK, let's listen to MRA's opinion first*
MRA : *I think 20 students registered in the second month and 20 students registered in the fourth.*
AFN : *Let's read the question again to know the correct opinion.*

This statement is also supported by the interviews conducted by researchers with FA, SIS, and MF.

R : *How do you and your friends respect opinions in a group?*
FA : *We listened to the explanations of group friends who expressed their opinions, then found out whose opinion was right.*
SIS : *We listen to the explanation given.*
MF *We listened to the explanation of a friend who was having an opinion.*

Based on the interview results, all students were able to fulfil the indicators of respecting others. It can be seen that each student tries to respect the different opinions of their group friends by listening to the explanations given by their group friends and then finding out whose opinion was right.

Deliberate

Based on the results of observations, the deliberate indicator fulfilled by students has a percentage of 71.5%. Student conversations in groups show the emergence of deliberate indicators as follows.

AFN : *In my opinion, what is known in activity question 1 is that 20 people is the total number of students in the second month and fourth month, or* $U_2 + U_4 = 20$.
MRA : *Sorry, but I have another opinion.*
FA : *OK, let's listen to MRA's opinion first*
MRA : *I think 20 students registered in the second month and 20 students registered in the fourth.*
AFN : *Let's read the question again to know the correct opinion.*
FA : *If you look closely, what is known is that 20 people are the total number of students in the second month and fourth months, or* $U_2 + U_4 = 20$, *while* $U_5 + U_6 = 40$. *We use elimination and substitution to find the increase in students each month.*

AFN : *I agree with FA's opinion.*
MRA : *OK, I agree, too. So, we use the solution given by FA*

This statement is also supported by the results of interviews conducted by the researcher, FA, and SIS.

R : *Does each group member discuss with each other?*
FA : *Yes, we discussed it with each other.*
R : *Does each group member participate in making decisions to solve problems on the Student Worksheet?*
FA : *Yes, we discuss with each other to make decisions by looking for the most appropriate answers to fill in the Student Worksheet.*
SIS : *Yes, we discussed with each other to decide on solving problems on the Student Worksheet.*
R : *Does each group member use joint decisions to solve problems on the student worksheet?*
FA : *Yes*

Based on the observation results, students can produce indicators of deliberation. It can be seen that each student actively discusses with their group friends and participates in making decisions to resolve problems on the Student Worksheet.

Participate

Based on the observation results, the deliberate indicator fulfilled by students has a percentage of 71.7%. Student conversations in groups show the emergence of participation indicators as follows.

FA : *In activity 2, we are asked about the total length of the hanging blade, which means we are looking for the number of the 11th terms.*
MS : *Where did you get 11 from?*
FA : *There are 11 hanging blades, so we find the number of the 11th term.*

This statement is also supported by the results of interviews conducted by researchers with FA and SIS.

R : *Do you respond when someone in your group asks a question?*
FA : *Yes*
R : *How do you respond when someone in your group asks a question?*
FA : *We explain in a good way and don't use a high tone.*
R : *How do you and your group of friends share tasks in the group?*
FA : *There are 5 people in one group, so 2 people look for the solution, 2 look for the answer, and 1 person records the answer on the Student Worksheet. Even though there was a division of tasks within the group, I still looked for ways and answers to become material for discussion together.*
SIS : *2 people are working on Activity 1 and 3 people working on Activity 2. Researcher*
R : *Where did you and your friends look for various references to solve problems on Student Worksheets?*

FA : *From notebooks, the internet, and several applications such as Brainly and Qanda.*
SIS : *From notebooks and the internet.*

Based on the observation results, students can produce indicators of participation. It can be seen that each student shares tasks with their group friends, looks for various references to solve problems on the student worksheet, and provides feedback to each other in group discussions.

Creative mathematical thinking Skills

The percentage of students' creative mathematical thinking skills for each category is presented in Table 6.

Table 6. The percentage of students' creative mathematical thinking skills for each category

Total Score (TS)	Frequency	Category	Percentage
81-100	20	Very Good	80%
61-80	4	Good	16%
41-60	1	Pretty Good	4%
21-40	0	Not Good	0%
0-20	0	Very Not Good	0%
Total	25		

Table 6 shows that most students' creative mathematical thinking skills are in the Very Good Category. No students are in the Not Good and Very Good Categories. This means that most of the creative thinking indicators appeared in each student. These further describe the emergence of creative thinking indicators in student answers.

Analysis of MRA's Answers

Figure 3 shows that MRA fulfills the fluency indicator in problem 1a because MRA makes an idea correctly to determine the increase in bird migration for each row using trial and error. MRA also fulfills the originality indicator because, in general, to find the increase, use the formula for the nth term of an arithmetic sequence, but MRA can provide an idea for finding the increase in each row by trying one by one until finding the increase in each row is a constant value and presenting the idea in tabular form. Besides, MRA can detail the idea, and it can complete each step until the right solution is found so that it can fulfill the elaboration indicators. MRA tries to add the value of 1 to each row, but on the 12^{th} row, the result is not 50, so the addition is not constant. MRA tries to add a value of 2 to each row, but in the 12^{th} row, the result is not 50, so the addition is not constant. MRA tries to add the value of 3 to each row, but on the 12^{th} row, the result is not 50, so the addition is not constant. Next, MRA tried to add the value of 4 to each row; in the 12^{th} row, the result was 50, so the addition was constant, and the added value was 4. However, in problem 1a, MRA can only provide one solution, so it can't fulfill the flexibility indicator.

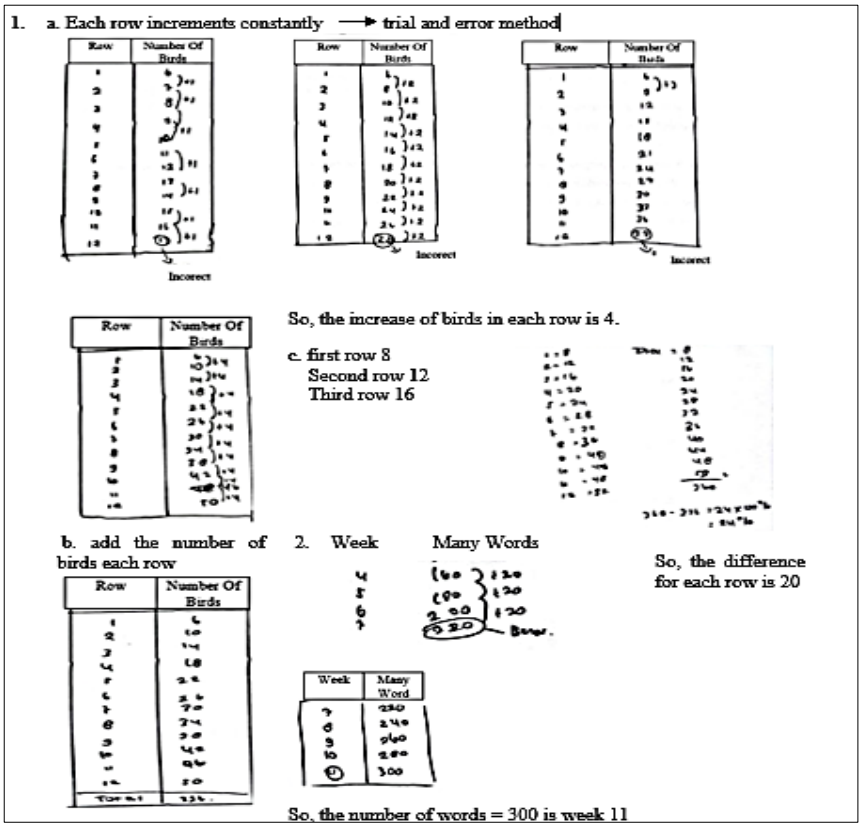


Figure 3. MRA's answers

In problem 1b, MRA can fulfill the fluency indicator because MRA can use the right idea to find the number of all birds that enter by adding the number of birds in each row. MRA also fulfills the originality indicator because usually, to find the number of birds, use the formula for the sum of the nth terms of an arithmetic series. However, MRA can provide ideas by adding the 1st until the 12th term and presenting the idea in tabular form. Besides that, MRA can fulfill elaboration indicators because it can detail its ideas until it finds the right solution. However, in problem 1b, MRA can only provide one solution, so it can't fulfill the flexibility indicator.

In problem 1c, MRA can fulfill the fluency indicator because MRA can make the right idea to find the number of all birds that come out by adding the number of birds in each row. MRA also fulfills the originality indicator because usually, to find the total number of birds, one can use the formula for the sum of the nth terms of an arithmetic series, but MRA can provide ideas by adding one by one the terms and writing ideas with the addition down. Besides that, MRA can fulfill the elaboration indicator because it can detail its ideas at each stage, but the solution provided is not appropriate.

In problem 1c, MRA can only provide one solution, so it can't fulfill the flexibility indicator. In problem 2, MRA can fulfill the fluency indicator because MRA can make the right idea to find in what week Andi can write 300 words by adding 20 words each week. MRA also fulfills the originality indicator because usually, to find the value of n, he uses the formula for the

nth term of an arithmetic sequence. However, he can use a different method by adding 20 words weekly to find the week in which Andi can write 300 words. He can also present the idea is in tabular form. Besides that, MRA can fulfill elaboration indicators because it can detail its ideas until it finds the right solution. In problem 2, MRA can only provide one solution, so RI can't fulfill the flexibility indicator.

Analysis of A's Answers

Figure 4 shows that student A fulfills the fluency indicator in problem 1a because A can correctly make an idea to determine the increase in bird migration for each row using trial and error. A also fulfills the originality indicator because, in general, to find the increase, use the formula for the nth term of an arithmetic sequence, but A can give an idea to find the increase in each row by trying to make add value 2 to each row and presents the idea with additions to the side. Besides that, A can detail her ideas, and A can complete each step until he finds the right solution so that A can fulfill the elaboration indicator. A tries to add the value of 2 to each row, but on the 12th row, the result is not 50, so the addition is not constant. Next, A tries to add the value of 4 to each row; in the 12th row, the result is 50, so the addition is constant, and the value obtained is 4. However, in problem 1a, A can only provide one solution, so A can't fulfill the flexibility indicator.

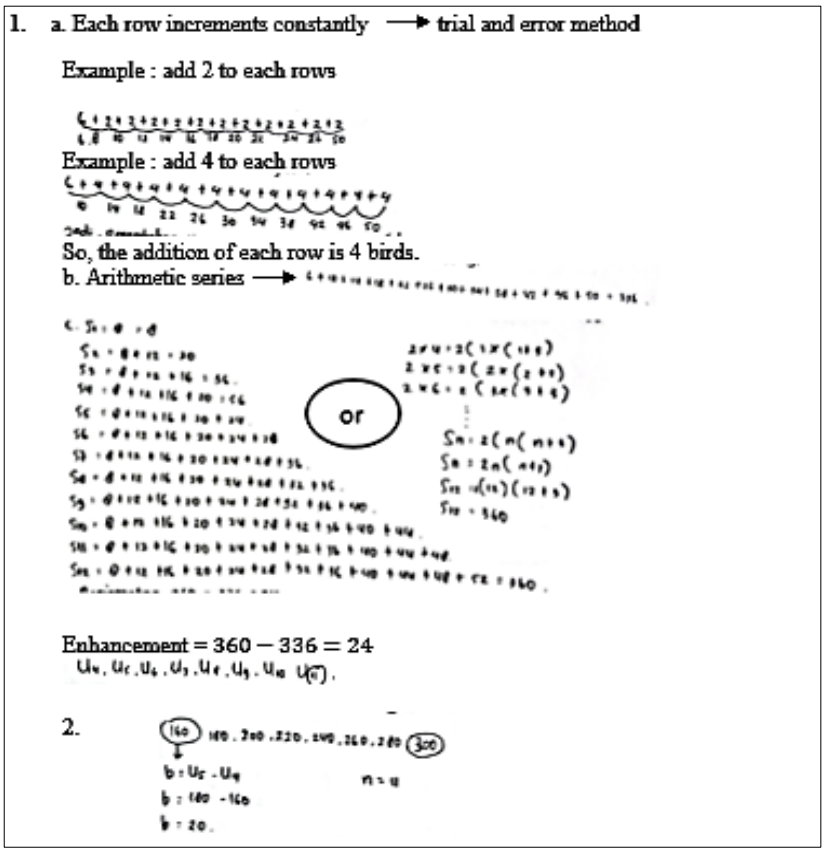


Figure 4. A's answers

In problem 1b, A can fulfill the fluency indicator because A can make the correct idea to find the number of all birds that enter by adding the number of birds in each row. A also meets the originality indicator because usually, to find the total number of birds, he uses the formula for the sum of the nth terms of an arithmetic series, but he can provide an idea by adding the 1st term to the 12th term and presenting it in the form of a sideways addition. Besides, A can fulfill the elaboration indicator because he can detail her ideas until he finds the right solution. However, in problem 1b, A can only provide one solution, so A can't fulfill the flexibility indicator.

In problem number 1c, A can fulfill the fluency indicator because A can make the right idea to find the number of all the birds that come out by adding the number of birds in each row. A also fulfills the originality indicator because usually, to find the total number of birds, one can use the formula for the sum of the nth terms of an arithmetic series, but A can provide an idea by finding the value from the sum of the first term until the sum of the 12th terms of an arithmetic series. Besides, A can fulfill the elaboration indicator because A can detail her ideas at each stage, but the solution is incorrect. In problem 1c, A can provide two different solution methods: finding the value of the sum of the 1st term until the 12th term and looking for the pattern of the nth term using a number pattern. Even though two different methods are used, A produces the same answer, so A can fulfill the flexibility indicator.

In problem 2, A was able to fulfill the fluency indicator because he was able to make the right idea to find out in what week Andi could write 300 words by looking for the increase in words each week. Student A also fulfills the originality indicator because usually to find the value of n use the formula for the nth term of an arithmetic sequence. However, A can use a different method by adding 20 words every week to find which week Andi can write 300 words and A can also present the idea is in the form of an arithmetic sequence. Besides, A can fulfill the elaboration indicator because A can detail her ideas until he finds the right solution. In problem 2, A can only provide one solution, so A can't fulfill the flexibility indicator.

Analysis of SZ's Answers

Figure 5 shows that SZ can fulfill the fluency indicator in problem 1a because SZ can make an idea correctly to determine the increase in bird migration for each row by finding the value of b using the formula for the nth term of an arithmetic sequence. SZ can also fulfill the flexibility indicator because he can use more than one solution method to determine the value of b. Even though it uses two different methods, it produces the same answer. Besides that, SZ can fulfill the originality indicator, because SZ determines the b value in an unusual way, namely $b = \frac{U_{n2} - U_{n1}}{n_2 - n_1}$. SZ can also fulfill the elaboration indicator because he can use a formula and then detail the steps to solve it until he finds the right solution. In problem 1a, SZ can provide two different solutions

so that SZ can fulfill the flexibility indicator. In problem 1b, SZ can fulfill the fluency indicator because he can make an idea to find the total number of birds by using the formula for the sum of the nth terms of an arithmetic series. SZ can also write the formula for the sum of the nth terms of an arithmetic series correctly and precisely. Besides, SZ can also fulfill elaboration indicators because he can use formulas and then detail the steps to solve them until he finds the right solution. However, in question 1b, SZ has not been able to fulfill the originality and flexibility indicators.

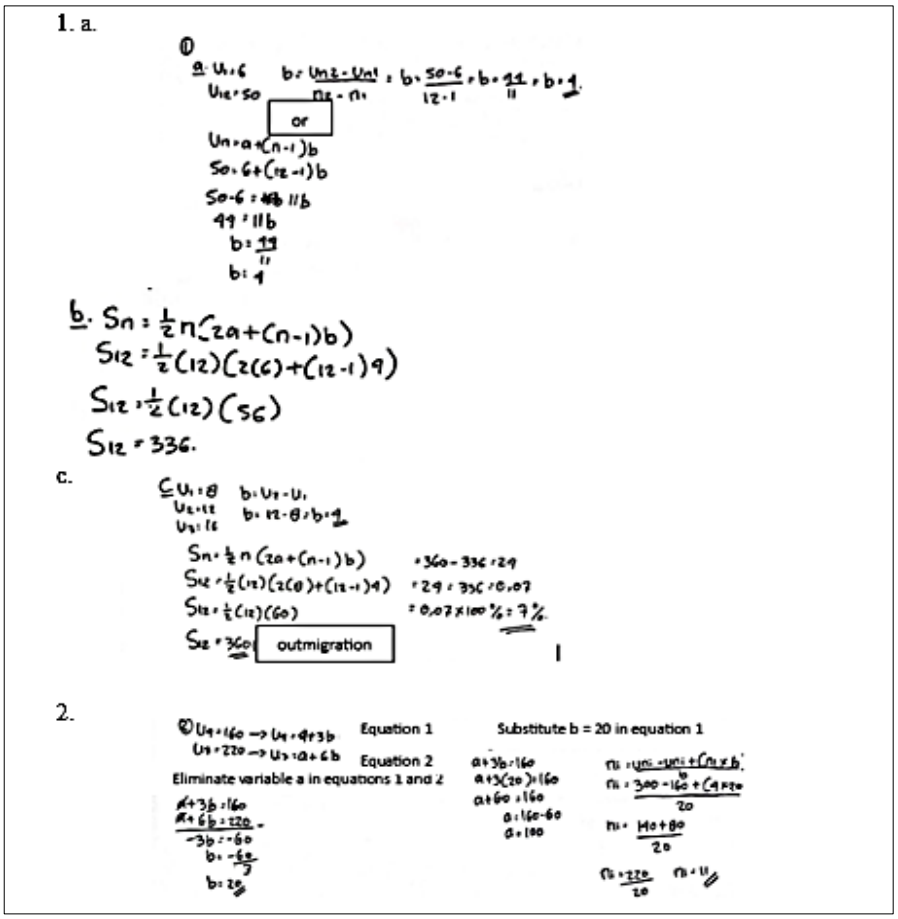


Figure 5. SZ's answers

In problem 1c, SZ can fulfill the fluency indicator because SZ determines the number of birds migrating out by using the formula for the sum of the nth terms of an arithmetic series. SZ also fulfills the originality indicator because he uses his method and ideas to determine the percentage increase in the number of birds migrating out compared to the number of birds migrating in by determining the increase first, then multiplying it by 100%, so the result is 7%. SZ also fulfills the elaboration indicator because he can use a formula and then detail the steps to complete it until he finds the right solution. However, SZ has not been able to fulfill the flexibility indicator because it only provides one solution method. In problem 2, SZ can fulfill the elaboration indicators because SZ can create ideas for finding the values a and b by elimination and substitution. Next, SZ explains the idea in detail; for example, eliminate variable a in

equations 1 and 2, then substitute the value of b in equation 1. After that, find n using an unusual method using the formula $n_i = \frac{U_{n_i} - U_{n_1} + (n_1 \times b)}{b}$ so that SZ also fulfills the originality indicator. Besides that, the SZ indicator also fulfills the fluency indicator because SZ can create ideas for finding the values a and b by elimination and substitution. However, SZ has not been able to fulfill the flexibility indicator because he only provides one solution method.

Based on the emergence of the indicators of creative mathematical thinking skills above, it can be seen that MRA can fulfill 3 indicators, namely fluency, elaboration, and originality in questions number 1a, 1b, 1c, and number 2, while MRA cannot show the flexibility indicator in every problem. Furthermore, A can fulfill three indicators, namely fluency, elaboration, and originality in problems 1a, 1b, and 2, while the flexibility indicator cannot yet appear. However, in problem 1c, A can fulfill all indicators: fluency, elaboration, originality, and flexibility. Furthermore, SZ was able to fulfill all the indicators, namely fluency, elaboration, originality, and flexibility, in questions number 1a and number 2, while in problem 1b, SZ could only fulfill two indicators, namely fluency, and elaboration, then in problem 1c, SZ was able to fulfill three indicators, namely fluency, originality, and elaboration.

The emergence of collaboration ability indicators almost appeared in all students. This happens because students are asked to work in groups to solve the numerical problems given. This is in line with Safarini's research (2019), revealing that students make substantive decisions based on group agreement, take an important role in implementing the project, and depend on each other to complete the project. This also aligns with experimental research conducted by Hidayatullah, Ariyanto, Mubarok, and Yohannes (2020), showing the difference between students who can collaborate in solving problems and students who learn in direct learning.

Based on the analysis of the emergence of collaboration indicators, overall, the indicator of collaboration skills, namely respecting others, can be shown by every student. During group discussions, students can respect their group friends who have different opinions by listening to the opinions expressed and looking for the best opinion solution to solve the problem. Furthermore, the indicators for deliberation and participation have also been met. However, they are rarely seen because only some students can fulfill the indicators for deliberation and participation during group discussions. Some students can negotiate with their group friends by discussing with each other to make decisions in solving problems. Students complete assignments and engage in discussions to expand their knowledge (Sutanto, Harenda, Arsyi, Cahyani, & Prayitno, 2021). Some students can also participate in their groups by sharing assignments and looking for various references, for example, from books or the internet. Commitment indicators have been fulfilled but are rarely seen because only some students can fulfill commitment

indicators. The reason why some students are unable to fulfill commitment indicators is that they are not able to be responsible in using their time to solve problems.

The emergence of indicators of students' creative thinking skills also occurred in almost every student. This happens because the numerical problems given are non-routine and require students to solve using possible solutions they understand. The implementation of the problem-based learning method can improve students' critical and creative thinking skills (Ernawati, Rusdi, Asrial, Muhaimin, Wulandari, & Maryani, 2022; Nurkhin & Pramusinto, 2020).

Based on the analysis of the emergence of collaboration, overall, the indicator of collaboration, respecting others, can be shown by every student. During group discussions, students can respect their group friends who have different opinions by listening to the opinions expressed and looking for the best opinion solution to solve the problem. Furthermore, the indicators for deliberation and participation have also been met. However, they are still rarely seen because only some students can fulfill the indicators for deliberation and participation during group discussions. Some students can negotiate with their group friends by discussing with each other to make decisions in solving problems. Students complete assignments and engage in discussions to expand their knowledge (Sutanto et al., 2021). Some students can also participate in their groups by sharing assignments and looking for various references, for example, from books or the internet. Commitment indicators have been fulfilled but are still rarely seen because only some students can fulfill commitment indicators. The reason why some students are unable to fulfill commitment indicators is that they are not able to be responsible in using their time to solve problems.

In solving the problems, indicators of creative mathematical thinking abilities (fluency, originality, and elaboration), have often been fulfilled by each research subject. In the fluency indicator, students can provide an appropriate idea to solve the problem (Fattayati, Masrukan, & Dwijanto, 2021). In the originality indicator, students can provide ideas in their way, which are not commonly used by most people. Next, in the elaboration indicator, students can explain the ideas they provide in detail. Meriza, Zulkardi, & Susanti, (2023) also explained that students who can fulfill the elaboration indicators can be seen when students explain their ideas in detail. Students who can fulfill the elaboration indicators can detail each step in completing them until they find the right solution.

It's just that the flexibility indicator is still rarely fulfilled in research subjects. The flexibility indicator is still rarely fulfilled because students cannot use more than one solution method. The reason is that students are accustomed to answering with only one way of solving without looking for other solutions that are different from the concepts taught in the learning process (Meriza et al., 2023). Even though students only give one solution, the answers given by

students are very diverse, such as using tables columns, sideways additions, downward additions, and formulas. Most students display creative mathematical thinking indicators because researchers use problem-based learning with numeracy problems. Research by Maskur et al. (2020) also stated that students' creative mathematical thinking skills can increase using Problem-Based Learning.

Conclusion

Students' collaboration skills show that most are in the excellent category. Students can fulfill respect for others and commitment indicators, but the indicators of deliberation and participation are rarely fulfilled. The research results on students' creative mathematical thinking skills show that 80% are in the very good category, 16% are in the good category, and others are in the pretty good category. Students can fulfil three indicators, fluency, originality, and elaboration, but flexibility is rarely fulfilled. Creative thinking skills students need to improve.

Research is limited to collaboration skills and mathematical creative thinking, so it must be researched for other skills. The implication of this research is the application of problem-based learning using numeracy problems, which can train students to solve a problem using their creative mathematical thinking skills and get used to collaborating.

Acknowledgment

The authors are grateful to Sriwijaya University for providing research funding support through the SATEKS 2023 scheme grant with rector decree number 0189/UN9.3.1/SK/2023 and research contract number 0094.091/UN9/SB3.LP2M.PT/2023.

References

Amran, A., Perkasa, M., Satriawan, M., Jasin, I., & Irwansyah, M. (2019). Assessing students 21st century attitude and environmental awareness: Promoting education for sustainable development through science education. *Journal of Physics: Conference Series*, *1157*(2), 022025.

Amrianto, F. R., Dharmawan, A., & Sari, M. S. (2023). The relationship between creative thinking, collaboration, and communication skills in high school level biology learning. *Specialusis Ugdymas*, *1*(44), 299-310.

Amsari, D., Arnawa, I. M., & Yerizon, Y. (2022). Development of a local instructional theory for the sequences and series concept based on contextual teaching and learning. *Linguistics and Culture Review*, *6*(S2), 434-449.

Ernawati, M. D. W., Rusdi, M., Asrial, A., Muhaimin, M., Wulandari, M., & Maryani, S. (2022). Analysis of problem-based learning in the scaffolding design: Students' creative-thinking skills. *Cypriot Journal of Educational Sciences*, *17*(7), 2333-2348.

Fattayati, F., Masrukan, M., & Dwijanto, D. (2021). Creative mathematical thinkingability and self-regulation character of class X students in problem based learning assisted by google classroom in terms of goal orientation. *Unnes Journal of Mathematics Education Research, 10*(2), 144–150. http://journal.unnes.ac.id/sju/index.php/ujmer

Fauzi, K., Amin, M., Dirgeyase, I. W., & Priyatno, A. (2019). Building learning path of creative mathematical thinkingof junior students on geometry topics by implementing metacognitive approach. *International Education Studies*, *12*(2), 57-66. https://doi.org/10.5539/ies.v12n2p57

Hidayati, N. (2019). Collaboration skill of biology students at Universitas Islam Riau, Indonesia. *International Journal of Scientific & Technology Research, 8*(11), 208-211.

Hidayati, N., Zubaidah, S., & Amnah, S. (2023). Effective learning model bases problem based learning and digital mind maps to improve student's collaboration skills. *International Journal of Evaluation and Research in Education (IJERE), 12*(3), 1307-1314.

Hidayatullah, R. S., Ariyanto, S. R., Mubarok, H., & Yohannes, A. (2020). Collaborative problem-based Learning: An analysis of problem-solving skills in vocational schools. *IJORER: International Journal of Recent Educational Research, 1*(3), 209-217.

Kardoyo, Nurkhin, A., Muhsin, & Pramusinto, H. (2020). Problem-based learning strategy: Its impact on students' critical and creative thinking skills. *European Journal of Educational Research, 9*(3), 1141–1150. https://doi.org/10.12973/EU-JER.9.3.1141

Nurkhin, A., & Pramusinto, H. (2020). Problem-based learning strategy: Its impact on students' critical and creative thinking skills. *European Journal of Educational Research, 9*(3), 1141-1150.

Maskur, R., Sumarno, Rahmawati, Y., Pradana, K., Syazali, M., Septian, A., & Palupi, E. K. (2020). The effectiveness of problem based learning and aptitude treatment interaction in improving mathematical creative thinking skills on curriculum 2013. *European Journal of Educational Research, 9*(1), 375–383. https://doi.org/10.12973/eu-jer.9.1.375

Meriza, D., Zulkardi, Z., & Susanti, E. (2023). Kemampuan berpikir kreatif matematis konteks monpera pada materi kaidah pencacahan. *Delta-Pi: Jurnal Matematika dan Pendidikan Matematika, 12*(1), 38–50. https://doi.org/10.33387/dpi.v12i1.5454

Nahar, S. (2022). Improving students' collaboration thinking skill under the implementation of the quantum teaching model. *International Journal of Instruction, 15*(3), 451-464.

Nehru, N., Ananda, R., Zb, A., & Navalyyan, D. (2022). The analysis of mathematical critical thinking ability and mathematical creativity: Judging from the process of deriving the fermi-dirac formula. *International Journal of Education and Teaching Zone, 1*(2), 87-96.

Nurkhin, A., & Pramusinto, H. (2020). Problem-based learning strategy: Its impact on students' critical and creative thinking skills. *European Journal of Educational Research, 9*(3), 1141-1150.

Nurlaily, V. A., Soegiyanto, H., & Usodo, B. (2019). Elementary school teacher's obstacles in the implementation of problem-based learning model in mathematics learning. *Journal on Mathematics Education, 10*(2), 229–238. https://doi.org/10.22342/jme.10.2.5386.229-238

Prafianti, R. A., Novitasari, N., Albab, M. U., & Ambarwati, D. N. (2023). Analysis of student's creative thinking ability on arithmetic sequences in the lesson study framework. *Vygotsky: Jurnal Pendidikan Matematika dan Matematika*, *5*(1), 55-64.

Ramadhani, R., Farid, F., Lestari, F., & Machmud, A. (2020). Improvement of creative thinking ability through problem-based learning with local culture based on students' gender and prior mathematics ability. *Al-Jabar: Jurnal Pendidikan Matematika, 11*(1), 61-72.

Safarini, T. D. (2019). Developing students' collaboration skills through project-based learning in statistics. *ournal of Physics: Conference Series*, *1265*(1), 012011.

Selvy, Y., Ikhsan, M., Johar, R., & Saminan. (2020). Improving students' creative mathematical thinkingand motivation through GeoGebra assisted problem based learning. *Journal of Physics: Conference Series*, *1460*(1), 012004. https://doi.org/10.1088/1742-6596/1460/1/012004

Simanjuntak, M. P., Hutahaean, J., Marpaung, N., & Ramadhani, D. (2021). Effectiveness of problem-based learning combined with computer simulation on students' problem-solving and creative thinking skills. *International Journal of Instruction*, *14*(3), 519–534. https://doi.org/10.29333/iji.2021.14330a

Siregar, M. B., & Narpila, S. D. (2023). Influence of problem-based learning model on students' critical thinking ability and learning motivation in mathematics learning. *Numerical: Jurnal Matematika dan Pendidikan Matematika*, *7*(2), 263-274.

Suripah, S., & Retnawati, H. (2019). Investigating students' creative mathematical thinkingskill based on academic level and gender. *International Journal of Scientific & Technology Research*, *8*(8), 227-231.

Sutanto, A. R., Harenda, A. P., Arsyi, M. A., Cahyani, S. N., & Prayitno, B. A. (2021). The profile of collaboration skills of science students in SMA Negeri 07 Surakarta. *Jurnal Pendidikan Biologi*, *10*(1), 9-15.

Yayuk, E., Purwanto, As'Ari, A. R., & Subanji. (2020). Primary school students' creative thinking skills in mathematics problem solving. *European Journal of Educational Research*, *9*(3), 1281–1295. https://doi.org/10.12973/eu-jer.9.3.1281

Yu, M. V. B., Liu, Y., Hsieh, T. Y., Lee, G., Simpkins, S. D., & Pantano, A. (2022). "Working together as a team really gets them fired up": Afterschool program mentoring strategies to promote collaborative learning among adolescent participants. *Applied Developmental Science*, *26*(2), 347-361.