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Mathematical Problem-Solving Ability Viewed from Self-Emotions: Case Study through Problem-Based Learning

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ABSTRACT

Problem-solving ability is a skill that individuals must possess in the process of planning, making plans, implementing plans, and reviewing the correctness of the solutions obtained. However, many students still have difficulty solving the given problems. Self-emotion is an important factor in problem-solving because it is related to positive and negative emotions in responding to the questions given. To stimulate problem-solving abilities and control self-emotions, the PBL model is applied. The objectives of this study are (1) to describe students' problem-solving abilities in terms of self-emotions through the PBL model, and (2) to link mathematical problem-solving abilities with students' self-emotions. The study was conducted in a junior high school class VIII-H in West Bandung, Indonesia with 33 students. This study used a mixed qualitative-quantitative approach. For quantitative research, a One-Group Pretest-Posttest design was used. Data collection methods used a self-emotion questionnaire sheet, test questions, and semi-structured interviews. Data analysis was performed using SPSS 24 and NVIVO 12 software. This study shows that self-emotions play a significant role in students' mathematical problem-solving abilities through the application of Problem-Based Learning (PBL). Quantitative results indicate an increase in problem-solving abilities from pre-test to post-test in students with both positive and negative emotions, with better final outcomes in students with positive emotions. Qualitatively, students with positive emotions were able to systematically fulfill all stages of problem-solving according to Polya, while students with negative emotions only fulfilled some indicators and showed limitations in reflection and justification of solution steps. These findings confirm that PBL is not only effective in improving mathematical problem-solving abilities but also helps manage students' emotions during the learning process. Thus, the Problem-Based Learning model not only contributes to improving mathematical problem-solving abilities but also plays a role in managing and suppressing students' negative emotions during the learning process. Therefore, PBL can be recommended as an effective learning model for developing mathematical problem-solving abilities while supporting students' emotional regulation in mathematics learning.

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A. INTRODUCTION

The ability to solve mathematical problems is one of the key skills that students must possess within the real of mathematics education (Setiawan & Wahyuni, 2024; Tien-Trung et al., 2025). In a global context, problem-solving is not only regarded as a mathematical process but also as an essential skill required in daily life and the workplace. According to Amanah & Junaedi (2025); Santos-Trigo (2024); Tien-Trung et al. (2025), problem-solving in mathematics

education has become a primary focus in both research and teaching practices, particularly due to its capacity to foster critical thinking and creativity among students. However, despite the numerous teaching methods that have been implemented, students often still encounter difficulties in resolving mathematical problems.

The difficulties experienced by students in resolving mathematical problems arise from their inability to master various mathematical skills and a lack of cognitive abilities in learning (Hidayati & Shodikin, 2025; Tambychik & Meerah, 2010). Furthermore, Tambychik and Meerah (2010) emphasize that information skills are identified as the most critical mathematical skills due to their relationship with the process of information transfer, whereby an individual can comprehend and establish effective connections between pieces of information. Meanwhile, cognitive abilities in learning, such as the capacity to remember, memorize, and understand, significantly influence efficiency in problem-solving. Additionally, according to Saputri et al. (2024), students frequently encounter difficulties in problem-solving that are also related to operational skills. Factors contributing to these difficulties include students perceiving mathematics as a daunting subject, the suboptimal use of learning media, and students being more accustomed to solving routine problems.

In addition to the difficulties that have been outlined, one factor that also influences students' problem-solving abilities is their emotional state. Research indicates that emotions can affect the way students interact with mathematical tasks and can impact their performance (Corwin et al., 2022); (Muhtadi et al., 2022). According to Schiepe-Tiska and Schmidtner, as cited in (Kuzle, 2021), emotions play a significant role in shaping behaviour within educational environments, as well as influencing students' enthusiasm for learning and their drive to succeed, both of which are vital for fostering a positive school atmosphere. Positive emotions like self-assurance and motivation can boost students' participation in the learning journey, while detrimental emotions such as anxiety and frustration can hinder their capacity for critical thinking and problem-solving (Göller & Gildehaus, 2021). Thus, it is essential to investigate how students' emotional conditions can affect their abilities in tackling mathematical problems.

Problem-Based Learning (PBL) has been recognised as an effective method for improving students' abilities in problem-solving (Sapan et al., 2020; H. Xu et al., 2022; X. Xu et al., 2022). This approach promotes active participation from students in the learning experience by tackling pertinent and contextual issues. As a result of this framework, learners not only acquire problem-solving skills but also cultivate emotional regulation when confronted with difficulties (Fiteriani et al., 2021; Tze et al., 2023). Previous studies have indicated that PBL can enhance both the problem-solving capabilities of students and their positive emotional states, which subsequently can lead to better educational outcomes (Parno et al., 2020). Specifically, the relationship between problem-based learning models, problem-solving abilities, and self-emotions can be presented in the form of a vosviewer as shown in Figure 1.

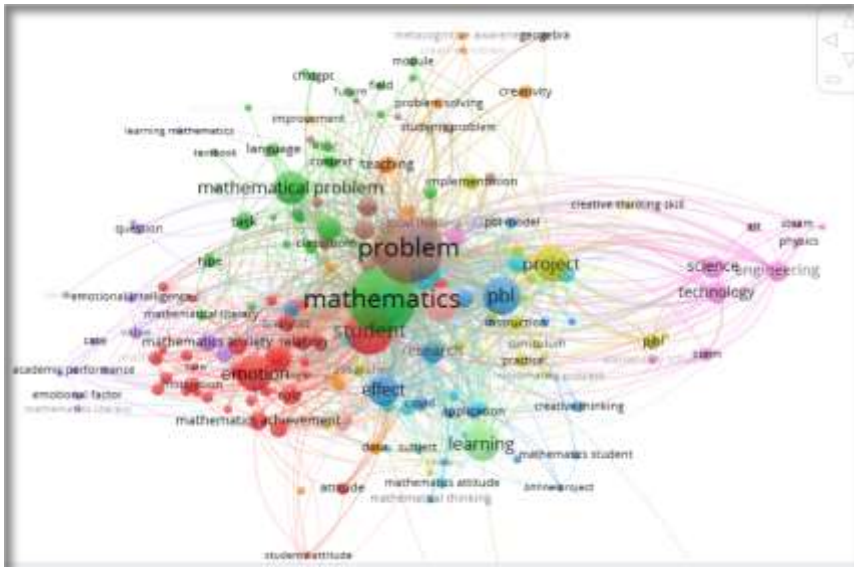


Figure 1. Vosviewer PBL, Problem-Solving, and Self-Emotion

Figure 1 shows that numerous international studies have been conducted over the past seven years on PBL, problem-solving, and emotions. However, these studies tend to link problem-solving with emotions, PBL with emotions, or problem-solving with PBL. The reviewer has not yet demonstrated a clear relationship between problem-solving, PBL, and emotions. Yet, all three are closely related and influence each other. According to Danuri et al. (2021); Erawati & Permana (2020); Suparman et al. (2021); Suryani et al. (2020), PBL significantly improves students' mathematical problem-solving skills in Indonesia. However, problem-solving ability is strongly influenced by emotions. This is supported by research by Bieleke et al. (2023); Riegel & Evans (2021) which found that students with high levels of positive emotions demonstrated better academic performance in problem-solving compared to those with negative emotions. Therefore, Tze et al. (2023) revealed that when students' emotions are well-managed, they can act as a strong mediator in the relationship between PBL and problem-solving ability. Indirectly, positive emotions such as self-confidence and motivation contribute to increased student self-efficacy, which in turn supports their problem-solving abilities.

Based on the explanation above, it was found that the PBL model is important for problem-solving ability and that self-emotion is very important in supporting problem-solving ability. This finding opens up opportunities for further research in this context. Therefore, this study aims to describe students' problem-solving ability in terms of self-emotion through a problem-based learning model, and to find out the conjecture that links problem-solving ability with students' self-emotion through a problem-based learning model. By understanding how emotions influence the problem-solving process, it is hoped that more effective strategies can be found in teaching mathematics to students. In addition, this study will also provide insights into how teachers can create a learning environment that supports positive emotions and student engagement in mathematical problem-solving.

B. METHODS

The design of this research employs a mixed-methods approach, incorporating both qualitative and quantitative methodologies, to obtain accurate data regarding students' problem-solving abilities. From a quantitative perspective, a One-Group Pretest-Posttest design is used to measure problem-solving abilities before (pretest) and after treatment (posttest) in a group of students to see the effects of the intervention and to compare the scores statistically. This design can be described as follows.

Pretest	Treatmeant	Posttest
O_1	X	O_2

Description: O1 is Problem-solving pretest; O2 is Problem-solving posttest; and *X* is PBL model. The sample in this study was 33 students in grade VIII-H of a public junior high school in West Bandung, Indonesia. Furthermore, to obtain qualitative data, the researcher conducted interviews with two groups of students based on their emotional categories to explore their problem-solving practices. Interviews were conducted based on Polya's problem-solving indicators Tohir et al. (2020) until data saturation was reached. This means that the students' answers during the interviews appeared consistent, leading to the termination of the interviews. Since the data obtained from the emotional categories had reached saturation, the researcher decided to randomly select two students representing each of the positive and negative emotions for analysis. According to Creswell Mastuti et al. (2022), with qualitative methods, factors related to the research object can be presented in depth.

The instruments used in this study included problem-solving test questions, including pretests and posttests, a self-emotion questionnaire, and a semi-structured interview guide. The self-emotion questionnaire was administered at the beginning of the meeting to identify students' positive and negative emotions. The emotion questionnaire was adapted from Bieleke et al. (2023) and employs a Likert scale ranging from 1 to 5. Before its application in the research, the questionnaire underwent testing for validity and reliability. A total of 60 items were utilized to measure self-emotion. The validity analysis revealed that for pleasure (α=0.047 and r=0.52), pride (α=0.002 and r=0.724), anger (α=0.026 and r=0.572), anxiety (α=0.008 and r=0.659), shame (α=0.002 and r=0.743), despair (α=0.000 and r=0.829), and boredom (α=0.047 and r=0.520), each of which exhibited α values less than 0.05 or r values exceeding 0.3, thus confirming their validity. Subsequently, the reliability testing yielded a Cronbach's Alpha value of 0.641 (indicating a high criterion) which exceeds the threshold of 0.6, leading to the conclusion that the instruments employed are reliable. Meanwhile, student work data were collected through the administration of tests after learning sessions employing a Problem-Based Learning (PBL) model. Following this, the researcher conducted follow-up interviews to delve deeper into the students' thought processes regarding the mathematical problem-solving tasks presented. The interview activities were carried out with both groups exhibiting positive and negative emotions until data saturation was achieved. Data saturation was determined to occur during the third round of interviews within each emotional category, at which point the interview process was ceased and not continued with subsequent student interviews.

Data analysis was conducted using the SPSS 24 software application and the NVIVO 12 application. The results of the data analysis from SPSS 24 were utilized to quantitatively

describe students' problem-solving abilities about their self-emotion. Subsequently, the analysis results from NVIVO 12 were employed to derive conjectures linking students' problem-solving abilities with their self-emotion.

C. RESULT AND DISCUSSION

1. Description of Students' Self-Emotios Categories

Following the analysis of the students' self-emotion questionnaire results, the data were subsequently classified into two categories: positive emotions and negative emotions. The categorization data regarding the students' self-emotions can be presented in the following Figure 2.

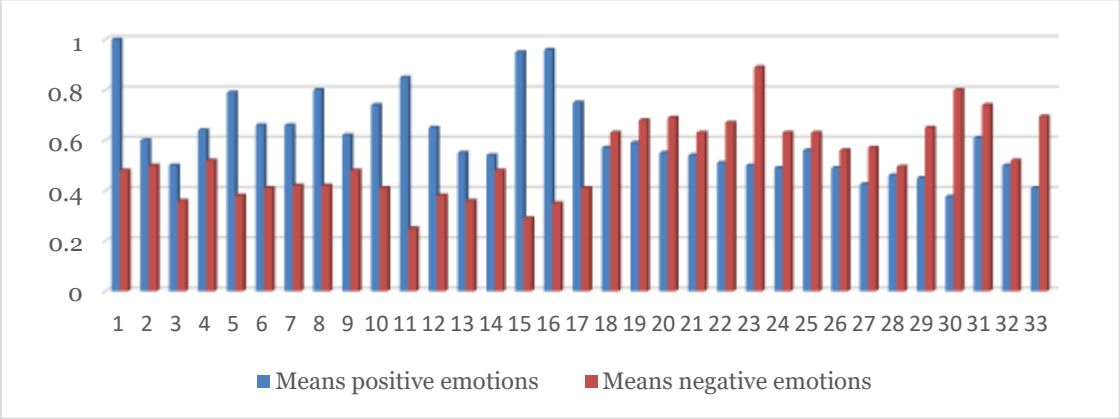


Figure 2. Data self-emotions

Based on Figure 2, it can be observed that out of a total of 33 students who completed the self-emotion questionnaire, 17 students exhibited positive emotions, while the remaining 16 students displayed negative emotions. Furthermore, an analysis of the indicators of positive and negative emotions can be found in Figure 3.

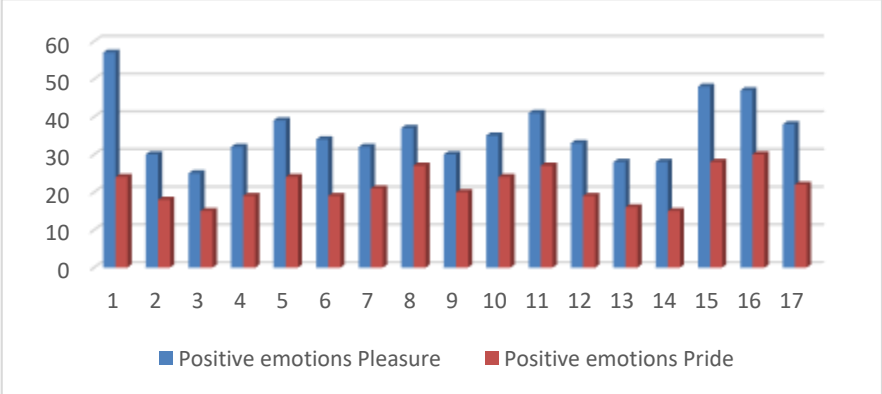


Figure 3. Positive emotions

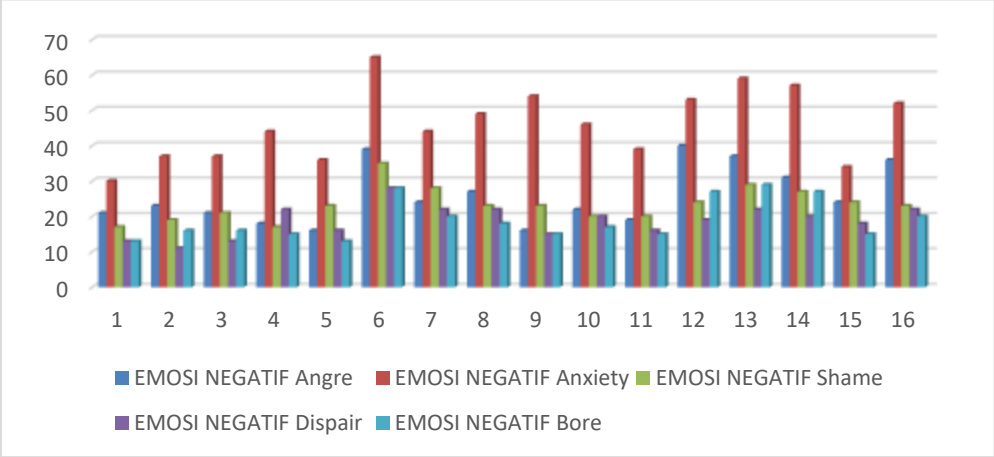


Figure 4. Negative emotions

Figure 4 illustrates that the most dominant indicator of positive emotion among the 17 students is the enjoyment derived from studying mathematics. In contrast, Figure 3 reveals that the negative emotion indicator predominantly experienced by 16 students is anxiety, as compared to the other indicators.

2. Description of Students' Problem-Solving Abilities According to Self-Emotion Category

To commence the learning activities, the researcher first administered a preliminary test to the students to obtain an initial understanding of their problem-solving abilities. This assessment serves as a reference for designing classroom instruction using the Problem-Based Learning (PBL) model. Subsequently, after the learning process, following three sessions, the students were given a final test to evaluate their problem-solving skills, to determine the students' ultimate achievements. The results of both the preliminary and final tests can be observed in the following Table 1 and Table 2.

Table 1. Self-emotions pre-test (Dependent Variable: Pretest KPM)

Self-emotions	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Positive emotions	39.464	4.557	30.158	48.770
Negative emotions	41.944	4.155	33.458	50.431

Table 2. Self-emotions post-test (Dependent Variable: Posttest KPM)

Self-emotions	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Positive emotions	63.725	5.175	53.156	74.293
Negative emotions	61.111	4.719	51.473	70.749

Table 1 demonstrates that the average pre-test score for problem-solving ability among students experiencing negative emotions, at 41.944, is higher than the average pre-test score for students with positive emotions, which stands at 39.464. Furthermore, as illustrated in Table 2, the average post-test score for problem-solving ability among students with positive emotions, at 63.725, exceeds the average post-test score for students with negative emotions,

recorded at 61.11. Additionally, there is a notable improvement in problem-solving ability from the initial test to the final test.

3. Conjecture That links Problem-Solving Ability With Students' Self-Emotion Through a Problem-Based Learning (PBL) model

After conducting a quantitative analysis, the researcher endeavors to explore the relationship between self-emotion and students' problem-solving abilities through a qualitative approach.

a. RP students with positive emotions in solving problems

After reading the provided questions, the students began to work on them by noting down initial information, as evidenced in the following excerpt of their work, as shown in Figure 5.

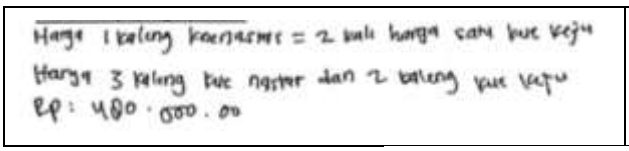
	The price of 1 can of pineapple cake = 2 times the price of one cheese cake. The price for 3 cans of pineapple cake and 2 cans of cheese cake is Rp. 480,000

Figure 5. Understand the problem

Based on the test data, it is evident that the subject RP possesses a comprehensive understanding of the given problem. The subject RP articulates all the information contained within the question, both the known elements and those being queried, with remarkable ease. In addition to this information, RP also emphasizes the initial conditions that need to be grasped to assist in resolving the problem at hand. During the interview, the subject RP stated, “One tin of pineapple cookies is valued the same as two tins of cheese cookies, which is a crucial condition that allows for the determination of the price of each type of cookie, with a total amount of 480,000.” Furthermore, the subject RP asserts that the information provided in the question is sufficiently clear to facilitate answering the requirements of the problem. After comprehending the issue, the subject RP proceeds to devise a resolution plan. This is illustrated in the following manner, as shown in Figure 6.

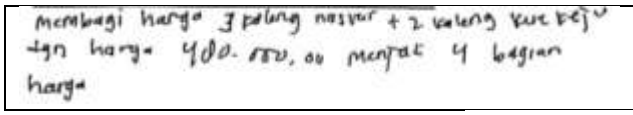
	Divide the price of 3 cans of pineapple cake + 2 cans of cheesecake at a price of Rp480,000 into 4 parts

Figure 6. Make a plan

Strengthened by interviews.

P : Have you ever seen a question like this before?
RP : Once
P : Can you please tell us what kind of problems you have seen?
RP : The problem is that there is a price of a book and a price of a pen. Later, the price of a book and the price of a pen will be searched for. There are also times when the teacher gives questions that are directly in the equation, so we solve them right away.

P : Can you see any connection between the question you told me about and this question?

RP : Mmm, there is sir. The first question uses pineapple cookies and cheese cookies. Well, in the question I told you about, it uses a pen and a book. But the point is the same.

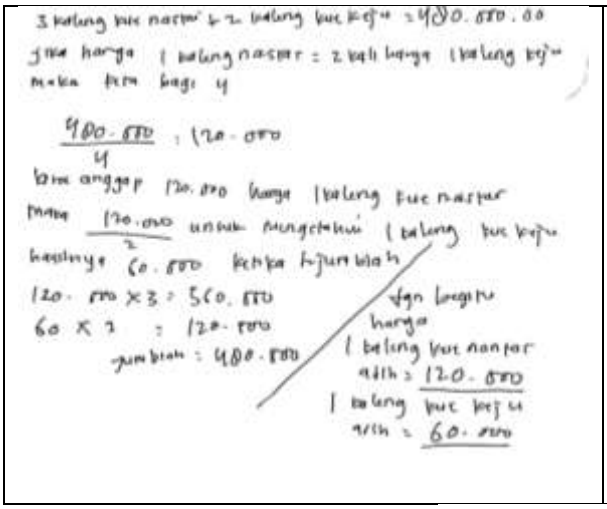
P : Do you know the formula to solve it?

RP : Mmm, I will answer this by dividing the price of the cake into 4 parts.

P : Why should it be divided into 4 parts? Please explain!

RP : There is a similarity in that the price of 1 pineapple cake is the same as the price of 2 cheesecakes. This means that pineapple cakes are more expensive. So I just assume that 4 pineapple cakes cost Rp480,000.

Based on Figure 6 and excerpts from the interview results, it is evident that the subject RP formulates a resolution plan by referencing analogous information, specifically that the price of one tin of pineapple cookies is equivalent to the price of two tins of cheese cookies. Consequently, from this information, the subject RP connects it with a second piece of information, namely that three tins of pineapple cookies plus two tins of cheese cookies amount to 480,000. By integrating these two pieces of information, the subject RP substitutes the first piece of information with the second, thereby determining that the total price of 480,000 can be divided into four parts corresponding to the four tins of pineapple cookies. This demonstrates that the subject RP tends to correlate the available information to facilitate the discovery of solutions to a given problem. Furthermore, the subject RP also expressed that a similar issue had been encountered previously during learning activities. However, the problem presented was slightly different from the concepts that had been previously taught. This indicates that the subject RP has prior experience related to the problem at hand and is capable of formulating a strategy that can be employed in problem-solving. Although the formula devised is not directly represented in symbolic form, it can convey an equivalent meaning. The subject RP then proceeded to execute the following plan, as shown in Figure 7.



3 cans of pineapple cake + 2 cans of cheesecake = Rp480,000
If the price of 1 can of pineapple cake is twice the price of 1 can of cheesecake, then divide the cheesecake price by 4.
Consider Rp120,000 for 1 can of pineapple cake, then $\frac{120.000}{2}$ to find the price of 1 can of cheesecake, resulting in Rp60,000. When added together, we get:

Rp120,000 x 3 = Rp360,000
Rp60,000 x 2 = Rp120,000
Total = Rp480,000

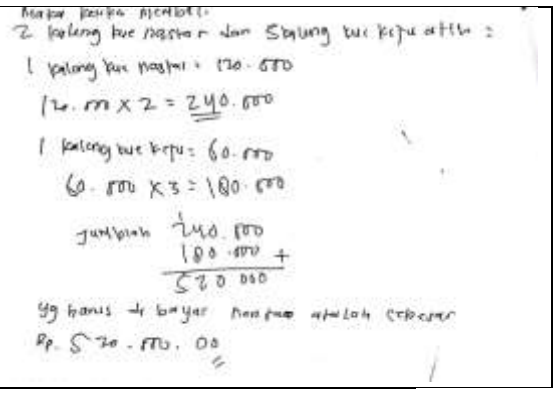
Therefore, the price of 1 can of pineapple cake is Rp120,000 and the price of 1 can of cheesecake is Rp60,000

Figure 7. Execute the plan

Strengthened by interviews.

P : Ok, next try to tell me how you answered that question.
RP : As I said earlier, because the price of pineapple cookies is more expensive per piece, the price of 3 cans of pineapple cookies + 2 cans of cheese cookies = 480,000 can be 3 cans of pineapple cookies + 1 can of pineapple cookies = 480,000. After that, 4 cans of pineapple cookies = 480,000 are obtained. That's why I said earlier that it was divided into 4 parts of pineapple cookies. So if divided by 4, the price of 1 can of pineapple cookies = 120,000.
P : Next, how do you get the price of 1 can of cheesecake?
RP : So, to find out the price of 1 can of cheesecake, it means 120,000: 2 = 60,000.
P : Why should it be divided into two?
RP : Eee because the question says the price of 1 can of pineapple cake = the price of 2 cans of cheesecake. This means that half the price of 1 can of pineapple cake is the same as the price of 1 can of cheesecake.
P : Are you sure the steps you are using are correct?
RP : Sure sir
P : What is the basis for you being sure about your answer?
RP : Here (pointing to his work), I operate 120,000 x 3 = 360,000 and 60,000 x 2 = 120,000 so that when added up 360,000 + 120,000 = 480,000. Thus, I am sure the answer is correct.

Based on Figure 7 and the interview, it is evident that the subject RP, in determining the price of one tin of pineapple cookies and one tin of cheese cookies, utilized the correlation present in the initial information, wherein the price of one tin of pineapple cookies is equivalent to the price of two tins of cheese cookies. With this information, the subject RP substituted values into the equation derived from the second piece of information, resulting in the equation stating that the price of four tins of pineapple cookies is equal to 480,000. Consequently, the price of one tin of pineapple cookies is determined to be 120,000. To ascertain the price of one tin of cheese cookies, the subject RP again substituted the price of one tin of pineapple cookies into the equation, leading to the conclusion that the price of one tin of cheese cookies is 60,000. To validate the results obtained, the subject RP conducted a verification by substituting the prices of each tin of cookies into the second equation, as illustrated in the subject's work, thereby yielding the same total of 480,000. Through this verification process, the subject RP concluded the accuracy of the findings, affirming that the price of one tin of pineapple cookies is 120,000 and the price of one tin of cheese cookies is 60,000. This demonstrates that the subject RP is capable of scrutinizing the solutions derived through a verification method, which reinforces their confidence in the correctness of the obtained answers. The final stage involves a review, as evidenced in the following excerpt, as shown in Figure 8.



So when buying,
2 cans of pineapple cake and 3 cans of cheesecake, the cost is:
1 can of pineapple cake = Rp. 120,000
Rp. 120,000 x 2 = Rp. 240,000
1 can of cheesecake = Rp. 60,000
Rp. 60,000 x 3 = Rp. 180,000
Total Rp. 240,000 + Rp. 180,000 = Rp. 520,000.
Nada has to pay Rp. 520,000.

Figure 8. Looking back

Strengthened by interviews.

P : Next, how much money do you have to pay?
RP : The amount of money to be paid is 520,000
P : Where did you get those results from?
RP : Yes, you were asked for 2 cans of pineapple cake and 3 cans of cheese cake so 1 can of pineapple cake = 120,000 so 120,000 x 2 = 240,000. then 1 can of cheesecake = 60,000 so 60,000 x 3 = 180,000. the resulting sum is 240,000 + 180,000 = 520,000.
P : Can you double-check the results you got? Try checking again
RP : Yes (the subject looks back at the results of his work), but the answer is correct, sir.
P : Try adding it up again.
RP : Ouch, wrong sir,,, it should be 420,000 sir, I added it up wrong.
P : Ok, you have realized the mistake. Is there any other method that can be made from the problem?
RP : It is possible, but I understand it better that way.
P : Next, what is the conclusion that can be made?
RP : Oh, so what Nada has to pay is 420,000

Based on Figure 6 and excerpts from the interview, it was found that the subject RP calculated the total amount to be paid for the purchase of 2 cans of pineapple cookies and 3 cans of cheese cookies by substituting the price of each can of cookies into the initial equation formulated. The substitution process was carried out separately for each variable, followed by summing the two results to obtain the outcome. The subject RP performed this operation by multiplying 2 by the price of a can of pineapple cookies, which is 120,000, resulting in 240,000. Similarly, for the cheese cookies, the subject RP multiplied 3 by the price of a can of cheese cookies, which is 60,000, yielding 180,000. Subsequently, the subject RP added 240,000 and 180,000, resulting in a final total of 420,000. Initially, the subject RP arrived at an incorrect sum of 520,000. However, during the interview, the subject RP recognized the error in the addition process. The researcher provided the subject RP with an opportunity to review their work, leading to the identification of the mistake in the summation, allowing the subject RP to make the necessary corrections and arrive at an accurate final result. Furthermore, the subject RP

expressed that there were alternative methods available to solve the problem; however, the subject RP preferred to understand the situation using the approach taken. Confident in the final result obtained, the subject RP concluded that the amount to be paid was 420,000. This demonstrates that the subject RP was able to execute the solution plan effectively by following the steps correctly. Additionally, the subject RP validated the solution obtained, which instilled confidence in the decision-making process. The subject RP also meticulously reviewed their work, enabling them to recognize the errors made in the addition operation and to rectify them, resulting in the correct outcome. The subject RP articulated the existence of other methods to address the problem, yet preferred the method employed. Based on the process undertaken, the subject RP was able to formulate a correct conclusion. In summary, the hypothesis that emerges from the topic of RP regarding the capacity to tackle mathematical challenges in the context of positive emotions via a problem-based learning approach can be articulated as shown in Figure 9.

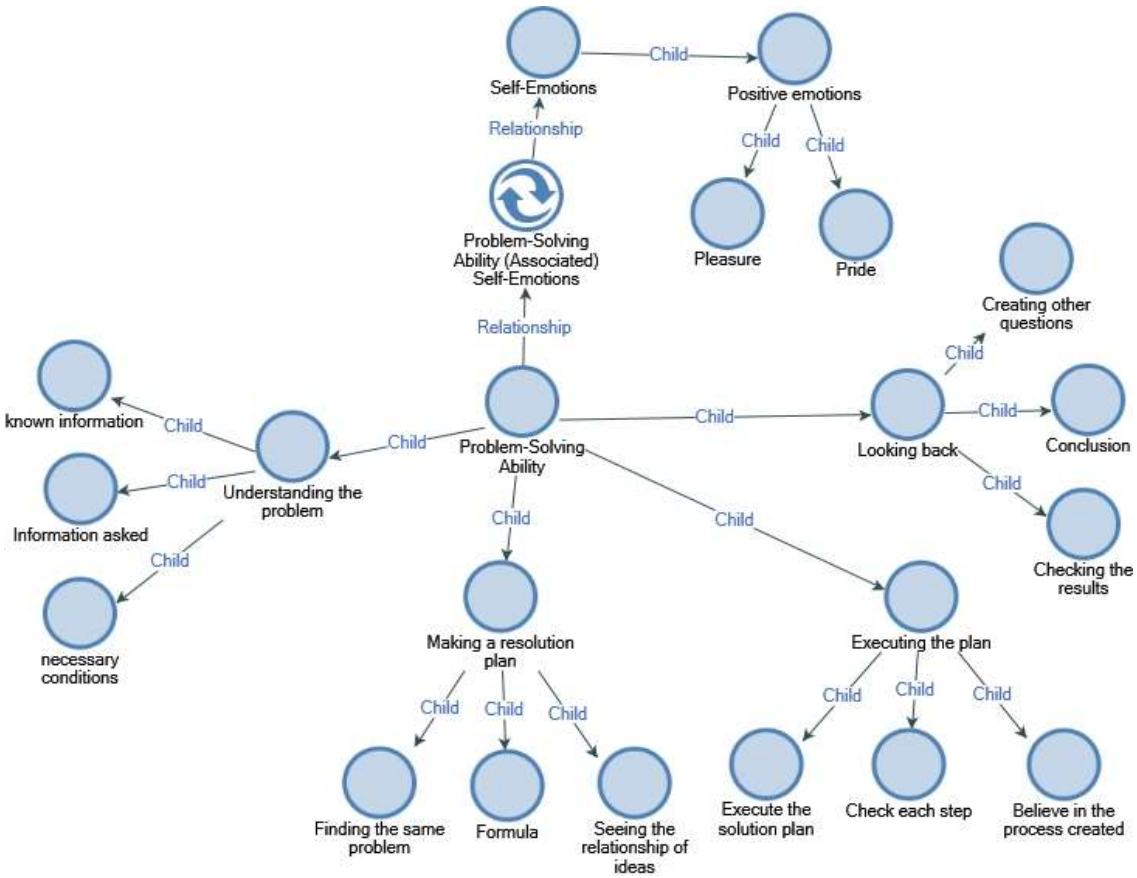


Figure 9. Konjektur self-emotions with problem-solving ability

b. SB students with negative emotions in solving problems

The subject SB serves as a representative of the category of negative emotions in problem-solving. The problem-solving process of subject SB begins with reading the provided question, followed by recording the information obtained from their reading. This is exemplified in the following excerpt of subject SB's response, as shown in Figure 10.

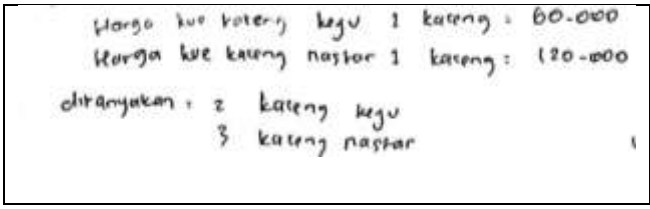
	Price of 1 can of cheese cake = Rp. 60,000 Price of 1 can of pineapple cake = Rp. 180,000 Asked, 2 tins of cheesecake 3 cans of pineapple cake

Figure 10. Understanding the problem by SB

Strengthened by interviews.

P : After reading the question, what information do you get?

SB : Eee, in the question it says that the price of 1 can of cheese cake is 60,000 and the price of 1 can of pineapple cake is 120,000. Will you look for 2 cans of cheese and 3 cans of pineapple?

P : Take another look, is the information you provided correct?

SB : Mmm, oh sorry sir, what should be asked is 3 cans of cheese and 2 cans of pineapple tarts. While the 2 cans of cheese and 3 cans of pineapple tarts are the information in question with the price of 480,000

P : Ok, next, where did you get the price of 1 can of cheese cake for 60,000 and the price of a can of pineapple cake for 120,000?

SB : I made a direct estimate, sir.

P : How do you make these estimates?

SB : I, because the question says that the price of 1 can of pineapple cookies is greater than the price of 1 can of cheese cookies, which is 2 times, so I tried to take 60,000 for the price of the cheese cookies, automatically (the subject was pensive and thought for a moment .....)
Well, it's 2 times so the price of pineapple cookies is 120,000

P : Did you try another possibility as well by taking another price of cheesecake?

SB : No sir, it just so happens that it's time to take this analogy (pointing to his work)

P : Are you sure about that answer?

SB : (Pause for a moment),

According to the sections of the study showcased in Figure 8 and the findings from the interviews, it is evident that the subject SB is capable of articulating the information contained within the questions; however, the information provided is incomplete. Furthermore, the information that was recorded tends to contain inaccuracies. Upon confirmation, the subject SB acknowledged the errors noted in their responses, which were subsequently rectified during the interview. Additionally, when tasked with documenting the information from the questions, the subject SB immediately assigned prices to both a tin of pineapple cookies and a tin of cheese cookies. The process of determining this information, as described by the subject, was conducted through estimation based on the conditions stipulated in the question, namely that "the price of a tin of pineapple cookies is greater than the price of a tin of cheese cookies by a factor of two." However, when the researcher sought to confirm this by testing alternative estimates, it became apparent that the subject SB did not pursue this avenue, as their

initial estimate happened to be correct. Nonetheless, the subject SB expressed a lack of confidence in the initial assumptions made. This indicates that the subject SB's articulation of the information from the questions was executed with insufficient completeness and a lack of precision. Subsequently, the subject SB began to formulate a resolution plan, as illustrated in the following Figure 11.

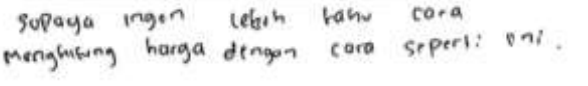
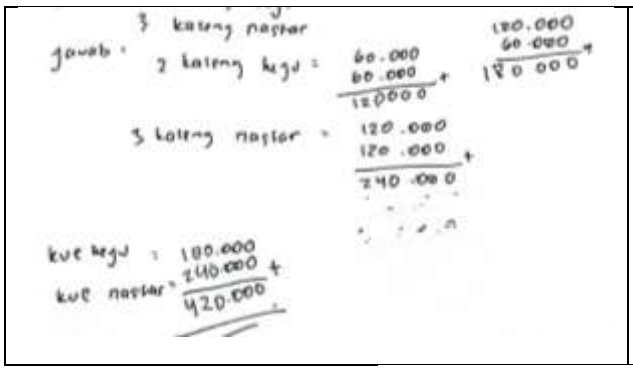
	So you want to know more about how to calculate prices in a similar way

Figure 11. Making plans by SB

Strengthened by interviews.

P : OK, what are your plans for solving this problem next?
SB : Eee I will use this method (while showing his work)
P : Tell me, what kind of method is that?
SB : Yes sir, so I have already got the price of each cake (while pointing to the results of his work), now I will divert to the question that was asked so that I get the final result.
P : Ohhhhh, isn't there another way?
SB : I know this way of calculating better than any other way.
P : Have you ever encountered a similar issue, albeit presented in another manner?
SB : Oh yes, sir, when the teacher taught me about equations, but I usually prefer working this way.

Based on Figure 11 and excerpts from the interview, it appears that the subject SB tends to rely on initial information or preliminary estimates when formulating a resolution plan. The existing preliminary estimates are subsequently substituted into the questions posed to derive a final solution. Although the plan devised is not explicitly documented, the subject SB is capable of articulating verbally the steps to be undertaken to achieve the outcome. Furthermore, the subject SB expressed that they have previously encountered a similar problem when taught by their teacher in class; however, the subject SB appears to prefer working through initial estimates rather than employing a procedural approach. This indicates that the subject SB is inclined to create a resolution plan, albeit not documented. Subsequently, the subject SB began to implement the resolution plan as shown in Figure 12.



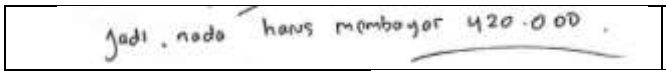
Answer
2 cans of cheesecake are Rp60,000 + Rp60,000 = Rp120,000 + Rp60,000 = Rp180,000
3 cans of pineapple cake are Rp60,000 + Rp60,000 = Rp120,000
So, cheesecake = Rp180,000
Pineapple cake = Rp240,000
Total = Rp420,000

Figure 12. Executing the plan by SB

Strengthened by interviews.

P : Next, how do you solve the problem?
SB : As I said before that 1 can of pineapple cookies is 120,000 and 1 can of cheese cookies is 60,000 so to find 2 cans of pineapple cookies, I did it by adding 120,000 + 120,000 in a row to get 240,000. Then for 3 cans of cheese cookies, I added 60,000 + 60,000 = 120,000 + 60,000 = 180,000.
Next, I added the two results I got again, which is 180,000 + 240,000 = 420,000.
P : Are you sure that every step taken to get the final result is correct?
SB : Mmm (the subject looks back at the results of his work), it seems like the answer is correct.
P : Can you prove the answer obtained?
SB : Mmm (subject looks confused)

Based on Figure 12 and excerpts from the interview with subject SB, it is evident that during the process of implementing the resolution plan, subject SB engaged in the substitution of initial information, specifically the preliminary estimates obtained, into the questions posed in the problem. In the substitution process, subject SB tended to employ cumulative addition, which is an application of repeated addition. The addition performed by subject SB involved calculating the total for two tins of pineapple cookies by summing 120,000 + 120,000 = 240,000. Subsequently, for three tins of cheese cookies, the calculation was carried out by adding 60,000 + 60,000 = 120,000 + 60,000 = 180,000. The two final results obtained were then summed, yielding a final solution of 420,000. To ensure the accuracy of the answer derived, subject SB subsequently reviewed the steps taken. However, the subject was unable to substantiate the steps followed to arrive at the correct solution. This indicates that while subject SB is generally capable of executing the resolution plan to achieve the final solution, they have yet to demonstrate the ability to validate that the steps taken were indeed correct. The final stage of this process involves a review, as illustrated in the following excerpt of the response.



So, Nada has to pay Rp. 420,000

Figure 13. Looking back at SB

Strengthened by interviews.

P : OK, then what is the conclusion reached?
SB : So the money you have to pay is 420,000
P : What is the basis for your conclusion?
SB : Because I have double-checked my work steps and there are no errors.
P : Can you use another method or way for this problem?
SB : *No sir, I can only do it like this.*
P : *But are you sure the answer is correct?*
SB : *Sure sir.*

Based on Figure 13 and excerpts from the researcher's interview with subject SB, it is evident that subject SB has reviewed each step of the resolution process undertaken, enabling them to conclude that the amount of money to be paid by Nada is 420,000. The decision made by the subject is underpinned by a conviction that the resulting answer is correct. However, about the application of the method employed for other problems, subject SB expressed that there is none. This indicates that subject SB tends to be capable of revisiting the stages of their problem-solving process, thus confidently arriving at a final decision in the form of a conclusion; however, subject SB is unable to apply this method to different problems. In general, the conjecture that can be generated by the subject SB concerning mathematical problem-solving abilities about negative emotional categories through a problem-based learning model can be described as shown in Figure 14.

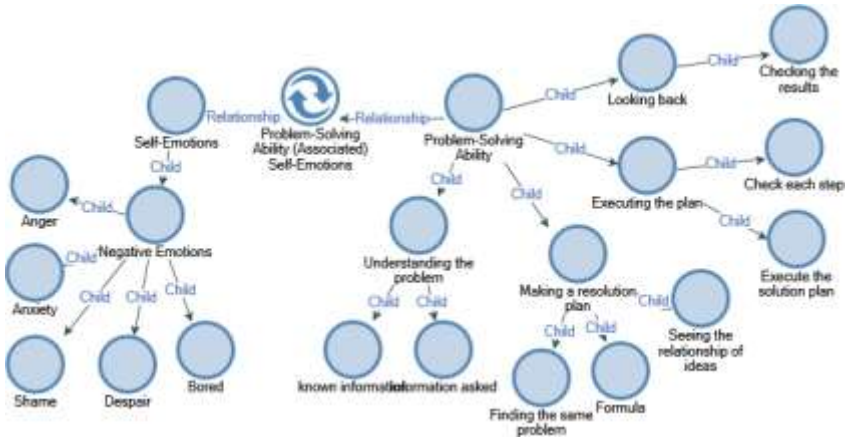


Figure 14. The conjecture of negative emotions with problem-solving abilities

4. Discussion

a. Describe Students' Problem-Solving Ability in Terms of Self-Emotion through a Problem-Based Learning Model

Problem-solving ability is a mental activity that a problem solver can perform from the moment a problem arises, wanting to solve it, and considering the task complete. In problem-solving, students with positive and negative emotions have similar average scores, but negative emotions outperform them. According to Schukajlow et al. (2023), negative emotional constructs, such as anxiety, are not always negatively related to academic achievement or performance results in mathematics. Anxiety can activate

motivation to avoid failure by investing in effort. Through the implementation of the PBL model, an increase in the mean score of students' problem-solving abilities for both positive and negative emotions was obtained, but the positive emotions were superior. This is because the PBL model in its application uses real-world problems as a context for students to learn and think, and students are directly involved in the investigation to solve problems (Mandasari, 2021). Students involved in PBL projects tend to report higher positive emotions such as a sense of accomplishment and satisfaction when successfully solving problems (Schukajlow et al., 2023; Tze et al., 2023). Furthermore, research by Musna et al. (2021) found that the PBL model influences students' mathematical problem-solving abilities with a relatively large effect size of 1.092.

b. Conjecture That Links Problem-Solving Ability with Students' Self-Emotion Through a Problem-Based Learning Model

Students exhibiting positive emotions while solving given problems can do so in a highly systematic manner by adhering to Polya's stages (Tohir et al., 2020), which are indicated by understanding the problem, devising a plan, executing the plan, and reviewing the process. In the initial stage of understanding the problem, students can articulate all relevant information effectively, encompassing the known elements of the question. For instance, a student might state, "The price of one pineapple cake is equivalent to two cans of cheesecake. Three cans of pineapple cake and two cans of cheesecake cost Rp. 480,000." Subsequently, the student can also articulate what is being asked in the problem. This understanding serves as a guide for the student to formulate the subsequent stages in their problem-solving process. According to Tze et al. (2023), emotions function as mediators in the problem-solving process. Consequently, students with stable emotions are capable of effectively identifying information from the given problem (Utomo et al., 2021). Such students can focus, think clearly, and remain unaffected by negative emotions. Emotional stability tends to enable students to utilize their cognitive abilities effectively in problem-solving. Furthermore, an important aspect that students must consider while understanding the problem is the necessary or sufficient conditions that will allow them to solve the problem. Students must carefully identify whether there are any requirements needed for the problem at hand.

Subsequently, concerning the stage of understanding the problem, students begin to formulate a resolution plan. It is essential to consider that when devising a plan, one must be able to connect the information that has been presented. Students with positive emotions tend to be more adept at recognizing the relationships that exist between different pieces of information (Chang et al., 2020). For instance, a student may articulate that “the price of 1 can of pineapple cookies = the price of 2 cans of cheese cookies.” Based on this reasoning, the student will utilize the second piece of information, namely “3 cans of pineapple cookies + 2 cans of cheese cookies = IDR 480,000,” as a substitute for the first piece of information to derive the desired price for each type of cookie. This aligns with the findings of Li et al. (2020), the text indicates that positive emotions are likely to boost motivation and focus, which in turn aids in the retention of information. Additionally, students can convert verbal problems into mathematical expressions. The formulas that students create do not rely on specific symbols, as the

equations they devise are simple enough to be utilised. This is illustrated by the examples given by students concerning the first and second sets of information. As a result, students find it quite straightforward to develop a solution plan, drawing on previous experiences where they faced similar issues during their learning journey (Li et al., 2020), albeit in a different setting. Students note that "a similar type of problem has been encountered, but the concept was more centred on calculating a child's age." This familiarity allows students to clearly understand how to devise an initial plan.

After the resolution plan has been formulated by the students, the next stage involves the execution of the resolution plan. The students executed the resolution plan exceptionally well. The initial phase of the resolution process entails determining the price of each cake. Once the students obtained the individual prices, they proceeded to substitute these values using either sequential addition or multiplication to arrive at the correct final solution. To ensure the accuracy of the solutions produced, the students meticulously reviewed each step undertaken. Furthermore, the students were able to validate the correctness of each step executed. This validation was carried out by re-substituting the prices of each cake obtained to confirm the equivalence between both sides of the equation.

The concluding phase of problem-solving activities involves reflection or revisiting the process. In this stage, students who experience positive emotions find it significantly easier to conduct a thorough review of their work, examining it step by step. This practice is essential for identifying any potential errors that may have arisen. However, during this reflection, students may not uncover any mistakes, allowing them to draw accurate conclusions. Moreover, students in a positive emotional state are more likely to devise alternative problems by increasing the number of tins related to the original issue. They then strive to solve these new challenges to achieve varied results. This suggests that students are inclined to apply similar strategies as those used in different problems. This claim is further corroborated by Street et al. (2022), who assert that students with a favourable view of their abilities are generally more open to new methods and more willing to explore diverse problem-solving techniques. Additionally, students demonstrating positive emotions, such as confidence and enthusiasm, tend to think more creatively and remain receptive to innovative solutions (Chen & Lu, 2022).

Furthermore students exhibiting negative emotions while tackling assigned problems follow the stages outlined in Polya's indicators; however, the resulting processes are not systematic. This begins with understanding the problem, where students can articulate the information gleaned from the question, yet the information presented is incomplete. Students who harbour negative emotions often find themselves feeling increased anxiety when faced with mathematical tasks, which appears to result in their avoidance of these challenges (Lajoie et al., 2020). Errors that occur are revealed during the interview process, where several mistakes made by students with negative emotions become apparent and can be recognized, allowing for rectification. Students' awareness is heightened when researchers prompt them to reread the question attentively and then guide them to identify complete information from the problem. Ultimately, students come to realize that certain pieces of information have been overlooked.

According to Wang & Wang (2024), Educators have a vital function in aiding students who are facing adverse emotions to acknowledge their errors. This can be accomplished by offering emotional support and guiding them in recognising and regulating their feelings. Furthermore, students' thought processes when documenting information involve making initial guesses or assumption (Ozturk & Guven, 2016), referencing the initial conditions contained within the question, although this appears to be inverted. When researchers attempt to guide students in correlating the information present in the question, students begin to recognize that one tin of pineapple cookies should cost 60,000, while one tin of cheese cookies should cost 120,000.

In the subsequent development of a resolution plan, students exhibiting negative emotions tend to reference their initial hypotheses previously articulated in their understanding of the problem. These students express that the attainment of a final solution is achieved by substituting their initial assumptions into the questions posed in the problem. Due to their limited comprehension of the initial problem, students with negative emotions often struggle to articulate the formula in the form of mathematical symbols. However, they generally demonstrate a capacity to clearly explain the plan they intend to employ in the resolution process. This indicates that students experiencing negative emotions are capable of formulating their strategies mentally, thereby enabling them to convey information succinctly.

Then, concerning the relationship between the problems presented and the student's prior experiences, it has been observed that these students have previously encountered similar issues during the learning process; however, the problems taught were predominantly simpler transactional scenarios. Consequently, when faced with a comparable yet slightly more challenging problem, students tend to opt for resolution through estimation or conjecture (Ozturk & Guven, 2016). This suggests that while students with negative emotions are inclined to devise a resolution plan, they do not articulate it verbally in a comprehensive manner.

Subsequently, the students commenced the execution of the resolution plan by employing multiplication between the initial estimate formulated and the number of cakes in question. The multiplication process was carried out in the form of repeated addition of the price of the cake, corresponding to the total number of cakes queried until an accurate final result was achieved. The outcome attained by the students was validated through a review of each step of their work. However, the students were unable to justify the procedural steps undertaken to arrive at the solution.

The final stage of problem-solving activities is a reflection or revisiting previous work. In this activity, students experiencing negative emotions can reassess their work by carefully examining each step of the solution, leading them to conclude that the final result obtained is 420,000. The decision made is based on the conviction that the answer produced is correct. According to Schukajlow et al. (2023), the construction of negative emotional states (that is, those that are unpleasant) such as anxiety during examinations does not always correlate negatively with performance outcomes in mathematics. Anxiety has the potential to stimulate a drive to prevent failure by encouraging effort. By means of avoidance motivation (a type of motivation focused on steering clear of

negative outcomes), anxiety can indirectly enhance performance, thereby aiding in specific task scenarios.

D. CONCLUSION AND SUGGESTIONS

This study shows that self-emotions play a significant role in students' mathematical problem-solving abilities through the application of Problem-Based Learning (PBL). Quantitative results indicate an increase in problem-solving abilities from pre-test to post-test in students with both positive and negative emotions, with better final outcomes in students with positive emotions. Qualitatively, students with positive emotions were able to systematically fulfill all stages of problem-solving according to Polya, while students with negative emotions only fulfilled some indicators and showed limitations in reflection and justification of solution steps. These findings confirm that PBL is not only effective in improving mathematical problem-solving abilities but also helps manage students' emotions during the learning process. Thus, the Problem-Based Learning model not only contributes to improving mathematical problem-solving abilities but also plays a role in managing and suppressing students' negative emotions during the learning process. Therefore, PBL can be recommended as an effective learning model for developing mathematical problem-solving abilities while supporting students' emotional regulation in mathematics learning.

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