

## Exploring student potential: The influence of growth mindset on mathematical problem-solving ability

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### Abstract

*Growth mindset in mathematics learning refers to students' belief in themselves that they can develop their mathematical abilities. This study aims to explore and explain the potential development of problem-solving skills of students who have a growth mindset. The method used in this is descriptive qualitative. The subjects in this study were three seventh grade junior high school students. The results found that the growth zone is strongly influenced by the extent of the green zone or the area that can be reached with students' current mathematical knowledge. The green zone is related to the basic mathematical abilities and concept understanding that students already have. subjects with a broad green zone can easily develop their potential in solving mathematical problems. Subjects with moderate green zones can develop the potential to solve math problems but experience slight difficulties due to gaps in their knowledge so that they need scaffolding to close the knowledge gap. Subjects with narrow green zones can also develop the potential to solve math problems but have difficulties so they need scaffolding and support from their friends to solve the problem.*

**Keywords:** *Belief, Growth Mindset, Problem-Solving, Scaffolding*

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## INTRODUCTION

Mathematical problem-solving ability is a fundamental skill essential not only in academic settings but also in real-life situations. As the world increasingly values analytical and critical thinking, students' proficiency in mathematics has become a critical indicator of their overall academic potential and future success. According to Polya, mathematical problem-solving is an attempt to find a way out of a difficulty in order to achieve a goal that cannot be achieved immediately (Purba & Lubis, 2021). Math problem-solving steps: (1) understand the problem, (2) develop a problem-solving plan, (3) implement the plan, and (4) evaluate the work (Widodo dkk., 2018; Astutiani & Hidayah, 2019; Cho & Kim, 2020).

Mathematical problem-solving ability is influenced by many factors. In general, it can be divided into factors of cognitive skills and affective skills of the individual. Cognitive skills include metacognition, reading comprehension skills, intelligence, and need for cognition or liking challenging cognitive activities. Affective skills include self-efficacy, math attitude, mathematical anxiety, confidence, interest in mathematics, and interest in math (Öztürk et al., 2020).

Students often experience difficulties and challenges when trying to solve math problems. The difficulties experienced result from a lack of understanding of mathematical concepts and concept construction errors. concept construction errors that often occur are pseudo-construction, construction holes, mis-analogical construction, mis-logical construction (Subanji, 2015). In addition, students with low adversity quotient tend to experience math anxiety (O'Hara et al., 2022; Živković et al., 2023).

Concept construction errors can be resolved by rearranging the cognitive structure of students. (Subanji, 2015) suggested defragmentation on the structure of students' thinking which is done by bringing up schemes, knitting schemes, cognitive conflict, improving logical thinking, and knitting connections in solving mathematical problems. Defragmentation can occur naturally (self-defragmentation) and can also occur with the help (intervention) of experts or more experienced people. Interventions provided in the form of scaffolding, disequilibrium, and cognitive conflict (Shahbari & Peled, 2015; Subanji, 2016; Hidayanto et al., 2017).

Growth mindset, a concept popularized by psychologist Carol Dweck, refers to the belief that abilities and intelligence can be developed through effort, learning, and perseverance (Campbell et al., 2020). Unlike a fixed mindset, where individuals believe their capabilities are static, those with a growth mindset are more likely to embrace challenges and persist in the face of setbacks (Limeri et al., 2020). In the educational domain, especially in mathematics, fostering a growth mindset has been linked to enhanced problem-solving abilities and academic achievement (Wijaya, 2023).

Growth mindset in mathematics learning refers to students' belief in themselves that they can develop their mathematical abilities (Kookken et al., 2016). Students' development while learning can be described as the ZPD (zone of proximal development) cognitive growth area conceptualized by Vygotsy (Johnston-Wilder et al., 2018). There are three zones from the learner's perspective: comfort zone, growth zone, and danger zone.

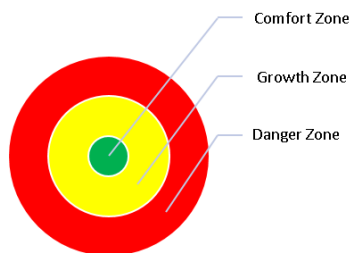


Figure 2. The growth zone diagram

The green zone is a region that can be reached with students' current mathematical knowledge. This region can be said to be the comfort zone. The yellow zone is an area where students try to use all the knowledge they have and their knowledge resources to solve mathematical problems. This area is called the growth zone. The red zone is the mathematical anxiety zone, which is an area beyond the reach of students' mathematical knowledge (Johnston-Wilder et al., 2018).

The green zone influences and strongly determines the students' cognitive growth zone (yellow zone). Students who have a wide green zone tend to have a fairly complete knowledge construction (Kusmaryono et al., 2021). Students with incomplete cognitive constructions when solving math problems tend to lead to the red zone. The red zone is also called the mathematical anxiety prone area (Dowker et al., 2016) (O'Hara et al., 2022) (Živković et al., 2023).

While there is a substantial body of research linking growth mindset to general academic success, there remains a gap in understanding its specific impact on mathematical problem-solving abilities (Zintz, 2018; Kusmaryono et al., 2021; Sahagun et al., 2021; Wijaya, 2023). This study aims to address this gap by exploring how fostering a growth mindset can potentially enhance students' capabilities in solving complex mathematical problems, thus contributing to the broader discourse on educational psychology and pedagogy.

The primary objective of this study is to explore the influence of growth mindset on students' mathematical problem-solving abilities. The research seeks to answer the following questions: how does comfort zone affect students' growth zone when solving math problems?

This paper is organized as follows: This section reviews the relevant literature on growth mindset and mathematical problem-solving. The next section describes the methodology outlining the research design, data collection and analysis methods. The results section presents the findings, followed by a discussion that interprets the results in light of the literature. The paper concludes with implications for educators and suggestions for future research.

**METHOD**

The approach used in this research is a qualitative approach with descriptive research type. To be able to explain or provide an overview of cognitive growth in the potential development zone of students when solving math problems. This research was conducted at SMP Negeri 4 Malang. In class VII students who take part in the math olympiad extracurricular program. Researchers took three students from 28 students as research subjects. Subjects in this study were selected using purposive sampling technique where subjects were selected based on certain criteria.

We categorized the research subjects into three groups based on the breadth of their green zone: subject with a broad green zone, subject with a moderate green zone, and subject with a narrow green zone.

Table1. Comfort zone eligible subject criteria

Zona	Knowledge that the subject already had
Comfort Zone	<ul style="list-style-type: none"> <li>• Understanding the concept of fractions as parts of a whole</li> <li>• Understand fraction operations</li> <li>• Understand the concept of least common multiple used to equalize denominators of fractions</li> <li>• Able to perform number counting operations</li> </ul>

The key instrument in this study is the researcher himself as a data collector. Data is obtained from the work of mathematical problem-solving problems and interview scripts as instruments that support the success of this study. Problem-solving problems have previously been validated by experts and are considered suitable for use. The problem used in this study is mathematical problem-solving fractions.

Tiga orang siswa dapat meminum air sebanyak  $\frac{1}{5}$  galon. Jika kemampuan minum air pada setiap siswa dianggap sama, butuh berapa siswa untuk menghabiskan air satu galon?



Three students can drink water as much as 1/5 gallon. If each student's ability to drink water is assumed to be the same, how many students are needed to drink one gallon of water?

**Figure 2. Problem-solving questions**

**RESULTS AND DISCUSSION**

**Description of Mathematical Problem-solving Ability of Each Subject**

The three subjects when trying to solve the problems given tend to have a positive and proactive attitude. The attitudes shown are never giving up, learning from mistakes, receiving feedback, having strong motivation to solve problems, and being confident. This indicates that the three subjects meet the growth mindset indicator. The researcher examines the work of each student then determines the extent of the basic mathematical knowledge they already have and their green zone. The observation data is presented in table 1.

Table 1. green zone (basic math knowledge that the subject already has)

Subject	knowledge that the subject already had	Description
S-BGZ	<ul style="list-style-type: none"> <li>Understanding the concept of fractions as parts of a whole</li> <li>Understand fraction operations</li> <li>Understand the concept of least common multiple used to equalize denominators of fractions</li> <li>Able to perform number counting operations</li> </ul>	has a good understanding of the problem, can apply their knowledge but not yet perfect
S-MGZ	<ul style="list-style-type: none"> <li>Understand fraction operations</li> <li>Understand the concept of least common multiple used to equalize denominators of fractions</li> <li>Able to perform number counting operations</li> </ul>	able to answer, but still showed some weaknesses or errors in the concept of fractions
S-NGZ	<ul style="list-style-type: none"> <li>Understand fraction operations</li> <li>Understand the concept of least common multiple used to equalize denominators of fractions</li> <li>Able to perform number counting operations</li> </ul>	could answer but had difficulty and showed limited understanding of the concept of fractions.

**Analysis of the answer of subject S-BGZ (Subjects With a Broad Green Zone )**

Although he did not write the information from the problem in his work, S-BGZ was able to understand the problem in the problem. Based on interview [1], S-BGZ can develop a good problem-solving plan, then carry out calculations according to the plan he has made. The results of the work of the subject S-BGZ are presented in the following figure.3

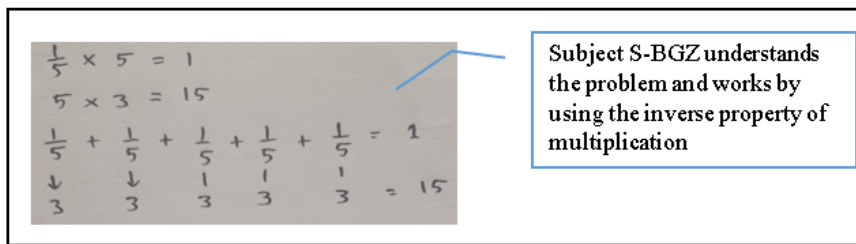


Figure 3. S-BGZ's work when solving problems

Interview [1]

R : Can you explain the problem again, what do you know from the problem?

S-BGZ : Three students drank  $\frac{1}{5}$  gallon of water, the question is how many students need to drink 1 gallon.

R : How do you solve the problem?

S-BGZ : Ehhh... I calculated  $\frac{1}{5} \times 5 = 1$ , I replaced  $\frac{1}{5}$  with 3 so  $3 \times 5 = 15$ . The answer is 15

Subject S-BGZ answered the questions with enthusiasm and high confidence. the researcher then continued the questions to investigate the calculation process.

Interview [2]

R : hhh...  $\frac{1}{5} \times 5 = 1$  where did you get that from?

S-BGZ : ohh... that's it sir, I want to find out how to get one gallon, it means there must be five times  $\frac{1}{5}$ .

Then  $\frac{1}{5}$  is for 3 people, so it will be  $3 \times 5 = 15$ .

R : Are you sure about your answer?

S-BGZ : sure, I tried by calculating  $\frac{1}{5} + \frac{1}{5} + \frac{1}{5} + \frac{1}{5} + \frac{1}{5} = 1$ , so  $3 + 3 + 3 + 3 + 3 = 15$ .

Researchers then asked questions that could trigger cognitive conflict to probe deeper into concept understanding. The concept that S-BGZ understood and used when answering the question is fraction multiplication. S-BGZ explained if  $3 = \frac{1}{5}$  then  $3 \times 2 = \frac{1}{5} \times 2 = \frac{2}{5}$ . Previously, it can be seen that S-BGZ used the same method to ensure the results of his answer. However, S-BGZ had difficulty when determining the number of gallons of water that could be spent by 5 students because he thought it was not a multiple of 3.

Interview [3]

R : If there are 6 students with the same drinking ability, then how many gallons can be spent?

S-BGZ : If 3 students can drink  $\frac{1}{5}$  gallon, multiply it, so 6 students can drink  $\frac{2}{5}$  gallon.

R : What about 5 students?

S-BGZ : Emm ... how well sir, if multiples of 3 can sir, other than that I don't know how to do it.

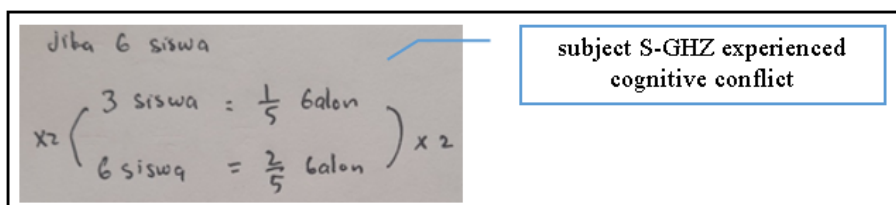


Figure 4. Cognitive conflict experienced by subject S-BGZ

Despite the difficulties, S-BGZ felt challenged to solve the problem. subject S-BGZ asked for additional time to investigate the answer. S-BGZ looked back at his work and then reorganized the problem-solving plan for the given question. From the information given, it is known that 3 students are able to drink  $\frac{1}{5}$  gallon. S-BGZ then tried to find how many gallons one student could drink. After knowing that 1 student can

drink  $\frac{1}{15}$  gallon, S-BGZ then did the same method by adding  $\frac{1}{15}$  every time 1 student increased. The improvement result of subject S-BGZ is shown in figure 5.

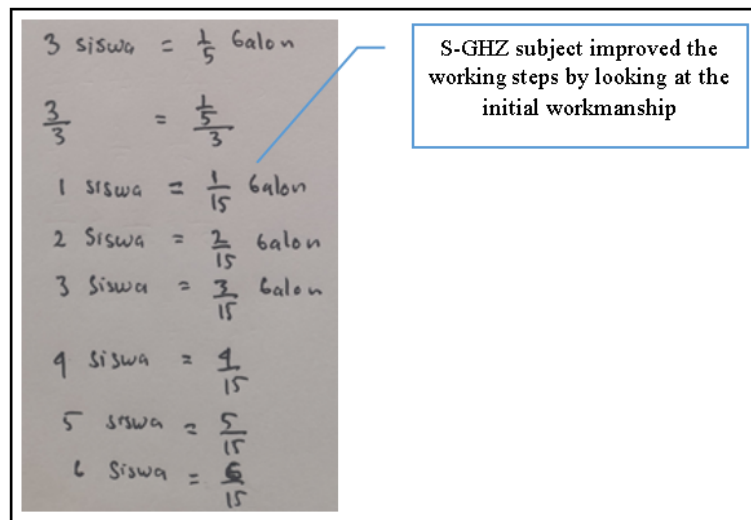


Figure 5. Correction result of subject S-BGZ

S-BGZ was good at understanding the problem, planning how to solve the problem, executing according to the plan, and evaluating. However, in the process S-BGZ experienced a little problem caused by a lack of understanding of the basic concepts of fractions. Based on the results of the work and interviews, subject S-BGZ showed strong confidence and motivation, was interested in the challenges given by the researcher and tried hard to solve the problem. S-BGZ was also good at receiving feedback and making improvements to his work and was able to provide alternative answers to problems.

**Analysis of the answer of subject S-MGZ (Subjects With a Moderate Green Zone)**

S-MGZ can understand the information from the problem well. the attitude shown when working on problems and interviews [4] is very enthusiastic and confident. the results of S-MGZ's work as in Figure 6.

Interview [4]

R : Can you explain the problem again, what do you know from the problem?

S-MGZ : If three students can drink  $\frac{1}{5}$  gallon, how many students can drink 1 gallon of water?

R : How do you solve the problem?

S-MGZ : I made  $3 = \frac{1}{5}$  gallons, so 1 gallon  $3 \div \frac{1}{5} = 3 \times \frac{5}{1} = 15$ . So 1 gallon can be drunk by 15 children.

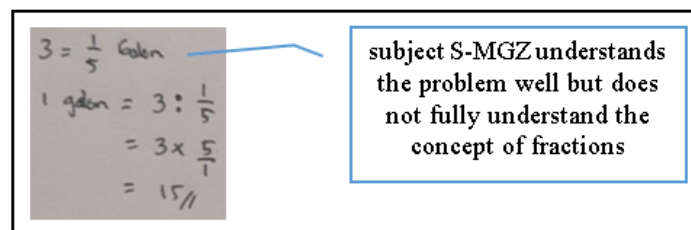


Figure 6. S-MGZ's work when solving problems

When looking at S-MGZ's work, the researcher found that the concept of fraction operations used was quite good. However, when asked why the division operation on fractions can turn into multiplication, MGZ began to doubt and could not explain this. Excerpts of the researcher's conversation with S-MGZ in the interview [5].

## Interview [5]

R : Why does  $3 \div \frac{1}{5}$  become  $3 \times \frac{5}{1}$ ?

S-MGZ : For fraction operations, division turns into multiplication and then I switch the numerator and denominator.

R : Why are the denominator and numerator swapped?

S-MGZ : That's it sir, what I know is that it has to be reversed, if the reason I don't understand.

R : Is there another way to solve the problem?

S-MGZ : Ehmm,, I don't know sir, let me see first

R : Okay, let's see first

after a few minutes....

S-MGZ : There is sir,  $3 = \frac{1}{5}$  gallons of both segments multiplied by 5 sir, so  $3 \times 5 = \frac{1}{5} \times 5$  gallons, so 15 children for 1 gallon.

In interview [5], S-MGZ showed curiosity and tried to find reasons to strengthen his answer. finally S-MGZ could give a good enough reason but still showed a little doubt. After the above conversation, the researcher provided assistance by trying to provide examples of division operations on fractions with assistance as in Figure [7].

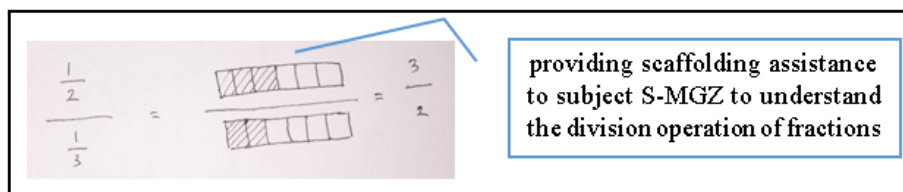


Figure 7. Scaffolding for division operation of fractions

## Interview [6]

R : The fractions  $\frac{1}{2} \div \frac{1}{3} = \dots$  try shading each of the fractions  $\frac{1}{2}$  and  $\frac{1}{3}$  in the column!

S-MGZ : Like this sir,  $\frac{1}{2}$  is 3 out of 6 squares, then  $\frac{1}{3}$  is 2 out of 6 squares.

R : Then, what is the result?

S-MGZ : This is the result  $\frac{3}{2}$ .

R : From the picture, what do you conclude?

S-MGZ : ooh... this way sir, if from the picture it is the same as we equalize the denominator first sir, then distribute.

R : What about your answer to question number 2?

S-MGZ :  $3 \div \frac{1}{5} = \frac{15}{5} \div \frac{1}{5} = \frac{15}{1} = 15$ . oh I see sir, the result is the same as in the reverse, but now I know the reason.

The interview was continued to find out S-MGZ's understanding of fraction concepts. at this stage, the subject was able to answer correctly, but the researcher saw a gap in S-MGZ's knowledge.

## Interview [7]

R : What if there are 6 students, how many gallons can be spent?

S-MGZ : Well, 3 students can use up  $\frac{1}{5}$ , so if there are 6 students, I multiply it by 2, so  $6 = \frac{2}{5}$ .

R : How about 2 students, how many gallons can be spent?

S-MGZ was silent for a moment, then hesitantly expressed his idea

S-MGZ : Humm... what if  $6 \div 3 = 2$  so then  $\frac{2}{5} \div \frac{1}{5}$  means 2 gallons, sir?

R : Does your answer make sense to you?

S-MGZ : Emm ... seems wrong, it can't be up to 2 gallons well

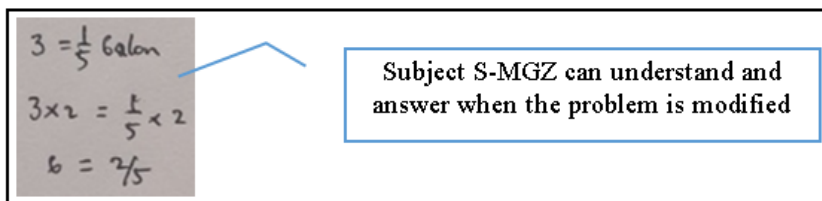


Figure 8. S-MGZ's answer to the modified question

Subject S-MGZ was inspired by the scaffolding provided as shown in Figure [7] so that he wanted to try to explore the division operation of fractions. At this stage, S-MGZ tried to think hard to solve the problem. after about 5 minutes, the researcher decided to provide scaffolding to solve the problem according to the last step that had been done.

Interview [8]

R : How, can you find the result?

S-MGZ : No sir, I want to turn 3 into 2, but it can't be divided, I don't know how.

R : Try to find the result of  $2 \times \frac{1}{2}$ ,  $2 \times \frac{2}{2}$ ,  $2 \times \frac{3}{2}$

S-MGZ : The answer is  $2 \times \frac{1}{2} = 1$ ,  $2 \times \frac{2}{2} = 2$ ,  $2 \times \frac{3}{2} = 3$ , oww... I'm starting to understand.

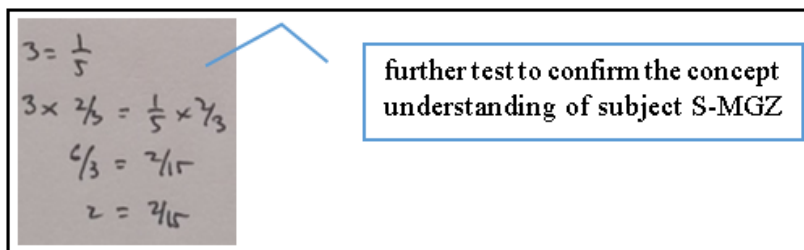


Figure 9. S-MGZ answer after passing cognitive conflict

After interview session [8], S-MGZ asked for additional time to try to solve the given problem. finally S-MGZ can show the solution by multiplying both segments of the equation with a fraction number to get the desired result. the result of S-MGZ's work is presented in figure 9.

Although S-MGZ's understanding of the concept of fractions is not as good as S-BGZ, S-MGZ's basic math skills such as arithmetic operations are quite good and can manipulate arithmetic operations. S-MGZ did experience some difficulties when trying to solve the given problem, but still showed a positive attitude in overcoming the problem. The positive attitudes shown are feeling challenged by the problems given, not giving up easily, receiving feedback well and trying hard to solve the problem.

**Analysis of the answer of subject S-NGZ (Subjects With a Narrow Green Zone )**

S-NGZ subject is able to understand the problem well and can explain how to work on it seen from interview 9. The results of S-NGZ's work are presented in Figure 10.

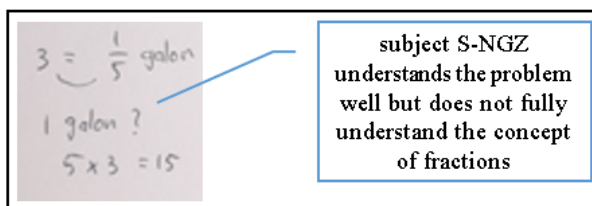


Figure 10. S-NGZ's work when solving problems

Interview [9]

R : Can you explain the problem again, what do you know from the problem?

S-NGZ : Three students can consume  $\frac{1}{5}$  gallon of water, then asked how many students can consume 1 gallon.

R : How did you solve the problem?

S-NGZ : I made it like this  $3 = \frac{1}{5}$ , to find 1 gallon I moved 5 so  $5 \times 3 = 1$ , so 1 gallon can be drunk by 15 students.

based on interview [9], the researcher saw a gap in S-NGZ's understanding of the concept that was similar to the subject S-MGZ. where they moved the segments in the equation but did not understand how the concept was. the researcher also continued interview [10] to investigate the problem.

Interview [10]

R : Why does the denominator of 5 change segments to  $5 \times 3$  ?

S-NGZ : Yes sir, if the division shifted segments, it became multiplication.

R : How is the process?

S-NGZ : Ehh... wrong, I asked you that.

R : Oww... you multiplied both segments by 5?

S-NGZ : Ohh... yes sir, both segments are multiplied by 5.

To explore the problem further, the researcher showed an example as in figure 7 and asked S-NGZ to solve it. Subject S-NGZ can understand, but has difficulty drawing conclusions from the examples given. the conversation is presented in interview [11].

Interview [11]

R : The fractions  $\frac{1}{2} \div \frac{1}{3} = \dots$  try shading each of the fractions  $\frac{1}{2}$  and  $\frac{1}{3}$  in the column!

S-NGZ :  $\frac{1}{2}$  is 3 out of 6 squares, then  $\frac{1}{3}$  is 2 out of 6 squares.

R : Then, what is the result?

S-NGZ : This is the result  $\frac{3}{2}$ .

R : From the picture, what do you conclude?

S-NGZ : Hmm... I understand but it is difficult to explain sir.

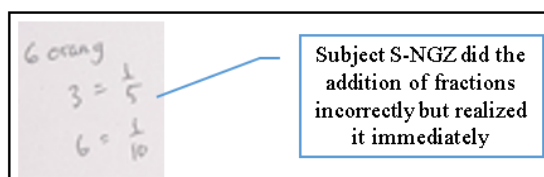


Figure 11. S-NGZ's answer to the modified question

The interview was continued to find out S-MGZ's understanding of fraction concepts. at this stage, the subject was able to answer correctly, but the researcher saw a gap in S-NGZ's knowledge.

Interview [12]

R : Okay, what if I change the question. If 6 students with the same drinking ability, how many gallons can be consumed?

S-NGZ : If 6 students means  $\frac{1}{10}$

R : Are you sure about your answer?

S-NGZ : Hmm... ohh I was wrong... this way sir  $2 \times 3 = 2 \times \frac{1}{5}$ , so the result will be  $\frac{2}{5}$ .

R : Is there another way to do it?

S-NGZ : I don't know sir, but can I ask a friend?

R : Okay, I'll wait for you.

After about 10 minutes...

R : Did you find the solution?

S-NGZ : Yes sir, one gallon for 15 people, I subtracted  $\frac{1}{5}$  gallon for 3 people, the result is  $\frac{4}{5}$  for 12 people.  
Then I divided it by 2 for 6 people. So 6 students can spend  $\frac{2}{5}$ .

The image shows handwritten mathematical work on a grid background. On the left, there is a circled '15' with an arrow pointing to '1 gallon'. Below it, the calculation  $\frac{5}{5} - \frac{1}{5} = \frac{4}{5}$  is written. To the right, there are calculations for '12 orang' (12 people) and '6 orang' (6 people). The work shows  $\frac{12 \text{ orang}}{2} = \frac{4}{5}$  and  $6 \text{ orang} = \frac{4}{5}$ . At the bottom, there is a calculation  $\frac{4}{5} \times \frac{1}{2} = \frac{4}{10} = \frac{2}{5}$ . A blue box on the right contains the text: 'Subject S-NGZ improved her work by connecting the information in the question'.

Figure 12. S-NGZ's answer after discussion

Although S-NGZ's understanding of the concept of fractions is not as good as S-BGZ and S-MGZ, S-NGZ's basic math skills such as arithmetic operations are quite good and can manipulate arithmetic operations. S-MGZ did experience some difficulties when trying to solve the given problem, but still showed a positive attitude in overcoming the problem. The positive attitudes shown are feeling challenged by the problems given, not giving up easily, receiving feedback well and trying hard to solve the problem.

## CONCLUSION

In conclusion, the growth zone is strongly influenced by the extent of the green zone that students have. The green zone is related to the basic mathematical abilities and understanding of concepts that students already have. Subjects with a broad green zone can easily develop their potential in solving math problems. Subjects with moderate green zones can develop the potential to solve math problems but experience slight difficulties due to gaps in their knowledge so that they need scaffolding to close the knowledge gap. Subjects with narrow green zones can also develop the potential to solve math problems but have difficulties so they need scaffolding and support from their friends to solve the problem.

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