Students' Proactive Interference in Solving Proportion Problems: How was the Met-before?

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Abstract: Students' difficulties in differentiating the direct proportion and inverse proportion problems cause interference. Proactive interference is the error that occurs when old information (concept of direct proportion) interferes with new information (concept of inverse proportion). In solving the problem of inverse proportion, students often use the concept of direct proportion. The student's mental structure regarding the concept of proportion as a result of previous learning is referred to as met-before. Therefore, this study aims to describe the met-before of students who experience proactive interference. This research is a case study involving 32 8th-grade students in Malang, Indonesia. These subjects were students who experienced proactive interference with specific fluency of communication and willingness. Data was collected through proportion problems and interviews. Students' work was analyzed based on the description of the met-before. The results showed that students who experienced proactive interference with the non-flexible type had suppressed problematic, while students with the flexible type have focus supportive met-before in solving direct proportion problems. Both students with non-flexible type and flexible type have focus problematic met-before when solving inverse proportion problems. This is because met-before about cross multiplication strategy interferes with students' problem-solving.

Keywords: proactive interference, direct proportion, inverse proportion, met-before

INTRODUCTION

Thinking carries an important role in the process of understanding and acquiring new knowledge (Sanjaya et al., 2018; Tohir et al., 2020), as well as facing and solving a problem (Hobri et al., 2021; Mairing, 2016; Tekin et al., 2021), and also reasoning (Faizah et al., 2022). Thinking is also related to mathematics and problem-solving. The tasks and exercises provided in the process of learning mathematics can be in the form of problem-solving. Solving mathematics problems is an important part of mathematics education research (Akyüz, 2020) and learning (Izzatin et al., 2021; Szabo et al., 2020) globally (Rahayuningsih et al., 2020). Problem-solving serves as the foundation (NCTM, 2000; Reys et al., 2009) and the heart of mathematics (Barham, 2020). Baraké et al. (2015) asserted that problem solving has been and still remains the basis for learning mathematics.

In addressing a particular problem, one needs to recall knowledge in their long-term memory. This act of recalling information in long-term memory is known as retrieval (Ormrod, 2020; Slavin, 2017). McBride and Cutting (2018) described retrieval as the process of calling/removing information from memory. However, one can experience failure when doing the retrieval process. In information processing theory, this retrieval failure is called interference (Slavin, 2017; Sternberg & Sternberg, 2012).

Interference is a disturbance or error that occurs because the process of calling one information interferes with other information (Slavin, 2017; Solso et al., 2014; Sternberg & Sternberg, 2012). Anderson (2020) and Slavin (2017) described that this interference refers to forgetting events caused by disruption in the information retrieval process. Besides, interference can also occur when existing information is mixed with other information (Ormrod, 2020; Sternberg & Sternberg, 2012). Therefore, interference is often defined as interference that occurs because one information interferes with other information and the mixing of information due to the similarity of the received information.

In the field of mathematics, interference is related to the failure of students to recall concepts that have been learned and are being studied. Sternberg and Sternberg (2012) states that interference occurs when students have an understanding of two or more different concepts where these concepts are interrelated. The same thing was expressed by Sukoriyanto et al. (2016) this interference is in the form of errors that occur due to conceptions that interfere with each other, so that one concept interferes or interferes with other concepts.

Interference in thinking is divided into retroactive interference and proactive interference (Georgiou et al., 2021; McBride & Cutting, 2018; Mercer, 2014; Slavin, 2017; Solso et al., 2014; Sternberg & Sternberg, 2012). Interference is said to be retroactive when new information interferes with the ability to recall old information. Furthermore, Anderson (2020) states that retroactive interference is defined as forgetting that arises as a result of new learning. In other words, someone who experiences this retroactive interference usually forgets old information, highlighting the process where learning a new task leads to forgetting previously learned information.

Conversely, proactive interference occurs when old information interferes with the ability to remember new information (McBride & Cutting, 2018; Slavin, 2017; Solso et al., 2014; Sternberg & Sternberg, 2012). In line with this, Anderson (2020) defines proactive thinking interference as forgetting that arises as a result of previous learning. Therefore, when a person experiences this proactive interference, memories that have been stored for a long time in long-term memory interfere with new information being entered into memory. Both forms of interference occur when the information received occurs in close temporal proximity.

For example, the mathematical materials that are often presented in close time proximity is the material for direct and inverse proportion (Sukoriyanto et al., 2016). Those two materials have similar problem structures, leading students to frequently experience interference (Irfan et al., 2019a). Following the curriculum guidelines, teachers typically introduce the topic of direct proportion as the initial material (Ben-Chaim et al., 2012; Billstein et al., 2016; Petit et al., 2020;

Walle et al., 2020). Subsequently, inverse proportion material is taught after students learn direct proportion. As the first information received by students is direct proportion material, this material becomes old information for students. Meanwhile, information regarding inverse proportion material is seen as new information. Consequently, when the student's firmly embedded memory is the concept of inverse proportion, they may solve the problem of direct proportion by using the concept of inverse proportion, thereby, they experience retroactive interference. On the other hand, when a student's strong memory is the concept of direct proportion, they solve the inverse proportion problem using the concept of direct proportion. Therefore, the student experiences proactive interference.

Mathematical materials that possibly cause interference with students include greatest common factors and least common multiple, direct and inverse proportion, arithmetic sequences and series, geometric sequences and series, and permutations and combinations (Sukoriyanto et al., 2016). In this study, we focus on direct and inverse proportion material in tracing the occurrence of interference. The concept of proportion is important in an education setting (Andini & Jupri, 2017; Artut & Pelen, 2015; Buforn et al., 2022; Diba & Prabawanto, 2019; Dougherty et al., 2016; Perumal & Zamri, 2022). Proportional material serves as the foundation for studying more advanced mathematical material (Dougherty et al., 2016; Misnasanti et al., 2017; Vanluydt et al., 2021; Weiland et al., 2021) such as algebra, geometry, statistics, and so on (Beckmann & Izsák, 2015; Misnasanti et al., 2017; Vanluydt et al., 2021). Apart from being important in learning mathematics, this proportion concept is also useful in everyday life (Phuong & Loc, 2020).

Research on direct and inverse proportion mostly focuses on proportional reasoning (Artut & Pelen, 2015; Castillo & Fernandez, 2022; Öztürk et al., 2021; Pelen & Artut, 2016; Tjoe & de la Torre, 2014). Irfan et al. (2019a) examined the interference that occurs when students solve proportion problems in terms of APOS theory. Then, Irfan et al. (2019b) examined semantic and procedural interference. Meanwhile, our observation conducted at Junior High School 3 Malang revealed that students were confused and interfered with when solving two problems (direct and inverse proportion). Most of the students solved the problem of inverse proportion with direct proportion concepts. This phenomenon is known as proactive interference. Proactive interference occurs when someone's old knowledge interferes with new knowledge.

In addition, interference is related to the process of recalling information in students' memory (Slavin, 2017; Solso et al., 2014; Sternberg & Sternberg, 2012). The thinking process of these students can be traced through their met-before. Met-before refers to a mental structure that a person currently possesses as a result of previously encountered experiences (McGowen & Tall, 2010; Mowahed & Mayar, 2023; Tall, 2013). Chin and Jiew (2019) elaborate that met-before refers to the results of previous student experiences that influence their current thinking and shaping mathematical conceptions. Through met-before, students' learning problems can be identified. This is in accordance with the statement of Tall et al. (2014) that previous learning experiences and prior knowledges (Martin & Towers, 2016; Wakhata et al., 2023) can affect a person's cognition. Previous learning experience used in current learning is also known as met-before (Mowahed & Mayar, 2023; Tall et al., 2014).

Research related to met-before was conducted by McGowen and Tall (2010), focusing on met-before, which caused students difficulties in studying algebra in college and problems related to the minus sign (-). Specifically, met-before can be supportive and problematic (McGowen & Tall, 2010; Mowahed & Mayar, 2023). Met-before becomes supportive when old ideas can be used in new contexts in a plausible way (McGowen & Tall, 2010; Mowahed & Mayar, 2023). Conversely, met-before becomes problematic when students cannot use the ideas or knowledge they have previously learned (McGowen & Tall, 2010; Mowahed & Mayar, 2023). This cases also often causes cognitive conflict for student which becomes problematic because of the difference between new information and existing mental structures (met-before) (HR et al., 2023). Similarly, Chin et al. (2019) described that supportive conceptions refer to old conceptions that have been studied before and are applicable to new contexts. In contrast, problematic conceptions refer to previously learned conceptions that are non-applicable in new contexts. The conception described by Chin et al. (2019) is a form of met-before (Chin & Pierce, 2019). In other words, a supportive met-before will aid and help students use their existing knowledge in learning or understanding new knowledge. Meanwhile, the problematic met-before will become an obstacle for students in learning further knowledge. This supportive and problematic is then examined by Chin et al. (2019), where the construction of this supportive and problematic conception can assist researchers in understanding the process of assimilation and accommodation occurs in the human mind.

Supportive met-before does not always offer a supportive nature, and it sometimes becomes an obstacle. According to Chin and Jiew (2019) Jiew and Chin (2020), supportive met-before may contain problematic aspects which are then referred to as suppressed problematic. Conversely, problematic met-before may contain supportive aspects which are then referred to as *suppress supportive*. Those forms met-before is illustrated in Figure 1.

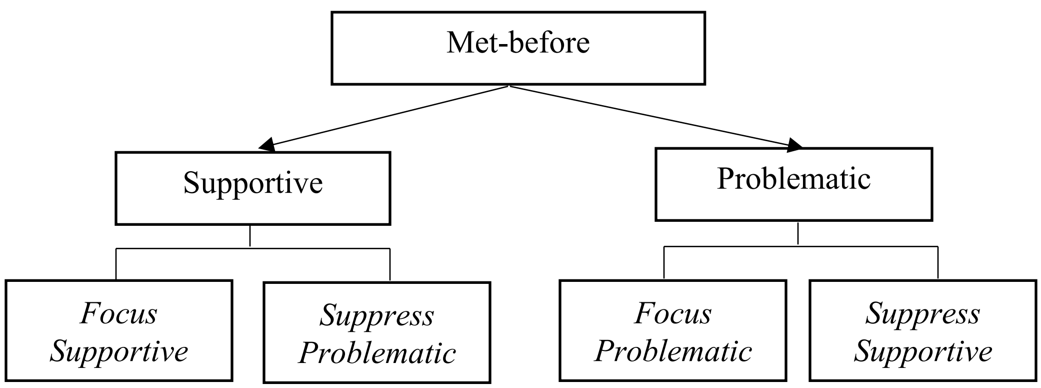


Figure 1: Supportive and Problematic Met-before
Source: (Chin & Jiew, 2019)

As presented in Figure 1, supportive met-before can be *focus supportive* and *suppress problematic*. According to Chin and Jiew (2019), *focus supportive* is a conception or met-before held by students that is supportive and applicable in new contexts. As an illustration, the met-before student about "concepts multiplication is repeated addition." That met-before will *focus supportive* in natural numbers, for instance, $3 \times 1 = 1 + 1 + 1$; $2 \times 5 = 5 + 5$, etc. However, supportive met-before about "concepts multiplication is repeated addition" may contain problematic aspects or are called *suppress problematic*. In this case, when the multiplier of multiplication is negative numbers, such as to solve "-4×2," attempting to represent it as repeated addition (e.g., "$2 + 2 + 2 + 2$") proves challenging and impractical. However, there is a case study where students can remove the problematic aspect by using their knowledge about the commutative property of multiplication ($p \times q = q \times p; p, q \in R$) (Jiew & Chin, 2020). Therefore, "$-4 \times 2 = 2 \times -4$" can be written as "$2 \times -4 = (-4) + (-4) = -8$". From these examples, *suppress problematic* is supportive met-before, which may contain problematic aspects. However, there may be a possible approach to remove problematic aspects using other knowledge that assists in effectively addressing the problem.

Besides being supportive, the met-before also contains problematic met-before, namely *focus problematic* and *suppress supportive*. Chin and Jiew (2019) define *focus problematic* as a problematic conception or met-before, which hinders or is non-applicable in new contexts. For example, with the same case for met-before about "concepts multiplication is repeated addition". This met-before becomes problematic when students apply it to the calculation of fractions such as "$\frac{1}{2} \times \frac{1}{4}$". Students can't write down."$\frac{1}{2} \times \frac{1}{4}$" as repeated addition. However, this problematic met-before also contains supportive aspects, referred to as *suppress supportive*. As an illustration, when students decide to use "concepts of multiplication as repeated addition" in the multiplication of fractions, they can solve "$\frac{1}{2} \times \frac{1}{4}$" with $\frac{1}{2}$ of $\frac{1}{4}$ or "$\frac{1}{2} \times \frac{1}{4} = \frac{1}{8}$".

Following up on the results proposed by Chin et al. (2019); Chin and Jiew (2019); and Jiew and Chin (2020) research, this study explores those forms met-before illustrated in Figure 1, specifically on students who experience interference. This study focuses on investigating the occurrence of met-before in students who experience proactive interference when solving problems of direct and inverse proportion. Students who are suspected of experiencing proactive interference present the ability to solve the problem of direct proportion using the concept of direct proportion. However, students solve the problem of inverse proportion with the concept of direct proportion.

Interference has been studied by several other researchers (Babai & Lahav, 2020; Hidayanto & Budiono, 2019; Irfan et al., 2019; Jayanti et al., 2018; Maulyda et al., 2020; Stavy & Babai, 2010; Sukoriyanto et al., 2016; Visscher et al., 2015). However, those studies mainly focused on students with dyscalculia (Babai & Lahav, 2020; Stavy & Babai, 2010; Visscher et al., 2015) and problem-solving (Hidayanto & Budiono, 2019; Irfan et al., 2019; Jayanti et al., 2018; Maulyda et al., 2020; Sukoriyanto et al., 2016). Existing research has not investigated the causes of interference through met-before. Through the students' met-before, their stored knowledge can be analyzed more effectively (Chin, et al., 2019; Chin & Jiew, 2019). Therefore, it is essential to examine the interference of students when solving proportion problems through their met-before. Therefore, the problem in this study is "how was students' the met-before who experience proactive interference in solving problems of direct and inverse proportion?".

METHOD

Research design

This research was designed using the case study research type. The approach was selected based on the findings of researchers regarding met-before students who experience proactive interference in solving proportion problems. Therefore, the researchers used a mathematical test on direct and inverse proportion problems and an interview guide. The test was used to identify the met-before and proactive interference that occurs in students. Meanwhile, the interview was used to confirm and deepen the understanding of the thinking processes of students who experience proactive interference. The results of the student's work were analyzed based on the student's work process, which was adjusted to the alternative answers prepared by the researcher. We analyzed the process of students' work indicated experiencing interference. This study adopts a case study following the assertion from Creswell and Creswell (2018) that case studies are applicable for describing and exploring a unique case in a particular phenomenon. The case study was performed specifically to deepen the understanding of a phenomenon for the general public (Bloomberg & Volpe, 2019). In this study, we describe the students' met-before who experience proactive interference.

To achieve this goal, we used the guidelines shown in Table 1.

Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
A preliminary study conducted observations of students in accelerated classes but there were indications of proactive interference when solving direct and inverse proportion problems.	We gave two mathematical problems (direct and inverse proportion) to 32 8th-grade students in Malang.	Researchers analyzed students' work and selected students who experienced proactive interference. Researchers consider the fluency of student communication and the student's willingness to be used as research subjects.	The researchers conducted interviews with two research subjects who had been selected based on the results of the researcher's analysis from Table 2. The researchers conducted interviews with the two research subjects outside of mathematics class hours.	The researchers triangulated data from the results of the research subject's work and the results of interviews to provide conclusions regarding the students met-before who experienced proactive interference.

Table 1: Research Stages

As described in Table 1, the data were collected from various sources, containing of student work and recorded interviews to obtain accurate results. After collecting the data, the findings were analyzed from the students' work through the indicators of the met-before presented in Table 2. After the analysis, we drew conclusive insights on the met-before of students experiencing proactive interference.

This research was conducted on students attending class category, thereby, they are regarded as having high abilities. This choice was made to clearly identify that interference does not exclusively occur in students with low or medium mathematical abilities, underscoring the need to investigate and address this phenomenon across a diverse spectrum of mathematical proficiency.

Research Subject

This research involved 32 8th-grade students in Malang. The selection of 8th-grade students was based on a preliminary study reporting indications that students experienced proactive interference in solving problems of direct and inverse proportion. The proactive interference being investigated in this study pertains to students who solve the problem of inverse proportion using the concept of direct proportion. To ascertain that proactive interference is occurring, we prepare a direct proportion problem. The problem of direct proportion serves as an instrument for identifying whether the interfering concept observed is related to direct proportion. Therefore, the selected research participants are those who correctly complete direct proportion problems but use the concept of direct proportion in solving inverse proportion problems. We also consider the fluency of student communication and student willingness in the selection of research subjects.

From these considerations, we determined two research subjects, with the first subject coded as S1 and the second subject as S2. S1 was a student with a non-flexible type, and S2 was a flexible type. This classification was made based on students' answers in solving direct proportion problems. They are classified as non-flexible when they make mistakes in algebraic algorithms, while flexible students can do the algebraic calculation process properly.

Data Collection and Data Analysis

We gave two proportion problems (direct and inverse proportion) to 32 8th-grade students. The problems are presented in Figure 2.

1. If the salary of 12 workers for 5 days is IDR 9,000,000.00. What is the salary received by 15 workers for 3 days assuming the performance of each worker is the same?
2. The project can be completed by 8 workers in 6 hours per day for 10 days. How long will it take 4 workers in 8 hours per day to complete the project? The performance of each worker is considered the same.

Figure 2: The Problem of Direct and Inverse Proportion

The results of student work were analyzed using the rubric of alternative answers. The results of this analysis will suggest the students who experience proactive interference.

In exploring the met-before of students who experienced proactive interference, we used a description of the met-before classification shown in Figure 1 (Chin and Jiew, 2019) and described in Table 2.

Met-before	Description
Focus Supportive	Supportive conceptions refer to old conceptions (direct proportion) that have been studied before and are applicable in new contexts (inverse proportion). Met-before is supportive of all concepts used in solving problems.
Suppress Problematic	Supportive conceptions contain problematic aspects and possible ways to remove problematic aspects by using other knowledge that is useful to solve the problem.
Focus Problematic	Problematic conceptions refer to previously learned conceptions (direct proportion) that are not applicable in new contexts (inverse proportion). Met-before is problematic in all the concepts used in solving problems.
Suppress Supportive	Problematic conceptions contain supportive aspects and use other knowledge that can be used to solve the problem and make sense.

Table 2: Description of Met-before

The collected data from students' works were analyzed following the description provided in Table 2. Subsequently, the interview was conducted. This interview was a semi-structured interview, allowing for adjustments based on the specific findings from the initial analysis. This interview aims to explore the met-before students who experience proactive interference. Researchers also triangulated data from the results of student work and interviews.

RESULT

From 32 students who solved the problem 2 presented in Figure 2, there were 3 students with correct answers, while 29 students answered incorrectly, as presented in Figure 3.

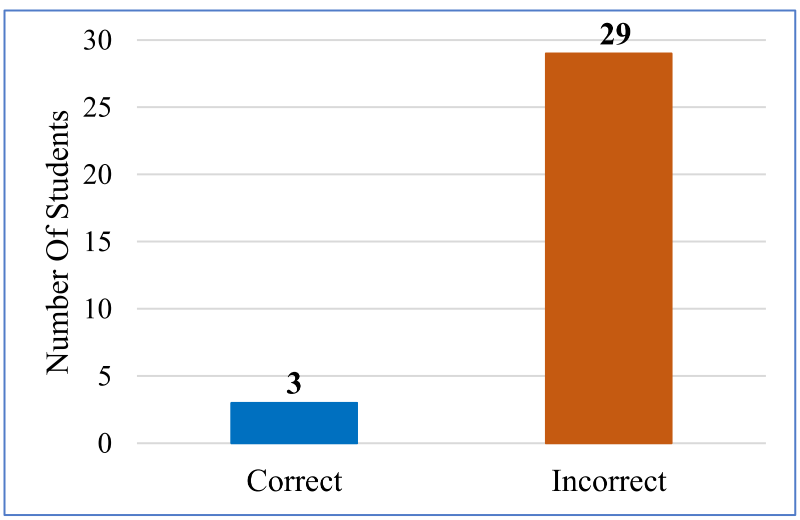


Figure 3: Students' Answer

Based on Figure 3, there are 29 students who are still wrong in answering the problem 2. Of the 29 students, 15 students did not answer the problem using the concept of proportion, 3 students were indicated as having retroactive interference, and 11 students experienced proactive interference. The results of these data are illustrated in Figure 4.

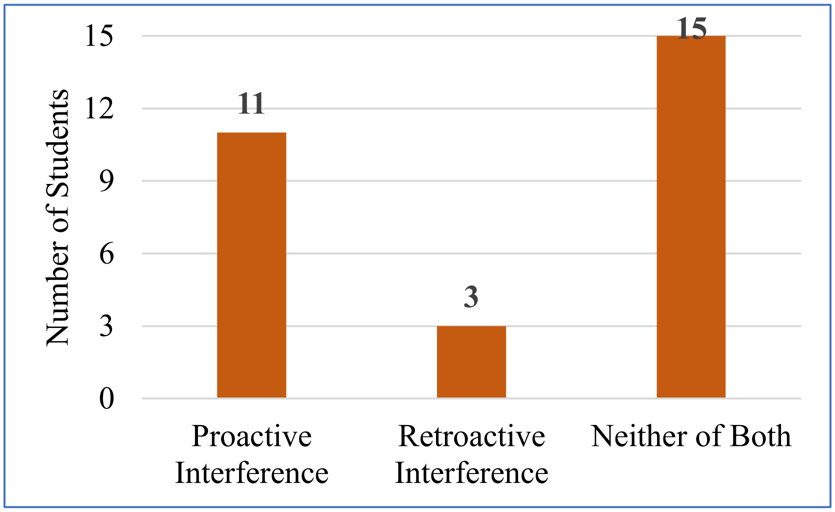


Figure 4: Types of Students' Errors

As shown in Figure 4, this study centered on students who experienced proactive interference. The work of the three students experiencing retroactive interference was unable to be explored as they had limited ability to articulate why they applied the concept of inverse proportion to solve problem number 1. Besides, the students' work also didn't show clear results. Therefore, to explore the cause of the problems faced by students encountering interference, we selected those who experience proactive interference.

The results from this study are manifest in a description of the met-before from students who experience proactive interference in solving direct and inverse proportion problems. Specifically, the proactive interference in focus pertains to students solving the problem of inverse proportion using the concept of direct proportion. In essence, this signifies that the memory and understanding of direct proportion interfere with their ability to correctly utilize the concept of inverse proportion.

The research data was collected from the results of student work during tests and interviews. In the presentation of the research data, we present the subject's correct answers in working out the direct proportion problem and wrong answers (interference) in working out the inverse proportion problem. This presentation of correct answers shows that the proactive interference experienced by the subjects is due to the concept of direct proportion being stronger in memory subjects. In other words, the concept of direct proportion interferes with the concept of inverse proportion. The following describes the proactive interference experienced by research subjects in solving problems of direct and inverse proportion.

S1 Work Results (Non-Flexible)

In problem 1, S1 performs calculations by multiplying the number of workers by the worker's time, thereby, $12 \times 5 = 60$ and $15 \times 3 = 45$, as presented in Figure 5.

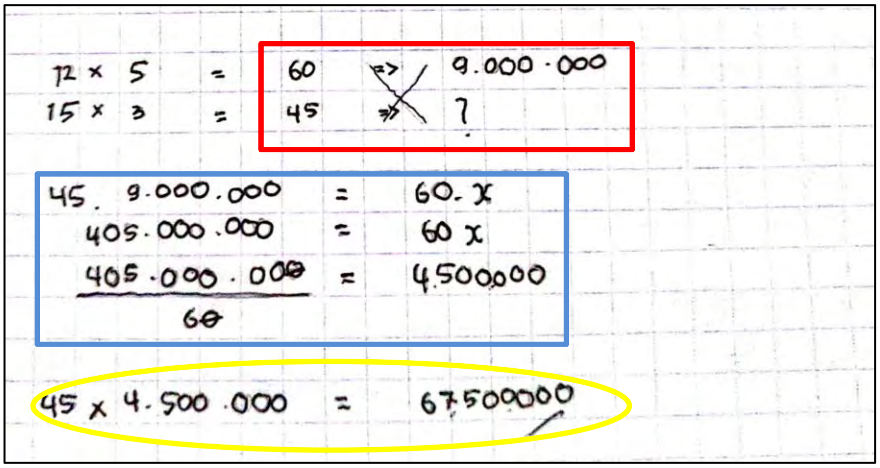


Figure 5: S1's Correct Answer in Problem 1

As shown in Figure 5, S1 carries out the calculation process with cross multiplication, as illustrated in the red box. To identify the process of working on the red box, we conducted interviews with S1. The following is an excerpt of the transcript of the researcher's interview with S1.

Q : *From your work on problem number 1, what is the meaning of writing "60 →9,000,000 and 45 →?" (while showing S1 work)*

S1 : *Oh, yes, ma'am. After I multiply 12 by 5, we get 60.*
So 60 gets 9,000,000. So if it's 45, how much will the worker get the money?
Then all cross I multiplied, as usual, ma'am.

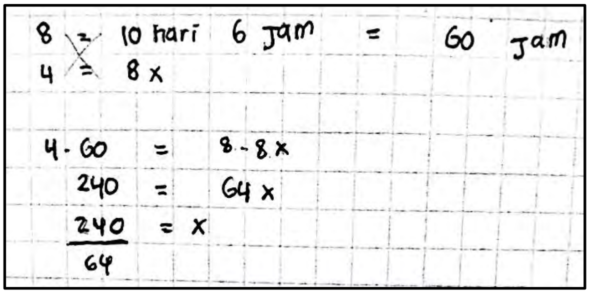
Through the interview, it was revealed that the length of work is 60, and the salary received is 9,000,000. However, when inquired about the salary for a working length of 45, S1 applied the cross multiplication method, as illustrated in the blue box. Regrettably, S1 writes in the last line $\frac{405.000.000}{60} = 4.500.000$. Ideally, the result from dividing 405,000,000 by 60 should be 6,750,000. However, when asked directly, S1 stated that the result of dividing 405,000,000 and 60 is 4,500,000. Then, S1 multiplies 45 by 4,500,000, resulting in 67,500,000. During the interview, S1 did not realize that the result of multiplying 45 by 4,500,000 was not 67,500,000.

From the data showing S1 work, S1 used the concept of direct proportion in solving the problem of direct proportion. However, S1 still made mistakes in calculating the results. Upon careful examination, S1 does not experience interference in solving the problem of direct proportion.

However, there were challenges in S1's met-before concerning the algebraic calculation process for determining the value of x. Even though the met-before of S1 supports the concept of direct proportion, it is still problematic for the concept of algebra. In other words, students' met-before is solving problem 1 is classified as met-before *suppress problematic*.

Then, we suspect the presence of interference when S1 solves the second problem. In this second problem, the inverse proportion problem is observed. However, when working on problem number 2, S1 still uses the concept of direct proportion, similar to when working on question number 1.

The results of S1's work on problem 2 is shown in Figure 6 below.



Translate:
$8 = 10$ days 6 hours $= 60$ hours
$4 = 8x$
$4 \,.\, 60 = 8 \,.\, 8x$
$240 = 64x$
$\frac{240}{64} = x$

Figure 6: S1's wrong answer in Problem 2 (Proactive Interference)

Referring to the information in Figure 6, S1 states "8 = 10 days 6 hours = 60 hours." S1 describes that with eight workers, the task can be completed within 60 hours.

In order to comprehend S1's approach to problem 2, researchers engaged in interviews with S1, and the interview transcript is shown in the following.

Q : *From problem number 2, how do you obtain the value of 60 hours? How do you solve this problem?*
S1: *Hmm.. 60 hours, I multiply 10 days by 6 hours.*
Q : *Why is that?*
S1: *Yes, ma'am, in that question, it said there were 8 workers. Then from those 8 workers, they work for 6 hours per day, and there are 10 days. It means total the time that the worker completed was 60 hours, ma'am.*
Q: *Then what does it mean 8 = 10 days 6 hours = 60 hours? (while designate S1 work)*
S1: *This means that if there are 8 workers, they complete their work in 60 hours, ma'am. So that's the same as this 4 = 8x, that's what was asked. If 4 workers, how long will it take? So it's the same as question number 1 it is equally cross-multiplied.*

From the interview excerpt, S1 stated that the value of 60 was obtained by multiplying the number of days by the time worked in a day. Then S1 writes " $4 = 8x$". S1 asserts that if there are 4 workers, the time to complete the work is 8 x, with x representing the length of time it takes for 4 workers to complete the work in 8 hours per day. Similar to the procedure adopted in solving problem 1, S1 solves problem 2 with cross multiplication of $\frac{8}{4} = \frac{60}{8x}$, thereby, the result is $x = \frac{240}{64}$. When asked by the researcher, S1 clarified that the results of the division of 20 and 64 were not whole, so S1 only wrote them in fractional form.

The results of S1's work on problem 2, make it apparent that S1 still experiences interference on the concept of direct proportion from his work on problem 1. From further analysis, at the initial stage, S1 begins to read and understand the problems. S1 assimilates the provided information, representing it in textual form as "$8 = 10\ days\ \ 6\ hours = 60\ hours$" and "$4 = 8x$" (Figure 7). In this case, S1 sorts out the information for solving the problem. S1 experiences interference when S1 multiplied the time "6 hours per day" with the information "10 days". Because S1 assumes that these two things represent time, thus, the result is 60 hours. This pattern repeats in the subsequent step, where S1 formulates "$8x$". This highlights that the student's met-before is still problematic, especially when understanding the meaning of the problem and connecting it to a comparison problem. The thinking structure of S1 in solving problem 2 is shown in Figure 7.

The following is the thinking structure of S1 when solving problem 2 as shown in Figure 7.

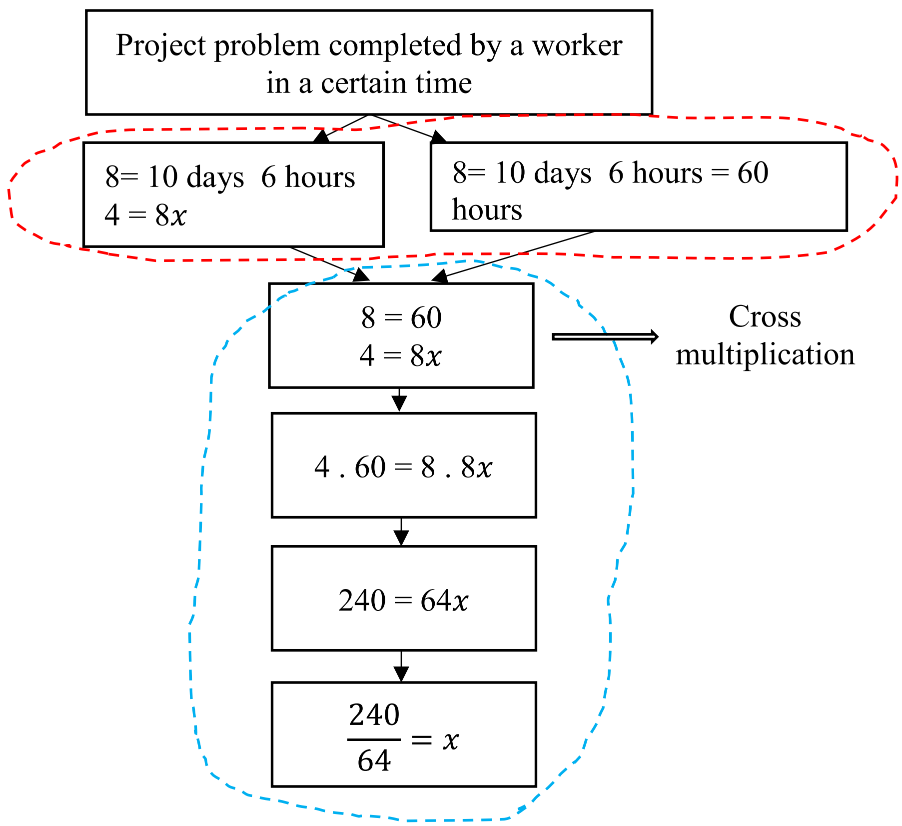


Figure 7: Thinking Structure of S1 when solving Problem 2

Note:

= Interference

= met-before

The met-before of students concerning the concept of comparison $\frac{a}{b} = \frac{c}{d}$ in such a way that $bc = ad$, proves to be problematic (Figure 7). This issue manifests particularly in solving problem 2 following the procedure for solving the concept of direct proportion. S1 assumes that in solving each proportion problem, the problem should be made into a solution model $\frac{a}{b} = \frac{c}{d}$. Therefore, S1 experiences interference in solving problem 2.

S2 Work Result (Flexible)

In problem number 1, S2 solves the given problem using the concept of direct proportion. The results of S2's work on problem number 1 is presented in Figure 8.

Gaji 12 orang 5 hari = 9 000.000 gaji 1 orang 5 hari = 9 000.000 ÷ 12 = 750.000 gaji 1 orang 1 hari = 750 000 ÷ 5 = 150.000 gaji 15 orang 1 hari = 150.000 × 15 = 2.250.000 gaji 15 orang 3 hari = 2 250.000 × 3 = 6.750 000 Jadi 15 orang 3 hari = 6.750.000	Translate: Salary 12 peoples 5 days = 9000000 Salary 1 people 5 days = 9000000 : 12 = 750000 Salary 1 people 1 day = 750000 : 5 = 150000 Salary 15 peoples 1 day = 150000 × 15 = 2250000 Salary 15 peoples 3 days = 2250000 × 3 = 6750000 So, 15 peoples 3 days = 6.750.000

Figure 8: S2's Correct Answer for Problem 1

In Figure 8, S2 systematically writes down the steps for calculating workers' salary. This is evident when S2 writes information on the problem regarding the salary of 12 workers for 5 days is Rp. 9,000,000.00, by "salary of 12 people five days = 9,000,000". Then, S2 determines the salary of 1 person for 5 days to be " 9,000,000 : 12 = 750,000". Consequently, the daily salary for 1 person is determined as " 750,000: 5 = 150,000". Then, on the salary of 15 workers for 3 days, S2 writes down "salary of 15 people for 1 day = 150,000 ×15 = 2,250,000". Thus, the salary of 15 people for 3 days is "2,250,000 ×3 = 6,750,000".

The met-before S2's on problem 1 is *focus supportive,* whereas S2's understanding related to direct proportion is supported by well-structured problem-solving procedures. Therefore, S2 can solve problem 1, correctly. However, when presented with a problem similar in structure but involving a different mathematical concept in problem 2, S2 experiences interference with the direct proportion formula. The results of S2's work on problem 2 are shown in Figure 9.

$8 \times 6 = 48$
$4 \times 8 = 32$
$48 = 10$
$32 = ?$

$$\boxed{\frac{\cancel{32}^{\cancel{8}\,4} \times \cancel{10}^{5}}{\cancel{48}_{\cancel{24}\,\cancel{6}\,3}} = \frac{20}{3} = 6\frac{2}{3} \text{ days}}$$

Figure 9: Wrong Answer of S2 in Problem 2 (Proactive Interference)

In Figure 9, S2 directly multiplies the number of workers by the time of workers ($8 \times 6 = 48$ and $4 \times 8 = 32$). To find out the S2's process of thinking in understanding problem 2, we conducted interviews with S2. The excerpt of the interview with S2 is presented in the following.

Q : *From problem number 2, can you tell me about the initial process of working on the problem?*

S2 : *First, I multiply 8 and 6, then 4 times 8, Ma'am. If I get the result, I write 48 = 10, then what about the 32 =?*

Q : *Hmm, what do you mean about 8×6 and 4×8?*

S2 : *From that problem, there are 8 workers who work for 6 hours so $8 \times 6 = 48$. Meaning that 48 will equal 10 days. Thus, similar for $4 \times 8 = 32$ equals how many days? After that, I just count, as usual, ma'am.*

Based on the excerpt from the interview with S2, S2 multiplies the information from the problem. Then, S2 writes 48 = 10, implying that with 48 hours of work, the work will be completed within 10 days. Therefore, S2 assumes that if there are 32 hours of work, then the problem is to find the duration of completing the work. At this stage, S2 performs calculations with cross multiplication (red box). The results obtained from these calculations are $6\frac{2}{3}$ days.

Figure 10 illustrates the S2's thinking structure when solving problem 2.

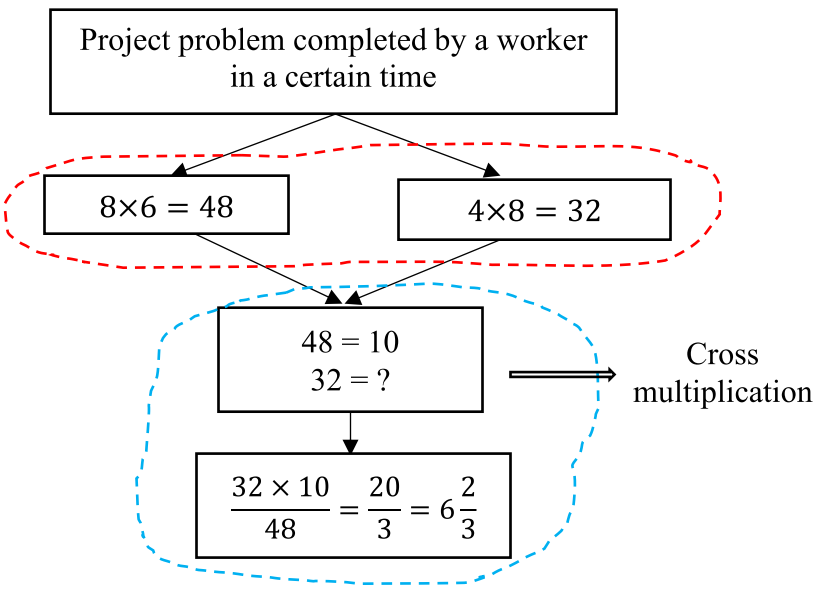


Figure 10: Thinking Structure of S2 when Solving Problem 2

Note:

= interference

= met-before

The results of S2's work on problem 2 suggested that S2 experiences proactive interference. From further analysis, initially, S2 interprets the problem as a matter of direct proportion. S2 states that problems number 1 and 2 are the same, both revolving around the completion of work. Because S2 initially perceived problem 2 as a direct proportion, S2 begins to assume that the total hours of the number of workers are obtained by multiplying the number of workers by the hours worked per day ($8 \times 6 = 48$ and $4 \times 8 = 32$) (see Figure 10).

In S2's thinking framework (met-before), this problem can be brought into a cross-multiplication formula as he has learned before. Thus, S2 performs the cross-multiplication calculation operation with the form " $\frac{32\times 10}{48}$ " with the obtained results of $6\frac{2}{3}$ days. Essentially, S2's met-before on the concept of comparison $\frac{a}{b} = \frac{c}{d}$ and cross-multiplication strategy ($bc = ad$) proves to be problematic. In addition to S2's problematic concept of proportion, problem 2, which revolves around workers, also poses difficulty for S2. S2 perceives problems related to work as direct proportion problems akin to problem 1. The summary of research results is shown in Table 2.

Proactive Interference	Question Number	Met-before
Non Flexible	1	Suppress problematic
	2	Focus problematic
Flexible	1	Focus supportive
	2	Focus problematic

Table 2: Met-before Student who Experienced Proactive Interference

DISCUSSION

The analysis results suggested that the proactive interference experienced by S1 and S2 has differences and similarities. In the met-before of S1 and S2 on problem 1 we observed differences. In problem 1 (direct proportion problem), met-before of S1 includes *supress problematic*, while the met-before of S1 is supportive of the concept of proportion. However, this supportive does not always aid S1 to solve the problem properly. During the process, S1 experiences problematic algebraic calculation procedures. This is in accordance with the statement of Chin and Jiew (2019) that a supportive conception may contain problematic aspects which is referred to as suppress problematic. In addition, McGowen and Tall (2010); Mowahed & Mayar (2023); Tall (2013); and Tall et al. (2014) also described that met-before can be supportive in certain concepts and problematic in other concepts.

In contrast to S1, S2 presents a *focus supportive* on problem 1. This is evident from met-before supportive of S2 in the process of solving problems. Consequently, S2 presents a correct answer. The supportive met-before in S2 facilitates the appropriate problem-solving procedure. In accordance with Chin et al. (2019), that supportive met-before can support the process of generalization and problem-solving.

However, when S1 and S2 experience proactive interference in problem 2, the met-before of both S1 and S2 is *focus problematic*. This problematic met-before leads to errors in solving problems 2. Chin et al. (2019) and Tall et al. (2014) asserted that problematic met-before can result in difficulty and confusion when facing math problems. In problem 2, proactive interference is not only limited to retrieval; it extends to when students understand the problem or receive incoming information. This is corroborated by the research from Irfan et al. (2019a) that the interference can be caused by students misunderstanding the meaning of the questions. This error causes students to incorrectly call the knowledge possessed by students. Irfan et al. (2019b) further categorized this misunderstanding as semantic interference.

Problem number 2 also has similarities with problem number 1, as the materials for direct proportion and inverse proportion have similar problem structures (Irfan et al., 2019a). Redick et al. (2020) described that problems with a similar structure, both in terms of content and processing procedures, are called near transfers.

Sometimes, specific information on the problem can mislead students to wrong perceptions. For instance, when S1's process in solving problem number 2, assumes that 6 hours per day with ten days are equivalent, so S1 multiplies the two numbers. In addition, the embedded met-before in the minds of students suggests proportion problems can be solved using the comparisons $\frac{a}{b} = \frac{c}{d}$ with $bc = ad$. It further confuses students, leading to interference every time they find a proportion problem. Students often assume that the problem can be changed in the form of this proportion. This problematic met-before caused students to experience interference. Thus, through met-before, the causes of the problems can be traced. Met-before can be used as a measuring tool or an analytical tool to analyze students' thinking processes and sense-making in solving problems (Chin et al., 2019; Chin and Pierce, 2019).

In addition to being related to mathematic concepts, the problem-solving process also involves problem-solving procedures and experience working on similar problems. In this study, the problem-solving approach employed by both S1 and S2 is notably centered around the cross-multiplication strategy. This aligns with the results of previous studies reporting that students often use cross-multiplication strategies (Avcu & Doğan, 2014; Ayan & Isiksal-Bostan, 2019; Öztürk et al., 2021; Parameswari et al., 2023; Tunç, 2020). For the cross-multiplication strategy, students cross the denominator and multiplier of the multiplication form $\frac{a}{b} = \frac{c}{d}$ such that $bc = ad$ (Çalışıcı, 2018; Im & Jitendra, 2020; Parameswari et al., 2023).

There are several reasons for the frequent usage of cross-multiplication strategy. One significant reason is that students are often taught cross-multiplication strategies in solving comparison problems (Öztürk et al., 2021). Linearly, Andini and Jupri (2017) described that students only remember the methods or procedures given by the teacher. In addition, proportion problems, such as direct and inverse proportion, are often associated with multiplication (Vanluydt et al., 2021). Therefore, students automatically solve the proportion problems with cross-multiplication strategies (Parameswari et al., 2023).

IMPLICATION FOR LEARNING ACTIVITY

This research focuses on the interference of students when solving problems of direct and inverse proportion. There are several alternatives that can be used to prevent this interference. First, the teacher provides a peer-assessment form to give students a chance to analyze each other work and find potential fruitful errors. Some leading questions can be very helpful in spotting mistakes. Second, teachers must provide meaningful learning to students. For example, learning that usually occurs in class is when the teacher gives a problem: “If a vehicle travels a distance of 50 km, then the vehicle has 2 liters of fuel. How far can the vehicle travel if it consumes 5 liters of fuel?”. The completion process is usually given as follows:

$2\ liters\ \rightarrow 50\ km$

$5\ liters\ \rightarrow ?\ km$

Then, the above problem is completed with $\frac{5}{2} \times 50 = 125$ km.

The previously mentioned solution primarily relies on procedural learning through symbols without conveying meaningful understanding. Teachers should help students understand each problem sentence used and not rely on the use of algebraic symbols (Edo & Tasik, 2022). Therefore, teachers should intervene in learning by providing the following directions: “If 2 liters of fuel can be used to cover a distance of 50 km, then 1 liter of fuel can be used to cover a distance of 25 km. So, if there are 5 liters of fuel, it can be used to cover a distance of $5 \times 25 = 125$ km”.

While the outcomes in both instances are identical, the process for finding the results is different. The intervention provided by the teacher makes learning more meaningful rather than providing formulas that confuse students, resulting in interference.

Third, the teacher can give some alternative problem-solving strategies, especially for students showing interference. The example questions include: have you tried to study another problem with some easier numbers, what would you expect to happen if one of the numbers approaches zero or is it consistent with your current numerical result or what you expected.

CONCLUSIONS

Based on the analysis results, the met-before of students experiencing proactive interference can be classified into non-flexible and flexible types. For the first problem (direct proportion), students with non-flexible type have *suppress problematic* met-before because students are able to solve direct proportion problems using the appropriate concept, but students experience problems in the completion procedure. It is evident that student’s understanding of the concept of direct proportion is supportive but it contains problematic aspects in the problem-solving process. On the other hand, students with a flexible type were categorized under the *focus supportive* category. This classification is attributed to their comprehensive understanding of the concepts and adeptness in the procedural aspects, enabling effective problem-solving.

For the second problem (inverse proportion), both students with non-flexible type and flexible type have *focus problematic* met-before because they assume that the first and second problems are the same. The problematic concept arises when students automatically resort to the cross-multiplication strategy ($\frac{a}{b} = \frac{c}{d}$ such that $bc = ad$). Students also cannot reason or link relationships between existing information. Thus, students experience problems determining the direction of changes in quantity in proportion problems.

The met-before that happened to students who experienced proactive interference turned out to be problematic. Accordingly, further research can examine the causes of met-before problematic further. This can be an input for educators to prepare learning that can prevent problematic met-before on students. In addition, this study is centered on proactive interference, while interference is very likely to occur retroactive interference or mixed (proactive and retroactive interference) so it is suggested for further research to examine the met-before students who experience retroactive and mixed interference (proactive and retroactive interference). Material that students have the potential to experience interference is not only material for direct and inverse proportion. Therefore, future researchers can analyze interference in other materials which allows for more variants of met-before.

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