



Mindsponge framework: Tracing students' proactive interference

Pradina Parameswari*

Universitas Negeri
Surabaya, INDONESIA

Nurul Rafiqah Nasution

Universitas Negeri
Surabaya, INDONESIA

Ulumul Umah

Universitas Negeri
Surabaya, INDONESIA

Susana Labuem

Universitas Pattimura
INDONESIA

Analisa Fitria

Universitas Islam Negeri
Antasari, INDONESIA

Jihan Hidayah Putri

Universitas Al Washliyah
Medan, INDONESIA

Article Info

Article history:

Received: Dec 03, 2025

Revised: Feb 20, 2026

Accepted: March 06, 2026

Keywords:

Mindsponge framework;
Proactive interference;
Proportion problem.

Abstract

Background: Many students have difficulty distinguishing between direct and inverse proportion problems. This difficulty can cause interference during problem solving. One form of interference is proactive interference, which occurs when previously learned information disrupts the understanding of new information. In proportion problems, students' prior knowledge of direct proportion often influences how they approach inverse proportion tasks, leading them to apply incorrect strategies.

Aim: This study aims to describe the process of proactive interference experienced by students when solving proportion problems using the Mindsponge framework.

Method: This study used a qualitative descriptive approach. The participants were 32 eighth-grade students from Junior High School 3 Malang. The selected subjects were students who could correctly solve direct proportion problems but applied the direct proportion concept when solving inverse proportion problems. Data were collected through proportion problem tests and interviews. Students' written work was analyzed using indicators from the Mindsponge framework, and the findings were triangulated by comparing students' work with interview results.

Results: The results show that proactive interference occurred at three stages of the Mindsponge framework: environmental, filtering, and mindset. At the environmental stage, students made errors in observing and understanding the problem. In the filtering stage, students incorrectly determined the quantitative relationship between variables. At the mindset stage, students relied on their prior knowledge of direct proportion and frequently used the cross-multiplication strategy.

Conclusion: The study indicates that proactive interference occurs when previously learned concepts dominate students' thinking processes. The Mindsponge framework helps explain how prior knowledge influences the way students interpret and apply new information when solving proportion problems.

To cite this article: Parameswari, P., Nasution, N. R., Umah, U., Labuem, S., Fitria, A., & Putri, J. H. (2026). Mindsponge framework: Tracing students' proactive interference. *Journal of Advanced Sciences and Mathematics Education*, 6(1), 89–103.

INTRODUCTION

Students often experience difficulties recalling previously learned mathematical concepts when they encounter new but related information. This condition is referred to as interference, a cognitive disturbance that arises when different pieces of information compete during the retrieval process in memory. As a result, students may confuse or incorrectly apply concepts because the information they receive shares similar characteristics. Such similarities can lead previously stored knowledge to overlap with newly learned material, which may cause misunderstandings or errors during mathematical problem solving. Parameswari (2024) states that interference occurs when students understand two or more different concepts that are related. Sukoriyanto et al., (2016)

* Corresponding author:

Pradina Parameswari, Universitas Negeri Surabaya, INDONESIA
pradinaparameswari@unesa.ac.id✉

expressed a similar view, stating that interference is an error that occurs because of conflicting concepts, such that one concept conflicts or interferes with another. Interference is a disruption that occurs when the retrieval of one piece of information interferes with the retrieval of another piece of information (Slavin, 2017; Solso et al., 2014; Sternberg & Sternberg, 2012). Anderson (2020) and Slavin (2017) add that interference refers to forgetting caused by interruptions in the retrieval process. In addition to mutual interference, interference can also occur when existing information is mixed with other information (Ormrod, 2020; Sternberg & Sternberg, 2012).

There are two forms of interference: retroactive interference and proactive interference (Georgiou et al., 2021; McBride & Cutting, 2018; Mercer, 2015; Slavin, 2017; Solso et al., 2014; Sternberg & Sternberg, 2012). It is said to be retroactive when new information interferes with old information. Proactive interference, on the other hand, occurs when old information interferes with new information. Both forms of interference occur when received information appears in close proximity.

The mathematical material in which interference occurs most frequently is direct and inverse proportions. In direct and inverse proportion problems, both have characteristics and keywords that distinguish them from each other. However, students sometimes get confused when solving direct and inverse proportion problems. Difficulties experienced by students include: difficulty connecting two quantities, procedural errors, and difficulty choosing the right strategy. Meanwhile, Pelen & Artut (2016) stated that the probability of answering correctly on direct proportion problems is greater than on inverse proportion problems. These difficulties likely arise from the similarity in problem structure between direct and inverse proportion problems. An inverse proportion can be written as $y = a/x$, while a direct proportion can be written as $y = ax$ (Dooren et al., 2009; Lamon, 2020). Because of these similar problem structures, students may have difficulty clearly distinguishing between the two (Doyle et al., 2016).

This concern is further supported by preliminary classroom observations indicating that students experience difficulties when solving proportion problems. The problems presented were inverse proportion problems. The problem presented to the students can be seen in Figure 1 below.

Ade, Putra, and Sandi can complete a job individually in 20 days, 30 days, and 60 days, respectively. How many days does Ade need to complete the job if every 3 days he is assisted by Putra and Sandi, with the first 2 days Ade working by himself?

Figure 1. Observation Questions

According to the preliminary study's findings, the majority of students used the idea of direct proportion to solve the problem. The problem presented was an inverse proportion problem. The researcher selected student work that was representative of other students' work. Figure 2 below shows the outcomes of the students' work on the given problem.

1) Diket = Ade = 20 hari
 Putra = 30 hari
 Sandi = 60 hari
 Dit = Berapa hari Ade menyelesaikan pekerjaan tiap 3 hari dibantu oleh Putra dan Sandi? dgn urutan 2 hari pertama Ade bekerja sendiri?

$$\begin{aligned} \text{Dit. ub} &= \frac{a}{20} = \frac{30}{60} \\ &= \frac{30 \times 20}{60} \\ &= \frac{600}{60} = 10 \text{ hari} \end{aligned}$$

Figure 2. Student Work Results on Question Number 1

Based on the student's work in Figure 2 above, the student wrote the information in the problem with known and question components. The student stated that working with proportion problems like those in Figure 2 is always done using the cross multiplication method. This is because

the solution procedure taught when students learn about direct and inverse proportions is the cross-multiplication method. When interviewed, students were still confused about distinguishing between direct and inverse proportion problems. Students stated that these problems were direct proportion problems. This indicates that students experienced interference. This interference is proactive interference, where memories related to the concept of direct proportions interfere with memories related to the concept of inverse proportions. Therefore, inverse proportion problems are addressed using the concept of direct proportions.

Interference has been studied by several other researchers, such as Babai & Lahav (2020), Hidayanto & Budiono (2019), Irfan et al., (2019), Jayanti et al., (2018), Maulyda et al., (2020), Parameswari (2024), Stricker et al., (2021), Sukoriyanto et al., (2016), and De Visscher et al., (2015). Babai & Lahav (2020) conducted a study on intuitive interference in blind and sighted people by comparing the circumference and area of geometric objects through the sense of touch (blind) and vision (normal). Research on specific subjects was also conducted by De Visscher et al., (2015), who examined interference in arithmetic fluency in individuals with dyscalculia. Meanwhile, research related to interference in problem solving (Sukoriyanto et al., 2016; Hidayanto & Budiono, 2019; Irfan et al., 2019; Jayanti et al., 2018; Maulyda et al., 2020).

Previous studies on interference in mathematics learning have primarily focused on identifying its occurrence and measuring its impact on students' performance. While these studies provide important empirical evidence, they tend to treat interference as an observable outcome rather than as a dynamic cognitive process. Consequently, the internal mechanism through which prior knowledge intrudes upon and distorts the processing of new information remains underexplored. Without a clear explanation of how information is filtered, evaluated, and accepted or rejected within long-term memory, interference is understood only at a surface level. Therefore, there is a need for a conceptual framework that can explain the cognitive mechanism underlying proactive interference during mathematical problem solving. The Mindsponge framework offers a promising perspective for examining this process because it conceptualizes the mind as a dynamic system of information absorption, filtering, and value integration. The mindsponge framework is considered suitable for analyzing the process of interference in long-term memory components. This is because Mindsponge is a framework that offers a new perspective on information processing (Vuong et al., 2022), explaining how a person's mind can be changed, adapted, or developed (Vuong et al., 2022). This framework is used to help explain how and why individuals perceive and reject cultural values depending on the environment. In education, this framework can help observe the process of information accepted or rejected by students, storing it in memory for later use in problem-solving. The mind, which consists of the mindset, buffer zone, and multi-filtering system, and the environment, as depicted in Figure 3, are the two parts of the mindsponge framework (Nguyen et al., 2022; Vuong et al., 2022).

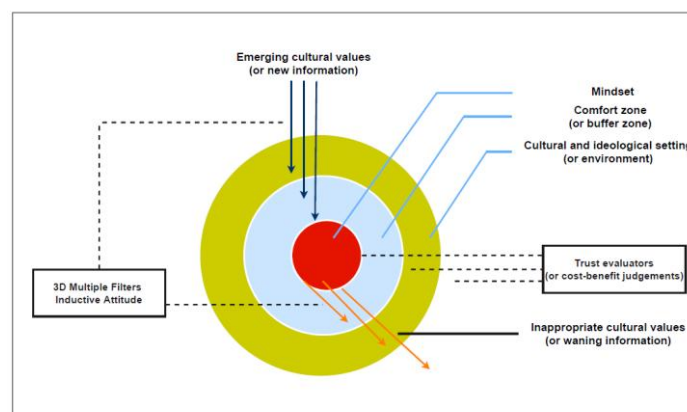


Figure 3. Mechanism of the Mindsponge (Nguyen et al., 2022)

The yellow part of the pie, which is the outermost part of the picture in Figure 3 above, depicts the environment of the individual (Nguyen et al., 2022). Information enters the mind through the surroundings. The attitude or core values are represented by the red core, which is the innermost part of the pie. A person's set of values is known as their mindset. The buffer zone is represented by the blue area in the middle, the outermost area, and the nucleus (Nguyen et al., 2022; Vuong et al., 2022). Information is assessed using a multi-filtering technique in the buffer zone. Information reception, assessment, and acceptance or rejection are all parts of this mindsponge process. In this study, the interference process was examined through the mindsponge process. Information reception occurs when students begin to read and understand the intended meaning of the problem. Evaluation occurs when students begin to recall the concepts and procedures used to solve the problem. This decision, meanwhile, represents the student's opinion regarding whether the answer obtained aligns with the problem.

In this study, the interference process will be traced through the mindsponge framework as previously explained. To identify interference, students are given problems that can cause interference. Mathematics materials that can cause interference include: GCF and LCM, direct and inverse proportion, arithmetic sequences and series with geometric sequences and series, permutations and combinations, and other mathematical materials can all lead to interference (Sukoriyanto et al., 2016). In this study, the proportion of direct and inverse values is the focus in tracing the occurrence of interference.

Based on the issues outlined above, this study focuses on proactive interference experienced by students when solving proportion problems using the Mindsponge framework. This study contributes theoretically by extending the application of the Mindsponge framework into the domain of mathematics education, particularly in explaining proactive interference as a dynamic information-filtering process. By tracing how previously internalized proportional concepts dominate the cognitive buffer zone during problem solving, this research provides a deeper explanation of why students systematically misapply direct proportion strategies to inverse proportion tasks. In this context, interference reflects the stability and dominance of prior conceptual structures within students' cognitive systems. Accordingly, the research question addressed in this study is: "How does proactive interference occur in students when solving direct and inverse proportion problems using the Mindsponge framework?"

METHOD

Research Design

This study was designed using a qualitative descriptive case study approach. The selection of this approach and type of research was based on the researcher's findings regarding the process of proactive interference experienced by students in solving proportion problems using the mindsponge framework. Therefore, the researcher used a mathematics test consisting of direct and inverse proportion problems, along with an interview guide. The mathematics test was used to identify proactive interference in students. The interviews aimed to confirm and deepen the thinking processes of students suspected of experiencing proactive interference. The students' work was analyzed based on their work processes, which were aligned with the alternative answers prepared by the researcher. The researcher analyzed the work processes of students suspected of experiencing interference.

The data collected by the researcher included not only student work but also interview recordings to obtain accurate results. After collecting the data, the researcher then analyzed the findings by systematically coding students' written responses and interview data, which were then interpreted and categorized according to the indicators of the Mindsponge framework presented in Table 1. The data collected by the researcher included not only student work but also interview

recordings to obtain accurate results. After collecting the data, the researcher then analyzed the findings by systematically coding students' written responses and interview data, which were then interpreted and categorized according to the indicators of the Mindsponge framework presented in Table 1. The sequence of the research process conducted in this study is illustrated in Figure 4.

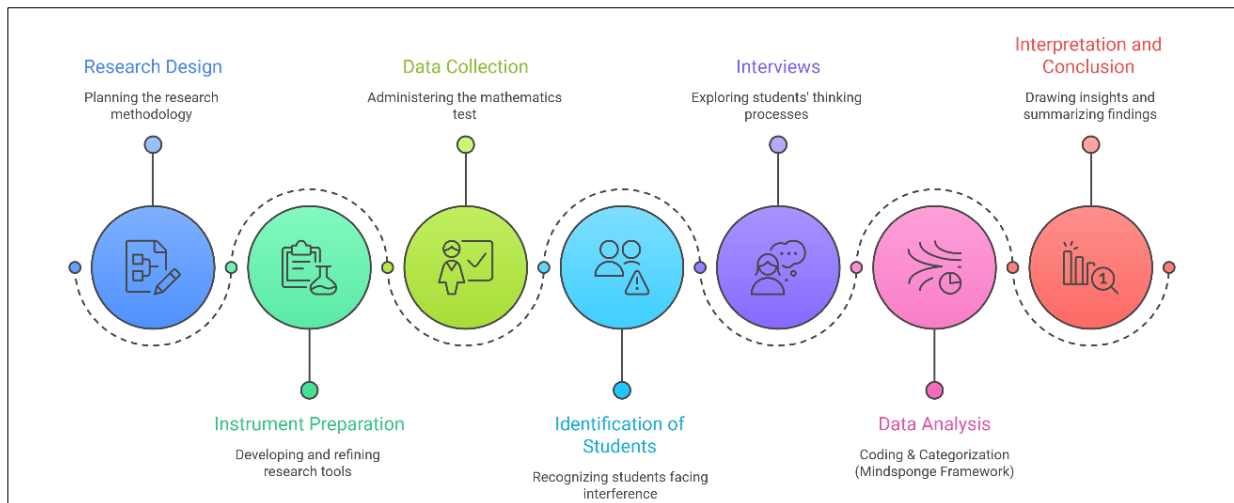


Figure 4. Research Process Sequence

Figure 4 illustrates the sequence of the research process used in this study. The research began with the research design stage, followed by instrument preparation, data collection through mathematics tests, identification of students suspected of experiencing proactive interference, and interviews to explore students' thinking processes. The collected data were then analyzed through coding and categorization based on the indicators of the Mindsponge framework, and the final stage involved interpreting the findings to explain the occurrence of proactive interference in solving proportion problems.

The research design employed by the researcher aligns with the characteristics of qualitative research outlined by Creswell & Creswell (2023), namely: 1) A scientific environment (natural setting) where the researcher collected data in the classroom with the research subjects solving the given problems. 2) The researcher acted as the primary instrument, collecting data through student work documented using a camera and interviews with the research subjects. 3) Multiple data sources: The researcher collected data from various sources, such as recordings, observations, and interviews. The data obtained was then examined by interpreting and categorizing it. 4) Data analysis. The researcher constructed categories or topics through analysis of previously collected data. 5) Conclusion drawing. This research process was dynamic, with all stages likely to change after the researcher entered the field and collected data.

This section should describe the research design in detail. It includes the data sources, data collection techniques, and data analysis methods used by the researchers. The methodology must be explained in paragraph form and should provide sufficient information for replication by other researchers.

Participants

Thirty-two eighth-graders from Junior High School participated in this study. Based on an earlier preliminary study that showed students encountered proactive interference when answering direct and inverse proportion problems, these eighth-grade students were chosen. Students who used the idea of direct proportion to solve inverse proportion problems were the proactive interference mentioned in this study. To obtain a clear picture of the proactive interference that occurred, the researcher prepared direct proportion problems. Direct proportion problems served as a tool to determine whether the interfering concept was direct proportion. Therefore, students

considered as research subjects were those who correctly solved direct proportions but used the concept of direct proportion when solving inverse proportion problems. The researcher also considered the students' fluency in communication and their willingness to be research subjects.

Based on these considers, the researcher determined two research subjects, hereinafter referred to as S1 and S2. S1 had a high level of mathematical skill, whereas those in S2 had an average level. Students with low mathematical proficiency were not chosen by the researcher. Students with low math abilities were not included in the study because they were unable to solve all types of proportion problems effectively. This was evident when they lacked a thorough understanding of the relationship between the two proportion concepts. Therefore, the interference process was not observed. The reasons of the selection of two participants was aligned with the qualitative case study design of this research, which emphasizes in-depth exploration of cognitive processes rather than numerical representation. The two students were purposively selected because they clearly demonstrated proactive interference and represented different levels of mathematical proficiency. The analysis was conducted iteratively, and no substantially new patterns emerged beyond these cases, indicating sufficient depth for analytical interpretation.

Data Collection and Analysis

The researcher presented two proportion problems (direct and inverse) to 32 eighth-grade students at Junior High School. The problems presented are shown in Figure 5 below.

1. If the wages of 12 workers for 5 days amount to Rp 9,000,000.00, how much will 15 workers receive for 3 days if each worker's performance is considered the same?
2. A job can be completed by 8 workers working 6 hours per day for 10 days. How long will it take 4 workers working 8 hours per day to complete the job? Assume each worker's performance is the same.

Figure 5. Direct and Inverse Proportion Problems

Based on the students' work, the researcher analyzed their answers using a pre-prepared alternative answer rubric. This analysis revealed which students experienced proactive interference. To analyze the process of proactive interference experienced by students, the researcher used indicators from the mindsponge framework (Vuong et al., 2022). These indicators are shown in Table 1 below.

Table 1. Indicators of the Components of the Mindsponge Framework

Components	Indicator
Environment	- Read the given problem - Focus and examine the information provided
Filtering	- Identify and select appropriate information to determine the relationship between quantities. - Determine the relationship of each known piece of information to the problem. - Determine a solution strategy. - Determine a solution based on selecting information that aligns with the concepts in the mindset.
Mindset	- Recalling existing information or concepts or prerequisite material used to solve the problem.

The researcher collected data and analyzed student work based on the indicators presented in Table 1. To enhance credibility, the analysis of students' written responses was conducted systematically and then followed by semi-structured interviews to confirm and clarify the identified patterns. These interviews served as a form of data triangulation. To ensure dependability, the researcher maintained detailed documentation of the coding and interpretation process. These interviews were semi-structured, tailored to the students' work. These interviews were conducted in order to investigate, using the mindsponge paradigm, the proactive interference process that

students went through. Additionally, the researcher combined information from interviews and student work.

RESULTS AND DISCUSSION

Results

The results of this study describe the occurrence of proactive interference when students solved direct and inverse proportion problems. Proactive interference was identified when students applied the direct proportion procedure while solving inverse proportion problems. In these cases, students consistently used a direct proportional reasoning strategy even though the problem required an inverse relationship.

The data for this study were obtained from students' work during tests and interviews. In presenting the research data, the researcher will present the subjects' correct answers when solving direct proportion problems and the incorrect answers (interference) when solving inverse proportion problems. The presentation of these correct answers aims to demonstrate that the proactive interference that occurs in this study is due to the stronger concept of direct proportion in the subjects' mindsets. In other words, the direct proportion concept interferes with the concept of inverse proportion. The following describes the subjects' proactive interference when solving direct proportion problems and inverse proportion problems.

Undergraduate Work Results (Medium Mathematics Ability)

S1 multiplied the number of workers by their time in order to do calculations for problem 1, i.e., $12 \times 5 = 60$ and $15 \times 3 = 45$, as shown in Figure 6 below.

Figure 6. Correct Answer S1 on Problem 1

Based on Figure 6 above, after S1 obtained the results of the previous multiplication, S1 performed the calculation using cross multiplication as shown in the red box. The researcher spoke with S1 in order to comprehend how the data displayed in the red box in Figure 6 were obtained. An excerpt from the interview transcript with S1 is provided below.

Q: Based on your work in problem number 1, what is the meaning of the sentence

"60 → 9,000,000 and 45 → ?" (while showing S1's work)

S1: Oh, yes, ma'am. After I multiply 12 by 5, the result is 60. So, 60 gives 9,000,000. So, if the worker gets 45, how much does he get? Then, he doesn't use cross multiplication as usual, ma'am.

In the interview, S1 stated that if he works for 60 hours, he gets a wage of 9,000,000, while if he works for 45 hours, what is the wage he receives? The cross multiplication computation was carried out by S1, as indicated by the blue box. On the final line, however, S1 wrote $405,000,000/60=4,500,000$. When 405,000,000 is divided by 60,000,000, the right answer is 6,750,000. In response to a direct query, S1 said that 4,500,000 is the result of dividing 405,000,000 by 60. S1 then calculated 67,500,000 by multiplying 45 by 4,500,000. S1 was unaware throughout the interview that the sum of 45 and 4,500,000 was not 67,500,000.

Based on S1's work, S1 solved direct proportion difficulties by applying the idea of comparable proportion. S1 continued to make mistakes during the computation process, nevertheless. After S1 resolved the second issue, the researcher began to suspect intervention. An inverse proportion problem is introduced in this second task. Nevertheless, S1 continues to apply the idea of direct proportion when working on problem number 2 in the same manner as when working on problem number 1. Figure 6 below shows the outcomes of S1's efforts on problem 2.

$$\begin{array}{l}
 8 = 10 \text{ hari } 6 \text{ jam} = 60 \text{ jam} \\
 4 = 8x \\
 \\
 4 \cdot 60 = 8 \cdot 8x \\
 240 = 64x \\
 \frac{240}{64} = x
 \end{array}$$

Figure 7. Wrong Answer (Proactive Interference) S1 on Problem 2

In accordance with Figure 7 above, S1 wrote, "8 = 10 days 6 hours = 60 hours." According to S1, it will take eight workers sixty hours to finish the task. The researcher spoke with S1 in order to comprehend how S1 approached problem 2. An excerpt from the transcript of S1's conversation with the researcher is provided below.

Q: From problem number 2, how did you arrive at the value of 60 hours? How did you solve the problem?

S1: Hmm... 60 hours is calculated by multiplying 10 days by 6 hours.

Q: Why is that?

S1: Yes, ma'am. The problem says there are 8 workers. Then, of those 8 workers, they work for 6 hours per day, for 10 days. This means the total time the workers complete is 60 hours, ma'am.

Q: So, 8 = 10 days 6 hours = 60 hours. What does that mean? (while pointing to S1's work)

S1: So if there are 8 workers, they will complete the work in 60 hours, ma'am. Well, that's the same as $4 = 8x$, as asked. If there are 4 workers, how long will it take? So it's the same as question number 1, which is cross-multiplication.

According to S1's statement from the interview clip, the number of days multiplied by the number of hours worked in a day yields the figure 60. S1 then wrote " $4 = 8x$." According to S1, it will take eight times as long to finish the work if there are four employees. x is the amount of time that four employees would need to finish the task in eight hours a day. Similar to how issue 1 was solved, S1 used cross-multiplication to solve problem 2, arriving at $x = 240/64$ ($8/4 = 60/8x$). In response to the researcher's question, S1 said that the result of dividing 240 by 64 is just a fraction because it is not a fraction.

It is evident from the outcomes of S1's work on problem 2 that S1 continues to struggle with the idea of direct proportion from his work on problem 1. According to the mindsponge framework, S1 starts reading and comprehending the supplied challenge in the first stage (environment). Then, "8 = 10 days 6 hours = 60 hours" and " $4 = 8x$ " are put down to represent the information that enters S1's thoughts. S1 performs a filtering procedure in this instance by classifying the data that is utilized to address the issue. S1 divides the time "6 hours per day" by the information "10 days" in this filtering stage, which results in an interference process. S1 multiplies these two items to get the answer of 60 hours since it believes that they both represent time. When S1 writes $8x$ in the subsequent phase, the same thing occurs. In the next stage of the calculation process, the memory stored in S1's mind is the form of $a/b = c/d$ proportion such that $bc = ad$ (mindset). Because the memory of the direct proportion concept exists in S1's mindset, the procedure for solving problem 2 also follows the procedure for solving the direct proportion concept. Therefore, S1 experiences interference at the filtering and mindset stages.

The following is a look at the proactive interference process that occurs in S1, from the moment information enters (reading the question) to solving problem number 2, as shown in Figure 8.

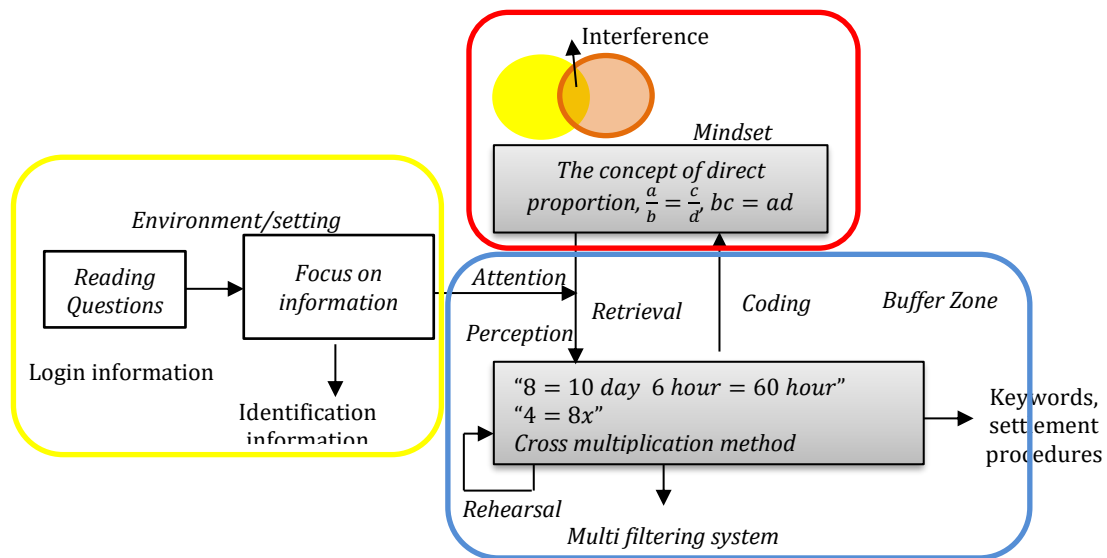


Figure 8. Proactive Interference Process experienced by S1

Based on Figure 8, S1 began to experience proactive interference when he was in the multi-filtering system. He was interfered with by the selection of information relationships used to solve problem number 2. Furthermore, S1 was also interfered with by his mindset, where he considered problem 2 to be a proportion problem, thus using the concept of proportion.

S2's Work Results (Higher Mathematical Ability)

S2 used the concept of proportion to solve the presented problem in problem number 1. Figure 9 below shows the outcomes of S2's efforts on problem number 1.

Gaji 12 orang 5 hari = 9.000.000
gaji 1 orang 5 hari = $9.000.000 \div 12 = 750.000$
gaji 1 orang 1 hari = $750.000 \div 5 = 150.000$
gaji 15 orang 1 hari = $150.000 \times 15 = 2.250.000$
gaji 15 orang 3 hari = $2.250.000 \times 3 = 6.750.000$
Jadi 15 orang 3 hari = 6.750.000

Figure 9. Correct Answer S2 on Problem 1

Figure 9 above shows S2 writing a step-by-step method for calculating workers' salaries. This is demonstrated when S2 discusses the issue of 12 workers' salaries for 5 days totaling Rp 9,000,000.00, specifically "salary of 12 people for 5 days = 9,000,000". Then, S2 calculates that " $9,000,000 : 12 = 750,000$ " is the salary of one employee for five days. Thus, " $750,000 : 5 = 150,000$ " is the salary of one person for one day. S2 uses the formula "salary of 15 people for 1 day = $150,000 \times 15 = 2,250,000$ " to calculate the pay for 15 employees for three days. Therefore, " $2,250,000 \times 3 = 6,750,000$ " is the salary for 15 employees for 3 days.

Although S2 didn't write down the formula for Problem 1, he was able to solve the problem using the concept of direct proportions. However, when S2 encountered a problem with a similar formula but a different concept, he encountered interference with the formula for direct proportions. The results of S2's work on Problem 2 can be seen in Figure 10 below.

Figure 10. Wrong Answer (Proactive Interference) S2 on Problem 2

Figure 10 shows that S2 quickly multiplies the number of workers by their time, resulting in $8 \times 6 = 48$ and $4 \times 8 = 32$. The researcher conducted an interview with S2 in order to comprehend how S2 approached problem 2. An excerpt from the transcript of S2's conversation with the researcher is provided below.

Q: For problem number 2, could you explain the initial process of solving it?

S2: First, I multiply 8 by 6, then 4 times 8, ma'am. When I get the result, I write $48 = 10$, then $32 =$ how much?

Q: Hmm, what do 8×6 and 4×8 mean?

S2: From that problem, ma'am, there are 8 workers working for 6 hours, so $8 \times 6 = 48$. So 48 equals 10 days. So, like that too. How many days does $4 \times 8 = 32$ equal? After that, just calculate, ma'am.

Based on the excerpt from the researcher's interview with S2 above, S2 multiplied the problem information as previously written. S2 then wrote that $48 = 10$, which indicates that the project will be finished in 10 days if there are 48 working hours. S2 therefore made the assumption that the task would be finished in? days if there were 32 working hours. At this point, S2 used cross multiplication to complete the calculation (red box). This computation yielded a result of $6 \frac{2}{3}$ days.

From S2's work on problem 2, it can be seen that S2 experienced proactive interference. When analyzed using the mindsponge framework, in the initial stage (environment), S2 began to read and understand the problem given. At this initial stage, S2 interpreted this problem as a proportion problem of value. S2 stated that problems 1 and 2 are the same. This is because both problems relate to the work being completed. Because S2's initial perception regarding problem number 2 was a direct proportion, in this filtering stage, S2 started assuming that the number of workers' total hours were calculated by multiplying their number by the number of working hours per day, which came out to be $8 \times 6 = 48$ and $4 \times 8 = 32$. S2 carried out the cross multiplication computation opeproportionn in the form because he believed that this problem could be converted into the cross multiplication formula he had previously learned, that is $\frac{32 \times 10}{48}$ so that the result was $6 \frac{2}{3}$ days. In the rechecking stage, S2 also felt confident that problem number 2 could be solved using the concept of direct proportion.

The following is the proactive interference process that occurred in S2 seen from the beginning of the information input (reading the problem) to solving problem number 2, as shown in Figure 11.

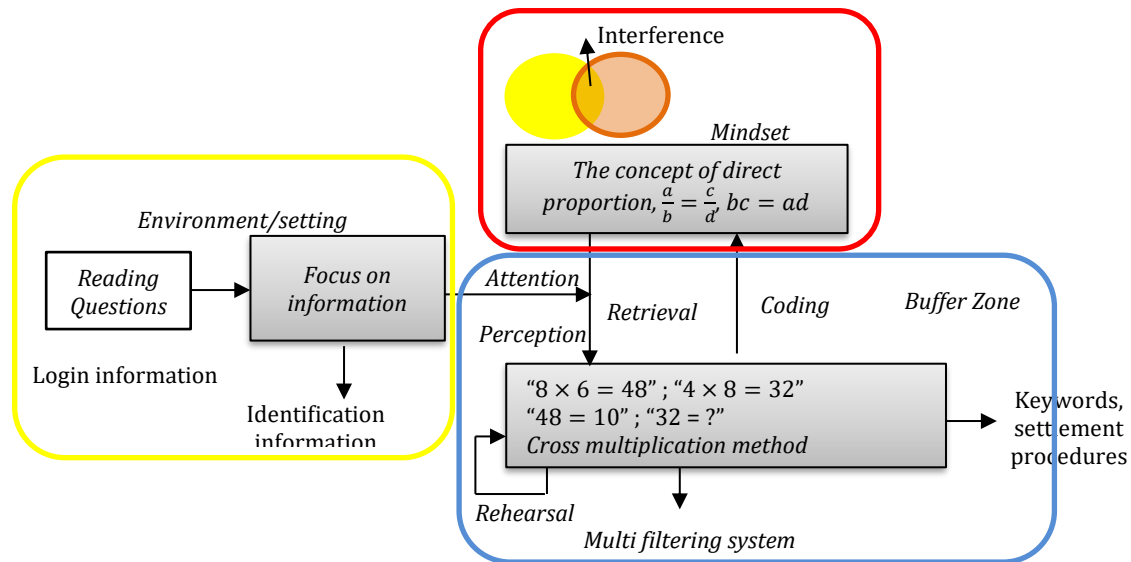


Figure 11. Proactive Interference Process experienced by S2

Based on Figure 11, S2 began to experience proactive interference when identifying the problem. In other words, S2 began to experience interference from the environment or when understanding the problem. S2 was interfered with by the problem number 2 given. S2 assumed that problems 1 and 2 were the same problem. This misperception then led S2 to experience proactive interference from the environmental, filtering, and mindset stages.

Discussion

Based on the research findings, the proactive interference experienced by S1 and S2 occurred at different stages of information processing, indicating that interference is not confined to retrieval failure alone. Within the Mindsponge framework, S1's interference emerged at the filtering and mindset stages, whereas S2's interference began at the environmental stage. This variation suggests that proactive interference operates as a multi-layered cognitive process, rather than solely as competition between stored memories as commonly described in traditional interference theories. Therefore, proactive interference appears to occur not only during retrieval, but also when pupils understand the problem or receive new information. According to the findings of a study by (Irfan, Nusantara, et al., 2019), students' misinterpretation of the problem's significance can lead to interference. Students make this mistake by recalling prior knowledge wrongly. In more studies conducted by (Irfan, Sa'dijah, et al., 2019), it was stated that when students misunderstand a problem, it is categorized as semantic interference.

In the mindsponge framework, this stage of student information reception is the outermost layer, or environment. Therefore, the environment can trigger interference. This is evident when S1 and S2 read problem number 2 and see that problem number 2 is similar to problem number 1. This is because the material on direct proportions and inverse proportions has a similar problem structure (Irfan, Nusantara, et al., 2019). In research by Redick et al., (2020), regarding this interference, it was stated that problems with similar structures, both in content and procedure, are referred to as near transfer.

During the filtering stage, some information in the problem sometimes leads to students' misperceptions. For example, when solving problem number 2, S1 assumed that 6 hours per day and 10 days were the same, so he multiplied the two numbers. Furthermore, the ingrained mindset that proportion problems can be solved using the $a/b = c/d$ and $bc = ad$ structure functioned as a dominant cognitive schema that shaped students' problem interpretation. While previous studies have identified cross-multiplication as a common procedural strategy in proportional reasoning, the

present findings extend this perspective by showing that such procedural dominance may actively trigger proactive interference when students encounter structurally similar but conceptually different problems. Students assumed the problem could be rephrased into this form. This misperception can certainly lead to interference. For example, in research by Babai and Lahav, (2020), students misperceived the problem and experienced interference. The specific type of interference mentioned by Babai and Lahav, (2020) is intuitive interference. Intuitive interference and proactive interference both refer to systematic errors in reasoning, but they differ in their cognitive sources. Intuitive interference occurs when salient but irrelevant features of a task are processed automatically and intuitively, thereby disrupting formal reasoning (e.g., relying on area when comparing perimeters) (Babai & Lahav, 2020). In contrast, proactive interference arises when previously learned knowledge interferes with the application of newly learned concepts. In mathematics, this occurs when students apply an earlier concept (e.g., direct proportion) to a new but different concept (e.g., inverse proportion) (Parameswari, 2024).

When students filter, they also indirectly recall information from their mindset. When the concept of direct proportion is deeply ingrained in this mindset, students naturally experience proactive interference. Within the mindsponge framework, the role of mindset is crucial because the information stored in this memory serves as a benchmark for accepting or rejecting external information (Nguyen et al., 2022; Vuong et al., 2022).

Students' memories, in addition to concepts, can also include problem-solving procedures and experiences with similar problems. In information processing theory, these memories are referred to as semantic, procedural, and episodic memory (McBride & Cutting, 2018; Slavin, 2017). These memories can contribute to interference. For example, this study demonstrated that the process of solving proportion problems used by undergraduate and graduate students was identical to the cross-multiplication strategy. To solve proportional problems, the majority of students employed the cross-multiplication technique. The cross multiplication approach is commonly used by students, according to a number of earlier research (Avcu & Doğan, 2014; Ayan & Isiksal-Bostan, 2019; Öztürk et al., 2021; Parameswari et al., 2023; Tunç, 2020). Students use the cross multiplication approach to produce $a/b=c/d$, where $bc=ad$, by crossing the denominator and numerator of the multiplication equation (Çalışıcı, 2018; Im & Jitendra, 2020; Parameswari et al., 2023).

This cross multiplication approach is frequently used for a number of reasons. One is that the cross multiplication method is commonly taught to students in order to address proportional problems (Öztürk et al., 2021; Parameswari et al., 2023). This finding is supported by research by Andini & Jupri (2017), which found that students only remember the methods/procedures provided by the teacher. Furthermore, multiplication techniques are frequently linked to proportion difficulties, including direct proportion and inverse proportion (Vanluydt et al., 2021).

The problem of interference can be prevented with learning strategies such as the following. The first, teachers can use peer assessment and guiding questions to help students identify and reflect on conceptual errors that may lead to interference (Parameswari, 2024). The second, teachers should promote meaningful learning by guiding students to understand the meaning of each piece of information in a problem before applying formal procedures or formulas (Edo & Tasik, 2022). The third, teachers can provide alternative problem-solving strategies to encourage flexible thinking and prevent students from automatically applying previously learned strategies in inappropriate contexts (Parameswari, 2024).

Implication

The findings of this study have important implications for mathematics instruction. Teachers need to design learning activities that help students clearly distinguish between conceptually similar mathematical ideas, such as direct and inverse proportions, rather than relying solely on procedural strategies like cross multiplication. Instruction should emphasize conceptual understanding by

encouraging students to analyze the meaning of each piece of information in a problem before selecting a solution strategy. In addition, reflective learning approaches such as guided questioning, discussion, and peer assessment can help students identify conceptual misunderstandings and reconsider the appropriateness of previously learned strategies. By fostering flexible thinking and deeper conceptual reasoning, these instructional practices can reduce the likelihood of proactive interference and support more accurate mathematical problem solving.

CONCLUSION

This study explored the process of proactive interference experienced by students when solving proportion problems through the Mindsponge framework. The findings reveal that proactive interference can occur at several stages of information processing, including the environmental, filtering, and mindset stages. At the environmental stage, interference emerges when students misinterpret the problem or fail to carefully analyze the information presented. During the filtering stage, students incorrectly identify relationships between quantities, which leads them to apply inappropriate reasoning strategies. Furthermore, the dominance of previously learned concepts, particularly direct proportion, within students' mindsets causes them to consistently apply cross-multiplication procedures even when solving inverse proportion problems. These results demonstrate that proactive interference is not merely a retrieval failure but a complex cognitive process influenced by the interaction between prior knowledge, information filtering, and problem interpretation. The Mindsponge framework therefore provides a useful perspective for understanding how prior conceptual structures shape students' reasoning processes when they encounter mathematically similar but conceptually different problems.

AUTHOR CONTRIBUTIONS STATEMENT

PP: Conceptualization, Methodology, and writing the article. **UU:** Resources, Review and check for the completion data. **NR:** Validated the instrument and finalization. **SL:** Assisted in data collection and supported implementation of the learning activities. **AF:** Contributed to data analysis and interpretation of findings. **JHP:** Provided technical support and assisted in discussion refinement.

REFERENCES

- Anderson, J. R. (2020). *Cognitive psychology and its implications* (9th ed.). Worth Publishers.
- Andini, W., & Jupri, A. (2017). Student obstacles in ratio and proportion learning. *Journal of Physics: Conference Series*, 812(1), 012048. <https://doi.org/10.1088/1742-6596/812/1/012048>
- Avcu, R., & Doğan, M. (2014). What are the strategies used by seventh grade students while solving proportional reasoning problems? *International Journal of Educational Studies in Mathematics*, 1(2), 34–55. <https://doi.org/10.17278/ijesim.2014.02.003>
- Ayan, R., & Isiksal-Bostan, M. (2019). Middle school students' proportional reasoning in real life contexts in the domain of geometry and measurement. *International Journal of Mathematical Education in Science and Technology*, 50(1), 65–81. <https://doi.org/10.1080/0020739X.2018.1501829>
- Babai, R., & Lahav, O. (2020). Interference in geometry among people who are blind. *Research in Developmental Disabilities*, 96, 103517. <https://doi.org/10.1016/j.ridd.2019.103517>
- Çalışıcı, H. (2018). Middle school students' learning difficulties in the ratio-proportion topic and a suggested solution: Envelope technique. *Universal Journal of Educational Research*, 6(8), 1761–1767. <https://doi.org/10.13189/ujer.2018.060813>
- Creswell, J. W., & Creswell, J. D. (2023). *Research design: Qualitative, quantitative, and mixed methods approaches* (6th ed.). SAGE Publications.
- De Visscher, A., Szmalec, A., Van der Linden, L., & Noël, M. P. (2015). Serial-order learning impairment and hypersensitivity-to-interference in dyscalculia. *Cognition*, 144, 38–48. <https://doi.org/10.1016/j.cognition.2015.07.007>

- Van Dooren, W., De Bock, D., Evers, M., & Verschaffel, L. (2009). Students' overuse of proportionality on missing-value problems: How numbers may change solutions. *Journal for Research in Mathematics Education*, 40(2), 187–211.
- Doyle, K. M., Dias, O., Kennis, J. R., Czarnocha, B., & Baker, W. (2016). The rational number sub-constructs as a foundation for problem solving. *Adults Learning Mathematics*, 11(1), 21–42.
- Edo, S. I., & Tasik, W. F. (2022). Investigation of students' algebraic conceptual understanding and the ability to solve PISA-like mathematics problems in a modeling task. *Mathematics Teaching-Research Journal*, 14(2), 44–60.
- Georgiou, A., Katkov, M., & Tsodyks, M. (2021). Retroactive interference model of forgetting. *Journal of Mathematical Neuroscience*, 11(1), 4. <https://doi.org/10.1186/s13408-021-00105-3>
- Hidayanto, E., & Budiono, E. (2019). Students' thinking interference in understanding functions. *Journal of Physics: Conference Series*, 1227(1), 012015. <https://doi.org/10.1088/1742-6596/1227/1/012015>
- Im, S., & Jitendra, A. K. (2020). Analysis of proportional reasoning and misconceptions among students with mathematical learning disabilities. *Journal of Mathematical Behavior*, 57, 100753. <https://doi.org/10.1016/j.jmathb.2019.100753>
- Irfan, M., Nusantara, T., Subanji, S., & Sisworo, S. (2019). Direct proportion or inverse proportion? The occurrence of student thinking interference. *International Journal of Scientific & Technology Research*, 8, 587–590.
- Irfan, M., Sa'dijah, C., Ishartono, N., Widodo, S., Rahman, A., & Hudha, M. (2019). Interference in solving mathematical problems. *Complexity*, 2019, Article 8970513. <https://doi.org/10.1155/2019/8970513>
- Jayanti, W. E., Usodo, B., & Subanti, S. (2018). Interference thinking in constructing students' knowledge to solve mathematical problems. *Journal of Physics: Conference Series*, 1008(1), 012069. <https://doi.org/10.1088/1742-6596/1008/1/012069>
- Lamon, S. J. (2020). *Teaching fractions and ratios for understanding* (4th ed.). Routledge. <https://doi.org/10.4324/9781003008057>
- Maulida, M. A., Rahmatih, A. N., Gunawan, G., Hidayati, V. R., & Erfan, M. (2020). Retroactive thinking interference of grade VI students: A study on the topics of PISA literacy lessons. *Journal of Physics: Conference Series*, 1471(1), 012037. <https://doi.org/10.1088/1742-6596/1471/1/012037>
- McBride, D. M., & Cutting, J. C. (2018). *Cognitive psychology: Theory, process, and methodology* (2nd ed.). SAGE Publications.
- Mercer, T. (2015). Wakeful rest alleviates interference-based forgetting. *Memory*, 23(2), 127–137. <https://doi.org/10.1080/09658211.2013.872279>
- Nguyen, M. H., La, V. P., Le, T. T., & Vuong, Q. H. (2022). Introduction to Bayesian Mindsponge Framework analytics: An innovative method for social and psychological research. *MethodsX*, 9, 101808. <https://doi.org/10.1016/j.mex.2022.101808>
- Ormrod, J. E. (2020). *Human learning* (8th ed.). Pearson.
- Öztürk, M., Demir, Ü., & Akkan, Y. (2021). Investigation of proportional reasoning problem solving processes of seventh grade students: A mixed method research. *International Journal on Social and Education Sciences*, 3(1), 48–67. <https://doi.org/10.46328/ijonses.146>
- Parameswari, P., Purwanto, P., Sudirman, S., & Susiswo, S. (2023). Correct-incorrect proportional reasoning strategies on proportional problems and SOLO taxonomy. *Acta Scientiae*, 25(5), 86–117.
- Parameswari, P. (2024). Students' proactive interference in solving proportion problems: How was the met-before?. *Mathematics Teaching Research Journal*, 15(6), 93–115.
- Pelen, M. S., & Artut, P. D. (2016). Seventh grade students' problem solving success rates on proportional reasoning problems. *International Journal of Research in Education and Science*, 2(1), 30–34. <https://doi.org/10.21890/ijres.13936>
- Redick, T. S., Wiemers, E. A., & Engle, R. W. (2020). The role of proactive interference in working memory training and transfer. *Psychological Research*, 84(6), 1635–1654. <https://doi.org/10.1007/s00426-019-01177-2>
- Slavin, R. E. (2017). *Educational psychology: Theory and practice* (12th ed.). Pearson.
- Solso, R. L., MacLin, O. H., & MacLin, M. K. (2014). *Cognitive psychology* (8th ed.). Pearson.

- Sternberg, R. J., & Sternberg, K. (2012). *Cognitive psychology* (6th ed.). Nelson Education.
- Stricker, J., Vogel, S. E., Schöneburg-Lehnert, S., Krohn, T., Dögnitz, S., Jud, N., Spirk, M., Windhaber, M. C., Schneider, M., & Grabner, R. H. (2021). Interference between naïve and scientific theories occurs in mathematics and is related to mathematical achievement. *Cognition*, *214*, 104789. <https://doi.org/10.1016/j.cognition.2021.104789>
- Sukoriyanto, S., Nusantara, T., Subanji, S., & Daniel, T. (2016). Students' thinking interference of real global type in solving permutation and combination problems. *IOSR Journal of Research & Method in Education*, *6*(4), 1–6.
- Tunç, M. P. (2020). Investigation of middle school students' solution strategies in solving proportional and non-proportional problems. *Turkish Journal of Computer and Mathematics Education*, *11*(1), 1–14. <https://doi.org/10.16949/turkbilmat.647091>
- Vanluydt, E., Supply, A. S., Verschaffel, L., & Van Dooren, W. (2021). The importance of specific mathematical language for early proportional reasoning. *Early Childhood Research Quarterly*, *55*, 193–200. <https://doi.org/10.1016/j.ecresq.2020.12.003>
- Vuong, Q. H., Nguyen, M. H., & La, V. P. (2022). *The mindsponge and BMF analytics for innovative thinking in social sciences and humanities*. De Gruyter. <https://doi.org/10.2478/9788367405119>