Volume 6, Nomor 2, Desember 2022
Numerical: Jurnal Matematika dan Pendidikan Matematika
http://journal.iaimnumetrolampung.ac.id/index.php/numerical
DOI:https://doi.org/10.25217/numerical.v6i2.

Cognitive Conflict of Relational Learners in Connecting Proportion Concepts on Three-Term Ratio Problems

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Article Info
Article History
Received: 20-07-2022
Revised: 02-11-2022
Accepted: 03-11-2022

Keywords:
Assimilation; Accommodation; Cognitive Conflict; Comparison; Mathematical Understanding

Abstract

The study's purpose is to describe the cognitive conflicts experienced by students with relational understanding when solving the problem of three-term ratios. The current research is a case study with a qualitative approach using a purposeful sampling technique. The three research objects are representations of the condition that (1) the student was sure of his solution (cognitive conflict was solved) and the solution is correct, (2) the student was confident with his solution (cognitive conflict was solved) but the solution is not correct, and he is not confident with the solution (cognitive conflict was not solved), and the solution was not correct. The results of this study describe students with relational understanding experience cognitive conflicts, that is, being aware of the conflict between the initial concepts they have and the results obtained. Students feel doubtful and worried, as indicated by the awareness that the initial scheme applied to one proportion problem cannot be applied to other comparison questions. Students' cognitive conflicts with relational understanding do not always lead them to get the correct solution to the three-term ratio problems. The reason is that the student believes comparison is wrong (misconception).

INTRODUCTION

Cognitive is one of the essential aspects of learning. It has been stated in the Regulation of the Minister of Education and Culture Number 23 of 2016 concerning Educational Assessment Standards that one of the assessments of student learning outcomes is their knowledge development, commonly known as cognitive development. Until now, researchers and experts have conducted research on individual cognitive development. It is evidenced by the search results of articles on Google Scholars with the keyword "cognitive development," which has reached 3,880,000 reports. Piaget's theory [1] is one of the cognitive development approaches that has been the subject of discussion among scholars until recently. Piaget [1] stated that cognitive development occurs when children adapt to their environment.

Piaget's theory [2] explains that every individual experiences an adaptation process. In this study, adaptation refers to applying assimilation and accommodation during the scheme adjustment process [1]. An individual will adapt to assimilation when the new conditions are under the scheme

Print ISSN: 2580-3573, Online ISSN: 2580-2437

one has while adapting to accommodation when the scheme one has is not following the new condition [3]. Piaget [4] further explained that one's capacity is triggered by a condition called disequilibrium, an imbalance between what is already known and what is encountered. It occurs when learners struggle to assimilate new knowledge into cognitive schemas in the accommodation process [5].

Several experts have expressed their viewpoints on understanding cognitive conflict during student learning. Lee & Kwon [6] urged that cognitive conflict is a perceptual state in which one notices the discrepancy between one's cognitive structure and the environment or among the different components of one's cognitive system. Moody [7] believed that cognitive conflict is used to describe an occurring tension when new evidence recognized by students contradicts their prior knowledge. In simple terms, it can be inferred that cognitive conflict is when an individual experiences a cognitive conflict between their new knowledge and prior knowledge.

The signs of cognitive conflict experienced by learners are referred to as characteristics of cognitive conflict. Otaibi [8] also mentioned that when an individual has conflicting cognitive elements, an emotional state will arise in the form of tension called dissonance. It means that the emergence of cognitive conflict can be recognized by the presence of signs shown or verbal statements uttered by students. The effects of cognitive conflict on the affective domain can be either positive or negative. The positive effects are identified by the rise of interest and curiosity, while the adverse effects are the rise of fear, worry, to severe frustration [9]. Students who experience cognitive conflicts in solving math problems show spontaneous body movements, such as muttering, shaking the pen, closing their lips, frowning, taking a deep breath, flipping through the answer/question sheet, holding both cheeks, and bowing their heads [10]. Lee et al. [9] described signs of cognitive conflict with awareness of contradictions, interests, worries, and hallucinations.

This study's signs of cognitive conflict are divided into four psychological constructs of verbal statements: contradiction, interest, anxiety, and doubt. In addition, the spontaneous gestures shown by students may indicate signs of cognitive conflict. The conflicting components in students' cognitive structure are identified based on the cognitive conflict occurrence indications. Hence, cognitive conflict can be divided into several types.

The results of the analysis of Kwon and Lee [11] demonstrated that cognitive conflict is divided into three types: type I (C1-R2), type II (C2-R1), and type III (C1-C2). Cognitive conflict type I is based on Piaget's theory; it occurs between the cognitive structure (C1) and one's environment (R2). Type III cognitive conflict is based on Hashweh's analysis. Cognitive conflicts occur in metacognitive between cognitive schemas (C1 and C2). This cognitive conflict is stimulated when one can examine his cognition without the influence of his surroundings. Type II cognitive conflict is based on Kwon and Lee's proposal, a cognitive conflict between the new concept (C2) and the experience of the individual's prior conception (R1). Kwon and Lee [11] show the three types of cognitive conflict, as shown in Figure 1 below.

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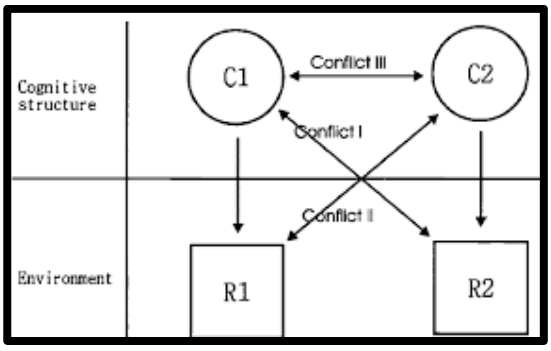

Information:
C1: the initial comparison concept in students' cognitive structure
C2: a scientific conception to be learned
R1: an environment that could be well explained by C1
R2: any environment that C2 well explains

Figure 1. Three Kinds of Cognitive conflict

Cognitive conflicts experienced by the subjects of this study are divided into three types based on the theory stated by Kwon and Lee [11]. In this study, the C1 code in Figure 1 is defined as a comparison concept in students' cognitive structures. The concept of comparison can be a misunderstanding of the idea. C2 is a comparison concept that students must construct to solve a proportion problem. R1 is the result of the experiment or calculation made by students from C1. R2 is the result of the investigation or analysis made by students from C2.

Cognitive conflict is one of the factors that affect students' learning process. It is supported by Piaget [1], who stated that individuals' learning engagement depends on the equilibration process. It is a restoration of disequilibrium to a state of balance (equilibrium). When compensation is chaotic, cognitive conflict occurs, and the individual's cognitive structure can be refreshed, empowered, and strengthened. Lee and Byun [12] revealed that the most significant role of cognitive conflict in the learning process is to be one of the main prerequisites for students' conceptual change. The success of students' conceptual change triggered by cognitive conflict has been the topic of debate among researchers in this field. Baser's research [13] showed that cognitive conflict-based teaching successfully facilitated students' conceptual change. The study by Dekkers & Thijs [14] showed that even though students' ideas can clash with contradictory things through teaching, students do not always recognize conflict, which may affect them negatively.

Concerning conceptual mathematics lessons, Skemp [15] distinguishes students based on their understanding: with instrumental and relational understanding. This study will review students' cognitive conflicts with relational understanding. Skemp [15] states that relational understanding is a person's ability to use a mathematical procedure after associating several relevant mathematical concepts when solving a problem and being aware of the reason for the procedure implementation. Hendriana [16] mentions that one of the characteristics of relational understanding is linking a concept/principle with the conception of other principles. It is assumed that this type of mathematical understanding will also affect how students deal with cognitive conflicts when facing contradictory situations.

Previous research conducted by Lestary et al. [10] found that students who can find relationships between concepts related to problems can overcome conflicts in their cognitive structures so that mathematical problems can be solved correctly. It is in line with Skemp's [15] mathematical understanding that students who can find relationships between concepts are potentially relational types of learners. Moreover, the researchers found an interesting phenomenon from the initial observations, namely that when class VIII SMPN 1 Malang students were faced with a proportion problem, there were indications of a cognitive conflict between the concepts of

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direct and reverse proportions—discussing how students with a relational understanding face cognitive conflicts that occur when solving three-term ratios are engaging. Therefore, this study aims to describe the cognitive conflicts experienced by students with relational knowledge when solving the problem of three-term proportions.

METHOD

This type of research is a case study research using a qualitative approach. Conducted from 10-28 September 2018, this study took place in class VIII SMPN 1 Malang. Researchers used a purposeful sampling technique to select research subjects. The researchers observed the ultimate phenomenon by setting standards for the issues and the place of research that provides rich information [17].

The subject selection began with a discussion with one of the mathematics teachers at SMPN 1 Malang. The debate aimed to select students interested in mathematics as prospective research subjects. Then, the selected 12 students were instructed to solve proportion tests. Based on the test results, students who consistently solve proportion tests with relational understanding are qualified. Finally, three students were re-elected, each of which represented three categories of conditions, namely 1) the condition where the student was sure of the solution he had (cognitive conflict was solved), and the solution was correct (Condition A), 2) the condition where the student was sure with the solution he had (cognitive conflict is solved), but the solution is not correct (Condition B), 3) the condition where the student was not confident with the solution he had (cognitive conflict has not been solved), and the solution is not correct (Condition C). For each condition, one student who experienced the most cognitive conflicts was selected in each condition categorization in each group. Determination of research subjects is carried out as shown in Figure 2, as follows:

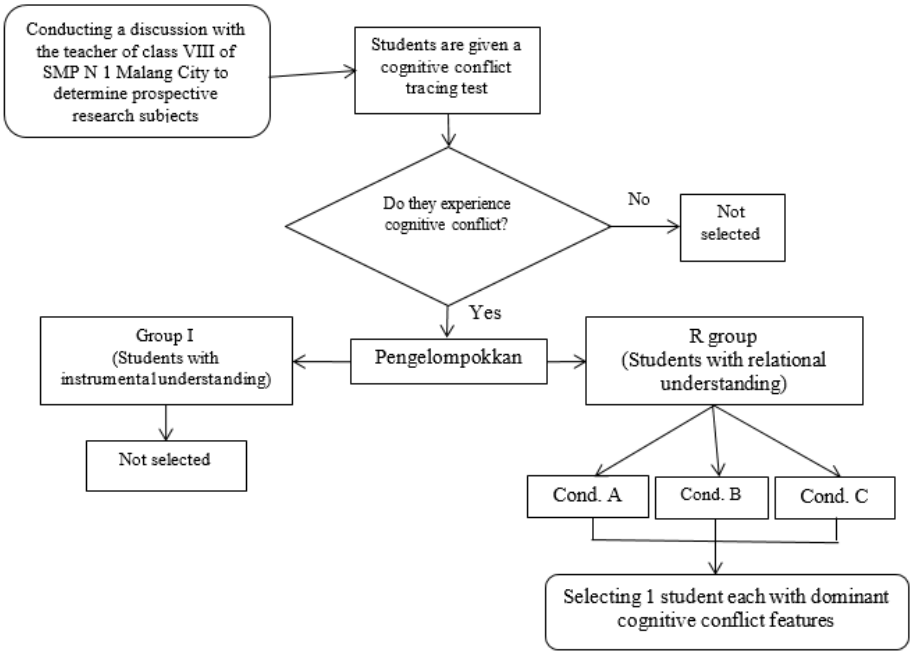

Figure 2. The Diagram of the Subject Selection Process

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Information:

Condition A : the student is sure of his solution (cognitive conflict is solved), and the answer is correct.

Condition B: the student is confident with his solution (cognitive conflict is solved), but the key is incorrect.

Condition C: the student is not confident with his solution (cognitive conflict is solved), and the answer is incorrect.

In this study, the research subject is the source of data. The data are from student answer sheets, interview results, and the analysis of image recordings while students complete the test. The main instrument in this study was the three researchers as human instruments. The researchers in this study were a planner, data collectors, analyzers, data interpreters, and reporters of research results [18]. The supporting instruments in this study were cognitive conflict test sheets, interview guide sheets, test validation sheets, and recording tools.

There are two comparison questions of three objects on the cognitive conflict tracing test, as follows.

1. *Ninety people can complete the manufacture of 90 tables within 90 days. If everyone's ability is the same, how many days will it take nine people to produce nine tables?*
2. *Six tailors can complete an order of 42 kebayas within 14 days. If everyone's ability is the same, how many kebayas can nine people produce in 18 days?*

The data analysis technique of this research applies constant comparative analysis. Glaser [19] stated that the continuous relative analysis technique compares phenomena that have simultaneously occurred throughout the study.

RESULTS AND DISCUSSION

the research findings revealed that when solving three-term ratios, students with relational understanding experienced cognitive conflicts when relating the concepts of comparison of direct and reverse proportions. In looking for the relationship between these concepts, students experience conflicts in their cognitive structures so that they reconstruct the connection of new comparative ideas to solve problems. Each student with different conditions has a unique way of constructing the relationship between relative concepts until they finally find a conclusion from the comparison problem.

1. Subjects Categorized in Condition A (RA)

   RA subject experienced cognitive conflict when solving comparison problems, but in the end, he was able to find a solution to the problem confidently and correctly. In solving the problem, RA only experienced conflicts in his cognitive structure when linking comparative concepts to solve problem number 1. Type III cognitive conflicts in subject RA solving three-object comparison math problems were type III. The following is a description of the cognitive conflict in Table 1:

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Table 1. Cognitive conflict Occurs in subject RA

Cognitive conflict	Type of Cognitive conflict
Awareness of the contradiction between the initial concept (the ratio of the number of people, the tables, and the days) concerning the three-term ratios.	Type III

The contradiction between the estimated student answers and the implementation results of the proportion concept of direct and reverse proportions. The following presents the cognitive conflicts of students with condition A when linking proportion concepts in solving problems:

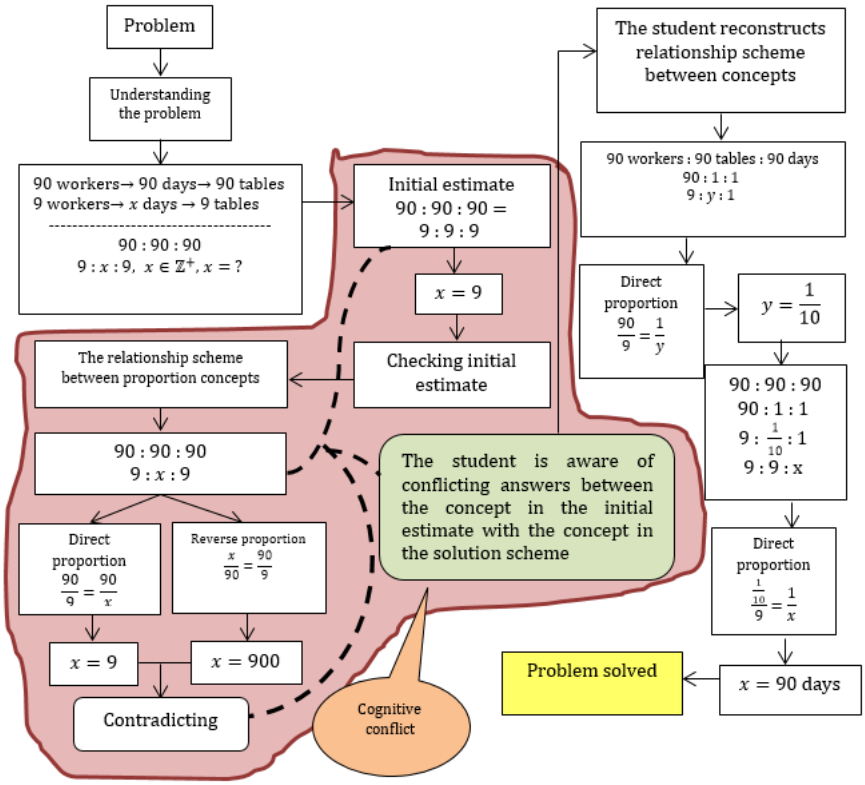

Figure 3. The student's Cognitive conflict When Connecting Proportion Concept Relationship(1)

Figure 3 shows that after students read the questions, their initial answer is nine days. Students spontaneously think the ratio 90: 90: 90 equals the ratio 9: 9: 9. Students need to prove their estimates. In the initial scheme, students apply the comparison concepts they learned in class. The motivation to check the estimated answers indicates student interest in solving proportion problems. This is supported by Berlyne and Festinger [9] and Anderson and Bourke [20], who said that when students experience cognitive conflicts, they will be motivated to resolve them.

The student divided the solutions into two parts and compared the results to find the answer. In the first part, the student reached the number of tables and the number of days using the direct proportion concept. In the second part, the student compared the number of days

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and the number of workers using the inverse proportion concept. Then, he reached both results and found contradicting answers.

The student realized that the initial scheme could not prove the answer's correctness of the estimated result. The two direct proportion concepts that produce the students' initial estimated response is C1, while the student's initial scheme compares the inverse proportion concept and straightforward proportion concept of the same problem is C2. Based on Kwon and Lee's [11] types of cognitive conflicts, the student is experiencing a cognitive conflict type III.

The cognitive conflict appeared to guide the students to construct a new scheme, connecting direct proportion concepts. He tried to solve the number of tables 90 workers can produce in one day by using a straightforward proportion concept between the number of tables and the number of days. Next, they looked for the number of tables manufactured by nine workers in one day using the direct proportion of the number of workers and the number of tables. In the last step, they searched the number of days needed by nine workers to produce nine tables by using the direct proportion of the number of tables and the number of days. Finally, the student found the correct answer to proportion problems.

Based on the body signals recorded in the video and confirmed during the interview, the signs identified when AR experienced cognitive conflict while solving the proportion problem are 1) acknowledging that there are contradictions, 2) there is an interest, and 3) there is hesitation. Hesitation indicates a cognitive conflict shown by a physical condition, frequently appearing when RA solves a math problem.

2. Subject Categorized on Condition B (RB)

RB experienced a conflict in his cognitive structure when connecting the proportion concepts to solve question number 2. The occurrence of hesitation and interest marked the emerging cognitive conflict. The cognitive conflict that occurred is cognitive conflict type III. When the last time asked, RB answered that they were sure of their final answer. However, RB's cognitive conflict did not guide him to proper problem-solving. The following Table 2 includes the late cognitive conflict:

Table 2. Cognitive conflict Occurred with Subject RB

Cognitive conflict	Type of Cognitive conflict
The acknowledgment of mistakes in solving process regarding the relation proportion of the number of people, the number of kebayas, and the number of days concept. The subject acknowledged that they made a mistake when applying the direct proportion of the number of kebaya and the number of days.	Type III

The cognitive conflict of students who failed to construct the relation of proper proportion concepts and gained a wrong conclusion is the hesitation towards the initial scheme. The uncertainty towards the result achieved by the student was not in line with the actual circumstance that he constructed a new proportion concepts relation to solve a problem. The

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following was the student with B condition's cognitive conflict when connecting proportion concepts in solving a problem served in figure 4:

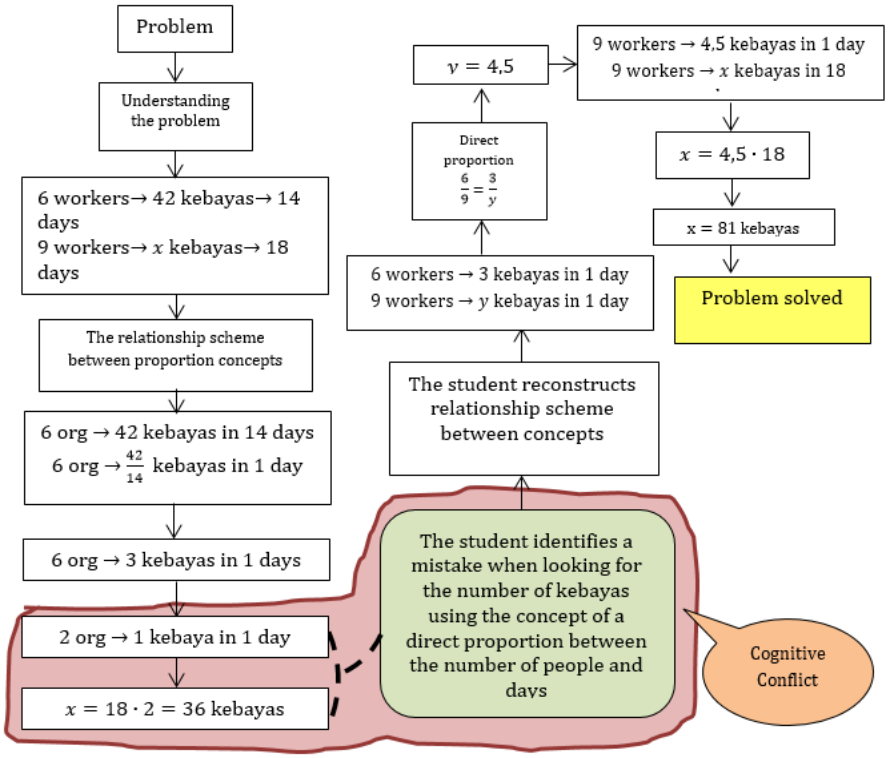

Figure 4. The student's Cognitive conflict When Connecting Proportion Concept Relationship (2)

The student's initial scheme is to solve the number of "kebaya" that some workers can produce within one day by using the direct proportion concept of the number of "kebaya" and the number of workers. After that, the student looks for the number of "kebaya" manufactured in 18 days by using a direct proportion of the people and days number. However, the student doubts their answer.

The hesitation made the student's cognitive structure distracted (disequilibrium). The cognitive conflict that occurred pushed them to think reflectively, re-checking their solution. When a student is in a conflict, they will use their cognitive ability to correct, confirm, and verify their opinion [21]. Therefore, they realized there was a mistake during the problem-solving process when they were solving the number of "kebaya" that can be finished in 18 days. They should have used a direct proportion of the number of "kebaya" and the number of days. Reviewing the solution to find out the mistake activity was described as a cognitive conflict that happened to the student's metacognition by Hashweh. Based on Kwon and Lee's types of cognitive conflict [11], the type of conflict experienced by the student is type III.

Students who experience cognitive conflict tend to use more effort to gain a better understanding [22]. Cognitive conflict emerged for students categorized in condition B, leading them to construct a new scheme connecting the direct proportion concept. They solve the number of "kebaya" that can be finished by a certain number of people in one day. After solving

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the proportion of "kebaya" and the number of people in one day, they search for the number of "kebaya" nine people can finish within a day using direct proportion. For the last step, the students look for the number of "kebaya" 9 people can complete within 18 days by using a natural ratio of the number of "kebaya" and the number of days. Finally, they solve the proportion problem correctly.

The student could connect the direct proportion concept in solving question 2. However, they did not acknowledge that the idea they applied in question number 1 was incorrect. It is because the student thought that questions number 1 and 2 were proportion problems with different concepts. The proportion in question 1 can be simplified into direct proportion, but the ratio in question 2 cannot. Thus, the student's cognitive structure does not read that there is a situational anomaly in solving question number 1. Finally, they failed to find the answer to the proportion problem in question 1 since they did not recognize the situational monster. Based on this situation, it is found that the cognitive conflict that occurred to the student categorized in condition B did not bring them to a conceptual change toward the correct problem-solving.

From the research on the subject RB, it can be concluded that the indications that emerged when RB was experiencing cognitive conflict in solving proportion problems are 1) acknowledging that there are contradictions, 2) there is an interest, and 3) there is hesitation. According to the recording, it is found that hesitation is the most common indication.

3. Categorized Subjects in Condition C (RC)

RC had conflicts in his cognitive structure while linking proportion concepts in solving every proportion problem. Subject RC experiences cognitive conflict types I and III solving three-term ratio problems. Despite experiencing cognitive conflicts, the proportion of problem-solving on the RC's cognitive conflict tracking test is still incorrect. RC realized this and was unsure he was right with the final answer. The following is a description of the cognitive conflicts in Table 3:

Table 3. Cognitive conflicts Experienced by Subject RB

Cognitive conflicts	Types of Cognitive conflict
Being aware of the initial scheme (looking for comparisons of the number of people, the number of tables, and the number of days) is inappropriate because it cannot be applied when solving other proportion problems. The subject realized that determining the direct proportion $90:90:90$ is $9:9:(x=9)$ is incorrect because the issue cannot assess the value of x that meets the ratio $9:x:18$ by looking for the direct proportion $6:42:14$.	Type I
Being aware of making mistakes in determining the concept of direct/inverse proportion is applied in solving a problem. After rereading the questions, the subject realized that his initial estimate, which stated the situation in the questions was a direct proportion problem, was incorrect. The problem is an inverse proportion.	Type III

Cognitive conflicts of students who are aware that they fail to construct the correct relation of the comparison concepts. They get the wrong conclusions which are the doubt of the initial scheme. The doubt about the students' results is caused because the circumstances do

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not align with expectations. Therefore, the students construct a new link from the comparison concepts to solve the problems. The cognitive conflict of students with the condition C linking the comparison concepts in solving the problem is displayed in Figure 5 below:

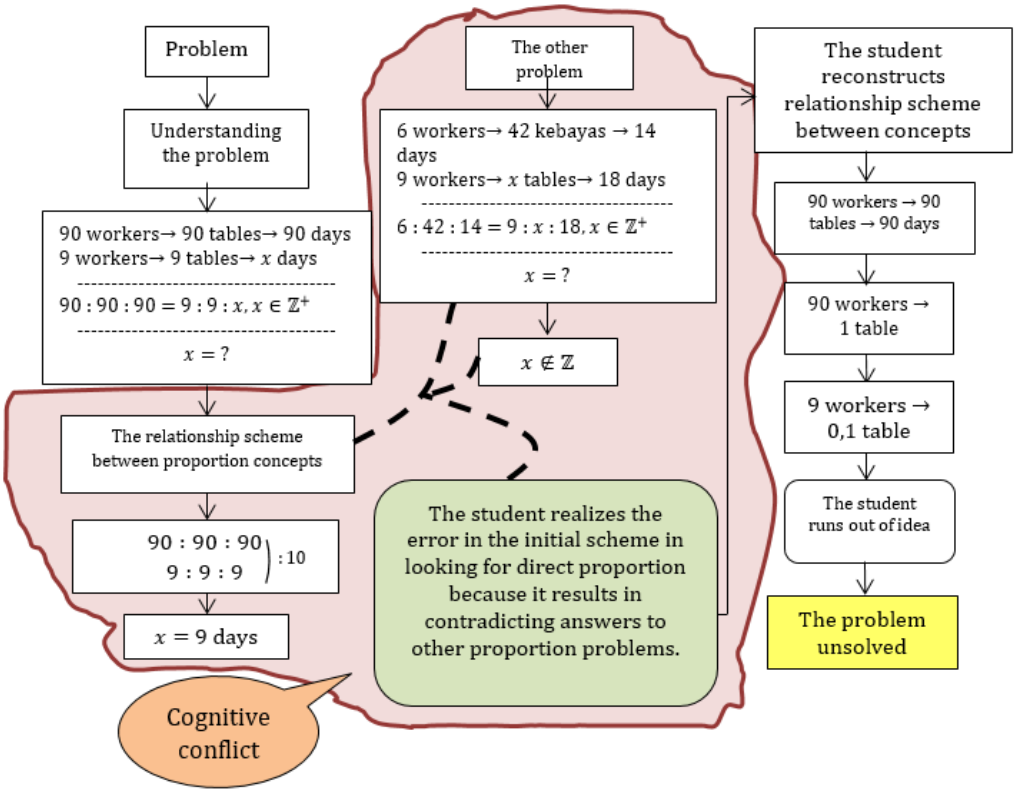

Figure 5. The student's Cognitive conflict When Connecting Proportion Concept Relationship (3)

The initial scheme of the students is to look for an equal ratio with the comparison created based on the information from the question. There is no cognitive conflict found when the students apply the initial scheme to solve question number 1. When the students use the system to solve problem number 2, they cannot find a comparison of integers equal to the ratio they made. The initial scheme students have is C1, and the comparison problem in question 2 is R2. Based on Kwon and Lee's [11] types of cognitive conflicts, the type of cognitive conflict experienced by the student is type I.

Cognitive conflicts lead students to construct new schemas relating to comparative concepts. Students look for the number of *kebayas* that one person can do in one day with a comparison between the number of days, the number of *kebayas*, and the number of people. Finally, students correctly answered the comparison problem in question number 2. Students start to doubt the answer to question 1. The student tries to apply the new scheme to resolve question number 1. However, it is still tricky. The student has no idea why they cannot use the new system on question number 1. So that even though the students are aware of the anomaly for question number 1, they cannot construct the relation of comparative problems to solve the comparison problem in question number 1.

The analysis of subject RC shows that some indications appear when RC experiences cognitive conflict in solving the comparison problems: 1) admitting that there is a contradiction,

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2) there is interest, 3) there is a concern, and 4) there is doubt. According to the record, doubt is the most common indication.

CONCLUSIONS AND SUGGESTION

Conclusions

The results of this study indicate that students with relational understanding experience cognitive conflict while linking the comparative concepts. Cognitive conflicts are shared by students with relational knowledge when solving three-object comparison problems does not always lead to the right solution. It is because the students believe in the misconception of the comparison concept. Doubt is the most common indication of cognitive conflict. Worry is an indication that only appears when cognitive conflict occurs, and the students realize that it does not lead to the problem-solving of comparison correctly.

Suggestion

In this study, cognitive conflict number III always occurs in the student with rational understanding in solving the comparison problem. Therefore it is suggested to conduct further research that focuses on the internal factors of the students, such as metacognitive ability or reflective thinking.

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Print ISSN: 2580-3573, Online ISSN: 2580-2437