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Instrumental Student Cognitive Conflict in Solving Mathematical Problems

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a b s t r a c t

This research was a case study research with a qualitative approach. The subject of this study was 6 class VIII students of SMPN 1 Kota Malang. The instruments of this study were cognitive quest conflict test sheets, general interview instructions, validation sheets, and record tools. The data obtained in the form of the results of the subject's work, interview data on the subject, and field notes. The results of this study indicated that cognitive conflict of students with instrumental understanding in solving comparison problems occurs when: (1) students determine the formula matching the problem and (2) students do algorithmic calculations. Student cognitive conflict when determining the appropriate comparison formula was the awareness of the contradiction between the answers obtained from applying a comparison formula worth the concept of a reverse value comparison. Student cognitive conflict when performing algorithmic calculations were (a) awareness that the initial scheme is to simplify the comparison of the number of people, tables and days was incorrect because it cannot be applied to solve all problems of comparison and (b) awareness that the calculation scheme was looking for multiplication patterns the known comparison cannot be applied because it produces an answer that was not an integer.

K e y w o r d s :
Cognitive conflict; Comparison; Mathematical understanding

INTRODUCTION

Children's cognitive development can be supported through learning Mathematics. This is supported by the BSNP (2006) which states that mathematics is a universal science that underlies the development of modern technology, has an important role in various scientific disciplines and human cognitive development. Therefore, it is understanable that mathematics is taught at every level of education.

In the learning process, students experience a process of cognition. According to Khiyarusoleh (2016) cognition is one aspect of individual development including mental abilities and activities related to the process of receiving-processing-and using information in the form of thinking, problem solving, and adaptation. Through the theory of cognitive development, Piaget suggests that the underlying intellectual development of children is adaptation (Ibda, 2015). Adaptation is defined as the process of adjusting the scheme in response to the environment by assimilation and accommodation (Slavin, 2006). When a person finds a new condition that is in accordance with the scheme he has, he will adapt in the form of assimilation, whereas when the scheme he has is not in accordance with the new conditions, he will adapt in the form of accommodation (Netti, et al., 2016). Furthermore, Piaget in Sukoriyanto, Toto, Subanji, & Tjang (2016) says that the adaptation process of individual accommodation is caused by a condition of disequilibrium, namely, an imbalance between what is known and what is encountered. The condition of students' difficulties in assimilating new knowledge into cognitive schemas in the accommodation process is shown as conflict (Shahbari & Peled, 2014).

Numerous researchers use cognitive conflict as central to cognitive development and strategies to achieve a particular learning goal. Lee & Byun (2012) revealed that the biggest role of cognitive conflict in the learning process is to be one of the main prerequisites for students' conceptual change. Other researchers are still in debate about the success of students' conceptual change triggered by cognitive conflict. The results of research conducted by Baser (2006) showed that cognitive conflict-based teaching was successful in facilitating students' conceptual change. Cognitive conflict also plays an important role in changing students' concepts by examining errors made by students (Zazkis and Chernoff, 2008). The results of research conducted by Dekkers & Thijs (in Wyrasti, et al., 2016) show that although students' ideas can be confronted with contradictory information through teaching, students often do not recognize conflict and sometimes contradictory information can negatively affect students. The absence of teacher support in overcoming cognitive conflict that can lead students experiencing mathematics anxiety, which in turn can lead students to the low self-esteem and, ultimately, poor performance in the subject (Devine et al., 2018). Research conducted Wyrasti (2016) also showed that not all students who experience cognitive conflicts in learning are able to overcome their conflicts. This means that cognitive conflict strategies do not consistently lead to conceptual change.

Based on several previous studies, no one has reviewed the process of cognitive conflict from the internal cognitive aspects of students. The internal aspect in question is the student's ability to capture the meaning and significance of the newly acquired knowledge or problem. By Winkel & Mukhtar (in Sudaryono, 2012) this ability is known as understanding. If the knowledge or problem is related to mathematical concepts, it is called mathematical understanding. Skemp's (1976) understanding of mathematics is divided into two types, namely, instrumental understanding and relational understanding.

Preliminary research conducted by Lestary, et al. (2018) found that students who are able to find relationships between concepts related to problems can overcome conflicts that occur in their cognitive structures so that mathematical problems can be solved correctly.

If it is related to Skemp's mathematical understanding, students who can find relationships between concepts may be students with relational understanding. It is interesting to discuss whether the type of mathematical understanding used by students will affect students' ability to overcome conflicts that occur in their cognitive structures when given math problems. Therefore, in this study, students' cognitive conflicts will be reviewed based on their understanding of the mathematics they use.

This study will fill the gap, namely reviewing the cognitive conflicts of understanding mathematics used by students in solving comparative problems, especially cognitive conflicts of instrumental students in solving mathematical problems.

LITERATURE REVIEW

Cognitive conflict is a series of events that occur in a person's cognitive structure when the accommodation process takes place. Accommodation is defined as the process of constructing knowledge or mathematical concepts that are created when the newly acquired knowledge contradicts or does not match the students' previous knowledge (Netti, et al., 2016). Cognitive conflicts that occur in students can be observed. This is supported by the results of research conducted by Kang, et al. (2010) that students who experience conflict tend to be more attentive during learning, encouraging them to use more effort to achieve better understanding.

The results of the analysis of Kwon & Lee (2003) cognitive conflict can be divided into 3 types, namely, type I (C1-R2), type II (C2-R1), and type III (C1-C2). Type I cognitive conflict is a cognitive conflict based on Piaget's theory, a cognitive conflict that occurs between the cognitive structure (C1) and one's environment (R2). Type III cognitive conflict is the result of Hashweh's analysis, cognitive conflicts that occur in metacognitive, namely conflicts between cognitive schemas (C1 and C2). This cognitive conflict will be stimulated when a person can examine his own cognition without contacting his environment. Type II cognitive conflict is the result of Kwon and Lee's proposal, namely cognitive conflict between the new concept (C2) and the experience of the individual's old concept (R1).

Instrumental understanding is also known as the rule without reason. Skemp (1976) defines instrumental understanding as a person's ability to use a mathematical procedure to solve a problem without knowing why the procedure may be used to solve the problem. Hendriana (2014) mentions the characteristics of instrumental understanding, namely: memorizing concepts / or principles without connection with others, being able to apply formulas in simple calculations, and doing calculations algorithmically.

METHODS

Population and Sample

The population is students class VIII at SMPN 1 Malang City who have taken comparative material and the sample is 12 students who have more interest in mathematics as prospective research subjects.

Reseach Design

This research was a case study research. According to Saldana (2011) a case study focuses on one unit to be analyzed, namely one person, one group, one event, one organization, and so on. Unlike studies that examine multiple participants to gather a wider and representative range of viewpoints, the case study is assessed as a unit that allows for in-depth examination. Crowe et al. (2011) s case study is a research approach that is used to generate an in-depth, multi-faceted understanding of a complex issue in its real-life

context. This study explores students' cognitive conflicts with instrumental and relational understanding in depth.

Frame Work Flow

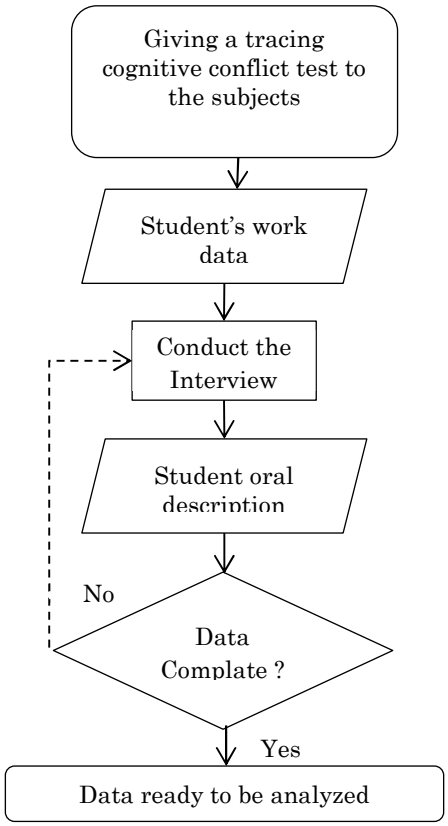

Figure 1
Data Collection Procedure Diagram

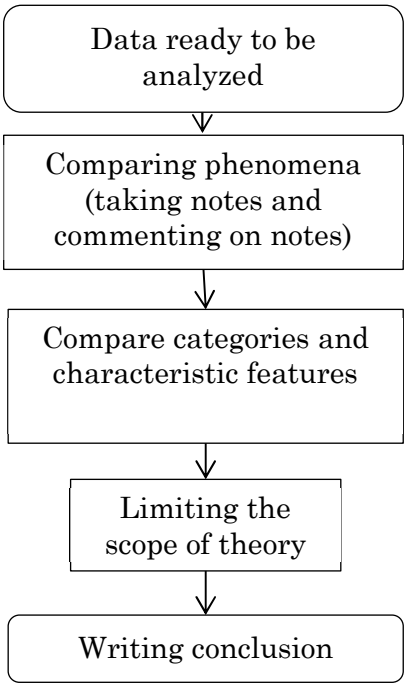

Figure 2
Data Analysis Process Diagram

Research Design, Site, and Participants

This research was conducted on eighth grade students at SMPN 1 Malang City who had learned comparative theory. The selection of subjects in this study used a purposeful sampling technique. In purposeful sampling, the researcher deliberately chooses individuals and places to understand the main phenomenon. The standards used in selecting research subjects and places are those that provide rich information (Patton in Creswell, 2012: 205).

Determination of the subject began with a discussion with one of the mathematics teachers of SMPN 1 Malang City on Monday, September 10 2018. The discussion aimed to select 12 students who have more interest in mathematics as prospective research subjects. On Friday, September 14, 2018, the first day of research was conducted on 6 prospective research subjects. The research was continued on the second day, which was Friday, September 21, 2018 on 6 other prospective subjects. From 12 students, 6 students were chosen as subjects who consistently solve comparison problems with instrumental understanding. After that 3 students were selected and divided in 3 categories of conditions, namely 1 student in condition A, 1 student in condition B, and 1 student in condition C. The students selected were students who experienced the most cognitive conflicts.

Data Collection and Analysis

The datas were collected from test sheets, general interview instructions, validation sheets, and recording tools. The datas were analysed using constant comparative analysis. Glaser (2014) states that the constant comparative analysis technique is a technique for comparing phenomena that have occurred continuously throughout the study. The constant comparative technique is explained through four stages, namely: 1) the stage of comparing events that can be applied in each category, 2) the stage of integrating the categories and their characteristics, 3) the stage of limiting the scope of the theory and, 4) the stage of writing theory

RESULT AND DISCUSSION

Description of test result

In accordance with the process of determining research subjects that have been described, there are 3 subjects in this study. The three subjects consisted of one instrumental subject in condition A (IA), one instrumental subject in condition B (IB), one instrumental subject in condition C (IC).

The three subjects (IA, IB, and IC) experienced the same cognitive conflict In determining the appropriate comparison formula which was marked by the emergence of doubts and awareness of contradictions. The three subjects did not experience cognitive conflict when applying the predetermined comparison formula. The three subjects experienced cognitive conflicts when doing algorithmic calculations that occurred marked by the emergence of awareness of the existence of contradictory conditions (contradictions), interest and doubt.

Data Analyze

After analyzing the results, it turned out that the three subjects experienced the same cognitive conflict. Therefore, in the discussion of this article, the cognitive conflict experienced by one subject (IA) will be taken as an example of the cognitive conflict experienced by the three subjects.

IA experienced a conflict in her cognitive structure when she wanted to determine the formula for the inverse proportion values to solve question number 2. IA's answer to question number 2 is presented in Figure 3 below. Problem Number 2 was "Thirty people can complete a project in 30 days. If everyone's abilities are the same, how many days will it take 3 people to complete the project?".

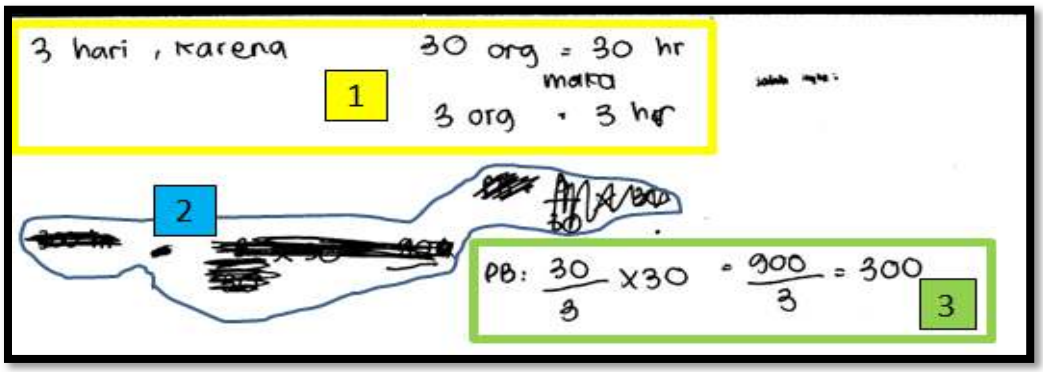

Figure 3
IA's Answer for Number 2

Information :
Number 1: IA's initial answer to question number 2
Number 2: IA's second answer for question number 2
Number 3: IA's final answer for question number 2

Cognitive conflict that occured is characterized by the emergence of doubts and awareness of contradictions. IA had doubts between the equivalent comparison formula and the reversed value comparison when solving problem number 2. The doubt was a cognitive conflict that occurred which is in line with the opinion of Lee and Kwon (2001) who are synthesizing the signs that indicate what students most likely show when faced with conflict cognitive. The signs described include anxiety, doubt, restlessness, tension, indecision, indecision, confusion, frustration and reassessment of the situation to try and resolve the conflict. IA's expression in the interview is transcripted in Dialogue 1 below.

[1]P : How did you get your final answer?
[2]IA : I use the reverse comparison method for the value, which was known above, which was asked below got multiplied by the number of days known. So get 300 days. This makes more sense ma'am (pointing to Figure 1 which is marked number 3).
[3]P : Why is this crossed out (referring to Figure 1 which is marked no 2)?
[4]IA : Hee, that's the wrong answer, ma'am.
[5]P : What made you realize it was wrong?
[6]IA : I used the formula incorrectly, ma'am. I used the comparison formula for which was asked above. I realized the time when I got the result equal to 3 days. That was same with my original nonsensical answer. Supposedly, if 3 people then we need more time.
[7]P : Why did you get the formula wrong?
[8]IA : I was confused, Ma'am, the formula for the reversed value comparison was the one known or asked.

(Dialogue 1)

The expression "I was confused, ma'am, the formula for the comparison of the reversed values is the one that is known or asked." in Dialogue 1 marked with number 8 is evidence that IA hesitated when determining the formula for the inverse comparison values. In addition, IA also realized and admited that there was a contradiction between the answers he got and the concept of inverse comparison values. This is evidenced by crossing out the

answer in Figure 1 which is marked with number 2 and the phrase "I used the formula incorrectly, ma'am. That's what I used the comparison formula for, which was asked above. I realized the time when I got the result equal to 3 days … if 3 people then we need more time." in Dialog 1 marked number 6.

The emergence of doubts and realizing/admitting the existence of these contradictions are signs that there is a conflict in the cognitive structure of IA when determining the formula for inverse comparison of values. The cognitive conflict experienced is a type II cognitive conflict. In the end, the conflict that occurred in his cognitive structure led IA to determine the correct value of reverse comparison formula. So IA concludes the correct answer as well.

Furthermore, IA did not experience cognitive conflict when applying the formula he has determined to solve the comparison problem. Both the answers that IA wrote on the answer sheet and the statements made by IA during the interview, there were no signs of conflict in her cognitive structure. This means that IA has understood the information from the components of the comparison formula that he remembers.

Although IA did not experience cognitive conflict in applying the formula he has determined, IA experienced cognitive conflict when performing algorithmic calculations. Cognitive conflict that occured was characterized by the emergence of IA awareness of the existence of contradictory conditions (contradictions), interest and doubt. This is in line with the opinion of Maume and Mathews (2000) which states that during mathematics learning, cognitive conflict occurs when students have preconceived ideas about how mathematical problems should be solved that are different from the way they are solved. This was experienced by IA, who initially felt confident with the calculations he did to answer question number 1 as shown in Figure 4 (see the section marked number 1). Question number 1 was "Question 1: Ninety people can complete 90 tables in 90 days. If everyone's ability is the same, how many days will it take for 9 people to make 9 tables?".

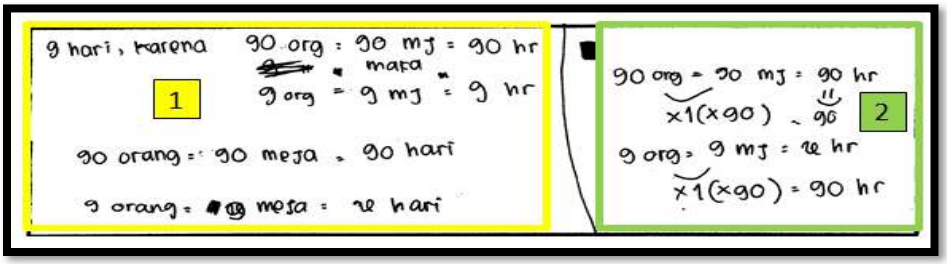

Figure 4
IA's Answer for Problem Number 1

Information :
Number 1: IA's initial answer to question number 1
Number 2: IA's final answer for question number 1

At first IA said 9 days was the time it took for 9 people to make 9 tables. IA makes a comparison between the number of people, the number of tables, the number of $days$ = $90 : 90 : 90$. Using this comparison, the value of $x = 9$ days is obtained for a comparison of $9 : 9 : x$. IA simplified the comparison of $90 : 90 : 90$ by dividing all the numbers by 10 in the ratio so that the ratio becomes $9 : 9 : 9$. This shows that the initial calculation scheme that IA did in solving the comparison problem was to simplify the known comparisons.

When working on question number 2, IA made a comparison of the number of people and the number of days = $30 : 30$. So with this comparison, the value of x = 3 days is obtained

for a comparison of $3 : x$. IA believed that his initial calculation scheme was correct until he solved problem number 3. IA tried to apply his calculation scheme to solve the problem number 3, but he met obstacles that caused changes in the calculation scheme in solving comparison problems. This is evidenced by the scribbles of IA's initial answer as shown in Figure 5 (look at the one marked with number 1). Question number 3 was "Question Number 3: Six tailors can complete an order of 42 kebayas in 14 days. If everyone's ability is the same, how many kebayas can 9 people complete in 18 days?".

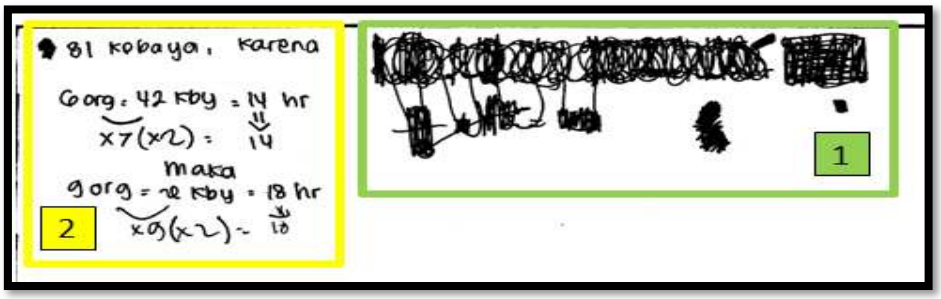

Figure 5
IA's Answer for Number 3

Information :
Number 1: IA's initial answer to question number 3
Number 2: IA's final answer for question number 3

IA compared the number of tailors, the number of kebayas, the number of days = $6 : 42 : 14$. Furthermore, IA was confused in determining the value of x that satisfies the $9 : x : 18$ ratio. This was what caused IA to cross out the original answer. This information is also evidenced from the following snippet of the interview transcript with IA:

[1]P : Wow, that was interesting. Tell me first how you got the answer for question number 3.
[2]IA : Heheh, at first I wanted to work on question number 3 by way of number 1 Ma'am. But the numbers are difficult to compare like the method number 1. I was confused, so I crossed out this (pointing to Figure 4.3 marked number 1) Ma'am. Finally I just looked at the multiples of the known numbers to find the answer ma'am.

(Dialogue 2)

Based on Dialogue 2 which is marked with number 2, it is known that at this stage IA began to experience conflicts in its cognitive structure. Starting with IA's confusion when the initial calculation scheme could not be applied to solve problem number 3. This caused IA to change his calculation scheme by finding a multiplication pattern in the comparisons he made. The following was IA's explanation of the new calculation scheme:

[1]P : Continue the story.
[2]IA : I made a $6 : 42 : 14$ comparison like this, Ma'am (see Figure 3 which is marked with number 2). Then I thought, what number we need to multipy to get from 6 to 42, times 7, right, ma'am. Then how much is 7 multiplied so that the result is 14, multiplied by 2, right? So I found the pattern $\times 7(\times 2)$. I used it to find out how many kebayas 9 people can make in 18 days. I assumed the number of kebaya was x, so $9 : x : 18$. I did it by looking at the day first, ma'am, 18 was divided by 2, the result was 9. So the number of kebayas was 9×9, ma'am, which was equal to 81 kebayas.

[3]P : Why can you look for patterns like that to find the answer? What is the underlying concept?
[4]IA : Ermmm, that was what I thought when I saw the comparison. Because you can see that 42 is divisible by 6, then 14 can also be divided by the quotient.

(Dialogue 3)

The cognitive conflict experienced by IA was not over. After IA found the answer for question number 3 which was 81 kebaya, IA's doubts appeared with the answers he previously got for questions number 1 and number 2. This doubts wwere caused by IA realizing that the initial scheme he applied to solve questions number 1 and number 2 could not be applied to solve problem number 3, while according to IA the three questions are the same type of problem. IA changed the calculation scheme by applying the inverse ratio formula to solve problem number 2 (look at Figure 3 which is marked with number 3). After IA got the final answer to question number 2. IA was so sure of all the answers she had have. This is evidenced by the expression of IA's belief in the following interview transcript:

[1]P : Do you still have any other doubts?
[2]IA : There is no ma'am.
[3]P : Are you sure with all the answers?
[4]IA : I'm sure ma'am.
[5]P : How sure are you with your answer?
[6]IA : Very sure ma'am, because I got integers, not fractions. Seeing the pattern is fixed and makes sense.

(Dialouge 4)

The emergence of interest, doubt, and realizing and acknowledging the existence of these contradictions are signs that there is a conflict in the cognitive structure of IA when performing algorithmic calculations in solving comparison problems. The cognitive conflict that occurs is a type I cognitive conflict. In the end, the conflict that occurs in his cognitive structure leads IA to find a calculation scheme that produces an answer that fits his logic. So IA concludes the correct answer as well. There was no indication of any more cognitive conflict when IA determined the final answer.

Based on the explanation, cognitive conflicts that occur in IA subjects in solving comparison problems are type I and type II cognitive conflicts. The following is a description of the cognitive conflict in Table 1:

Tabel 1
Cognitive Conflict which IA Experienced

No	Cognitive Conflict	Type of Cognitive Co nflict
1	The realization that the initial scheme of simplifying the comparison of the number of people, the number of tables and the number of days is incorrect because it cannot be applied to solve all comparison problems. The subject realized that simplifying the comparison $90 : 90 : 90$ *to* $9 : 9 : (x = 9)$ was a wrong solution because the subject could not determine the value	Type I

	of x that satisfies the comparison $9 : x : 18$ by simplifying the comparison $6 : 42 : 14$.	
2	Awareness of the contradiction between the answers obtained from applying certain formulas with the concept of inverse comparison values. The subject realized that the answer he got from applying the comparison formula was contrary to the concept of inverse comparison of values.	Type II

The video recording confirmed by IA also proved that IA experienced cognitive conflict when solving comparison problems. Cognitive conflicts that occurred were identified through body cues. The results of the video recording showed that IA consistently expressed conflicts that occured in his cognitive structure by doing the following:

1) When aware of a contradictory condition, IA: a) suddenly raised his head which was originally lowered and then focused on reading, then rested his chin on the table with pouting lips, b) shaked or noded his head, or c) mumbled with focused eyes forward.
2) When interest arised, IA read the problem by pointing to each word using the tip of a pen.
3) When in doubt, IA: a) pressed the top of the pen, b) rested his chin on the table and occasionally noded, c) swung his hands, d) lightly tapped the table surface with his index finger, e) scratched his lips, head or forehead, f) presed his lips together, g) rested his head on their hands, h) closed his eyes hard, i) puffed out his cheeks, j) placed his hands on the back of his neck or, k) proped up his face using both palms on his laps.

Based on a list of body cues that indicated IA was experiencing cognitive conflict when solving comparison problems, it was found that doubt was the most common indication. The following is a chart of the distribution of indications of cognitive conflict experienced by IA when solving comparison problems:

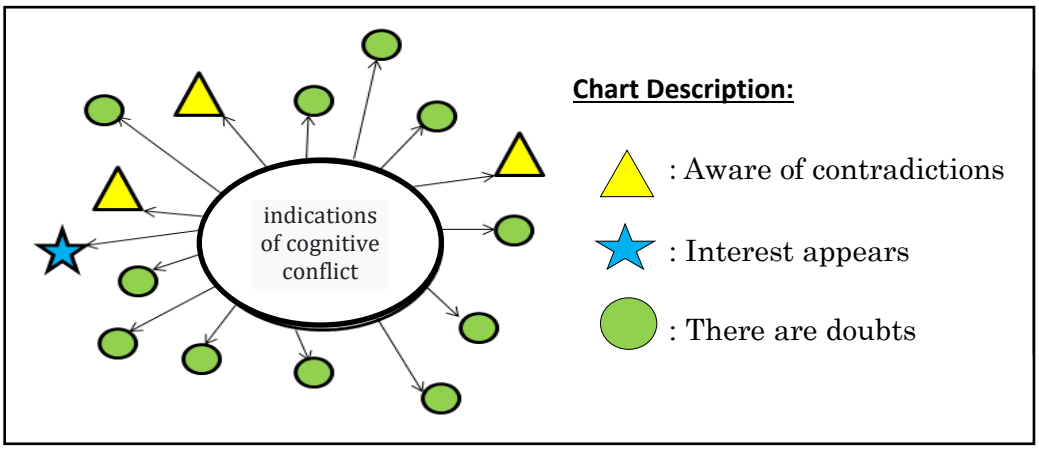

Figure 6
Indication IA Experienced Cognitive Conflict.

CONCLUSION AND IMPLICATION

Conclusion

Students' cognitive conflicts with instrumental understanding in solving comparison problems occur when: (1) students determine the appropriate formula for the problem and (2) students perform algorithmic calculations. Students' cognitive conflict when determining the appropriate comparison formula is the awareness of the existence of a conflict between the answers obtained from applying the equivalent comparison formula with the concept of inverse comparison values. Students' cognitive conflicts when doing algorithmic calculations are: (a) awareness that the initial scheme in the form of simplifying the comparison of the number of people, the number of tables and the number of days is incorrect because it cannot be applied to solve all comparison problems and (b) the awareness that the calculation scheme is in the form of looking for patterns of multiplication on known comparisons cannot be applied because it produces an answer that is not an integer.

Implication

The implications from this research are:

1. In this study, type III cognitive conflict only appears in students with relational understanding when solving comparative problems, it is recommended that further research be conducted on other students' internal factors, such as metacognitive abilities or reflective thinking.
2. The results of the research findings are the causes of students with instrumental understanding not recognizing the anomaly of the comparison problem situation that is being faced because students are accustomed to solving similar problems. In learning comparison material, the teacher can provide examples of more varied comparison problems so that students have a lot of experience in solving comparison problems.

Disclosure statement

Cognitive conflict in this study is still discussed too broadly, it is recommended to conduct research to discuss more specific cognitive conflicts such as: applying a cognitive conflict approach in learning strategies, classification/profile of cognitive conflicts that occur in students in understanding math problems or, tracing/description of cognitive conflicts that occur in students with certain methods. In addition, conflict cognitive between environment is not found in this research while this conflict can happen so that it becomes appealing thing to be studied in more depth.

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