



Applying Cognitive Conflict Strategy to Develop Mathematical Critical Thinking Ability and Character of Students

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ARTICLE INFO

o-ISSN: 2528-2026
p-ISSN: 2528-2468
Vol. 5, No. 1, June 2020
URL: <http://doi.org/10.31327/jme.v5i1.1174>

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Suggestion for the citation and bibliography

Citation in text:

Adnyani (2020)

Bibliography:

Adnyani, L. P. A. P. (2020). Applying Cognitive Conflict Strategy to Develop Mathematical Critical Thinking Ability and Character of Students. *Journal of Mathematics Education*, 5(1), 30-38. <http://doi.org/10.31327/jme.v5i1.1174>

Abstract

This study aims to design a valid, effective, and practical learning trajectory with a cognitive conflict strategy in developing critical thinking ability and character of students on set topic learning. In learning, counter-information and guided question were given to guide the students to manage built conflict. This research is a three-stage design study with the following steps: initial preparation and design, real field implementation, and retrospective analysis. Data on student's critical thinking skills were collected through student's works in worksheets, post-test results, and interviews. As for the character of the students were seen from the observations during the learning activities. The collected data are analyzed descriptive-qualitatively. The learning trajectory of this design study had the following characteristics: The students are observing and relating the problem with their prior understanding or information they got from the sources. Students are directed to comparing and writing arguments from the counter information given to choose the correct answer. The students are realizing or finding the correct information and construct their comprehension or understanding. The students are giving conclusions and finding their method to solve the problems.

Keywords: cognitive conflict strategy, critical thinking, character

A. Introduction

Students' critical thinking ability and a positive attitude are a must in the 21st century. A person with critical thinking ability is needed to get a job these days (Davies, 2016). Mathematics allows students to develop their critical thinking ability through solving problems. It is following the aim of mathematics' learning in secondary. Other than critical thinking ability, the aim of mathematics' learning at secondary is to develop a positive attitude (character) of students. Characters' education at school is highlighted on these days. It changes the education system in Indonesia, which now is concerned with students' positive attitude. In the learning process, the teacher was hoping to integrate the character's education in every lesson in the classroom.

This suggests the importance of developing a learning design of a set topic that can develop a positive attitude and critical thinking. One strategy that can be used to help is by creating

information or problem which can initiate students to give their comment/ argument/ idea/ point of view critically towards the information/problem given. Sometimes it needs guidance to help students to solve the problem given. It is because students might write the correct answer according to their comprehension/understanding, which was not entirely correct. That is a reason that critical thinking is needed to avoid any mistakes. The guidance to help students resolve their mistakes can be done by giving relevant counter-information, analogy, or relevant guided questions. These things will initiate students to rethinking about their answers and critically look at their answers and might find the mistake they made. This way of learning is known as cognitive conflict strategy. Besides, Sayce (2009) state that cognitive conflict helps students to think factually and realistically. Learning with cognitive conflict can be done by giving counter-information, which is given step by step.

B. Literature Review

1. Cognitive Conflict Strategy and Critical Thinking

The cognitive conflict term is related to the accommodation process, which was introduced by Piaget. In his theory, Piaget (Van De Walle, 2013) says that accommodation occurs when the new concept does not "fit" with the existing initial knowledge. This state is called disequilibrium by Piaget. If this state occurs, the brain replaces the existing schema with the new concept. Accommodation is a process to integrate a new stimulus to the cognitive structure that is formed unconsciously. Cognitive conflict is needed to solve accommodation that happens in a person's cognitive structure.

In a specific condition where people cannot adjust the initial cognitive structure with the new stimulus, they get from learning activity, people called having a cognitive conflict. The cognitive conflict also can be caused by a realization about the counter information with the information or idea they have prior. Moody (2010) states that cognitive conflict happens when there is a contradiction between fundamental knowledge and new information/knowledge of students. Fraser (2007) states that cognitive conflict is formed by giving a counter-example or two contradicting examples, where the conventional method will fail the process of solving the problem. Sayce (2009) states that cognitive conflict means a condition where the students were given a new thing, which can be a counter-example or a statement that makes students unsure about their prior comprehension/understanding of the fundamental knowledge they learn.

We can do is by giving the wrong example/statement to the students that have correct comprehension/understanding of a topic, and vice versa. The students are guided to recheck and compare the information given by their answers. Alan Bell (in Ponte, 1991) and Boaler (in Kaur, 2009) state that a discussion group is needed to create a conflict-discussion and also a chance to make the students communicate actively. It shows that mathematics learning with cognitive conflict is an excellent way to develop students' critical thinking ability.

Lai (2011) added by stating that even though adjustment examples or information given in learning are essential, but the presence of inconsistency or a contradiction will help to boost students' critical thinking rather than by only giving a consistent matter which commonly used in learning. This shows that giving a problem or material that can intrigue inconsistency or contradict can help the students think critically. Ennis (in Aizikovitsh, 2012) states that learning includes analysis process questioning a thing verifying a fact and a result of a problem, and redefining a concept are activities that require critical thinking ability.

Mathematics critical thinking can be shown by students' steps or ways of thinking in solving a problem. The problems that can initiate critical thinking activity are the problems that cannot be quickly done by using a conventional way or only applying a formula without go through the analysis. Based on Bloom's taxonomy, analysis, synthesis, and evaluation stages are the stages that represent critical thinking ability (Lai, 2011; Sudiarta, 2005). However, Sudiarta (2005) states that evaluation represents critical thinking, while synthesis represents creative thinking. Besides that, Sudiarta (2013) arranges the competencies of critical mathematical thinking, which include (1) investigating the context and spectrum of the problem; (2) formularizing the problems; (3) developing the answer's concept and reasonable argument; (4) doing induction and deduction; and (5) evaluating.

From (1) until (3) are the essential competencies that the students should have for solving mathematical problems. Point (4) represents the student's ability to give a hypothesis or prediction or other ideas to solve the problem given. The last point is point (5), which is the competence to give alternative ideas and use the ideas to solve the problems. This stage was done

by giving other answers to the problem. Critical thinking ability can be seen from the ways of students in solving the problem. Sudiarta (2007) also states that solving an open-ended problem can initiate critical thinking. Therefore, the indicators of critical thinking ability consist of the student's ability to give a correct answer, an alternative idea to solve the problems, and an alternative answer to the problem given.

By giving counter-information, students will compare it. The teacher will ask the student to think about other possibilities that can be the ways to solve the problems or other possibilities of the answers. They will evaluate their work and expect to know about their mistake by arguing why the counter information is correct or wrong. Indirectly, students train their critical thinking ability by solving problems to get the correct comprehension.

2. Cognitive Conflict Strategy and Character Development

Chan (in Limon, 2001) states that the usual cognitive conflict paradigm involves identifying students' current state of knowledge; confronting students with contradictory information usually presented through text and interviews, which make explicit the contradiction or only guide the debate with the student or among peers, or by teacher technology; evaluating the degree of change between students' prior ideas or beliefs and a post-test measurement after the instructional intervention.

Based on those steps, this research expanded the steps to be applied in classroom teaching and learning. Cognitive conflict strategy is done by the following steps: 1) giving the problems and checking students' fundamental knowledge; 2) giving different information/materials; 3) comparing and giving a reason to the contradictory information, and 4) concluding.

Form each step, the students have a chance to develop their value in learning mathematics. It is represented in the following diagram.

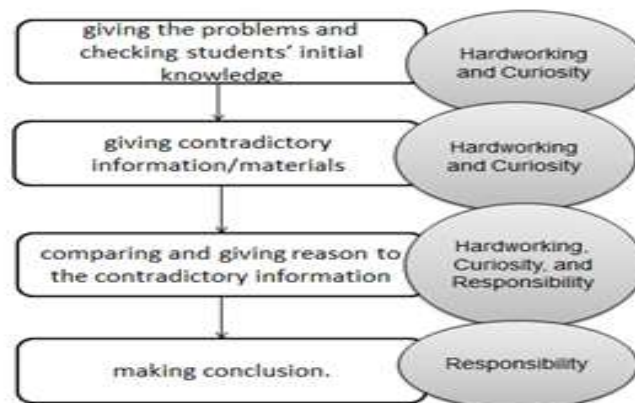


Figure 1. Cognitive Conflict Strategy and Character

In the first and second steps, students will be forced to find the answer to the problem given. Students need to make their best effort since the problems given are a new problem for them. Prompting problems to students will develop their hardworking and curiosity. Students have to use the sources and probably ask the teacher actively to help them solve the problems. When the contradictory information is given to the students, they will start to rethink their previous answers. For the third step, students need to rechecking, comparing, and choosing which answer or information is correct. Is it theirs or the contradictory information?

Moreover, they need to give a reason for why do they choose one of them. Students become more curious about the contradictory information, and they need to check the information given, whether it is true or not. It requires much work, and it can initiate students' hardworking in the learning process. The students' activities in giving a reason by choosing one can make them get used to being responsible for everything they choose. The same thing will happen when it comes to concluding. Students have to give a conclusion that they have understood and can explain why it turns to be the conclusion. It also can develop students' responsibility. Thus, this research's cognitive conflict strategy could develop three values in students' character while learning. Those values are hardworking, curiosity, and responsibility.

This study's problem is how the learning trajectory of a set topic by cognitive conflict strategy can develop the students' mathematical critical thinking ability and character. This research aimed to design a valid, effective, and practical learning trajectory with a cognitive conflict

strategy to develop students' mathematical critical thinking ability and character on set topics. The set topic was limited to the set at grade seven in junior high school in Indonesia. This learning design was expected to develop mathematical critical thinking ability and character of students.

C. Methodology

1. Research Design

This study was to design a research-based method to find the learning trajectory of junior high school students regarding the set topic. The study built a three-stage design to see the relationship between the goals of learning. The activities were given to achieve the goals and the prediction of how the students' thinking and understanding evolve in the context of the learning activities (Simon, 1995). This study consisted of observations and interviews, instruction, post-test, and interviews.

2. Instruments

This study was done at SMP Negeri 5 Kuta Selatan, which involved five students from VII.10 for the first cycle, thirty-two students from VII.4 for the second cycle, and thirty-two students from VII.1 for the third cycle. The instruments used were the Hypothetical Learning Trajectory (HLT), student's worksheet, lesson plan for teaching guide, and teacher's guidance book.

3. The technique of Data Analysis

In the preparation phase, researchers have analyzed the situations and problems that occur in mathematics learning. The activities included observing the learning process in classes VII.1, VII.4 and VII.10; interviewing the teachers and some students to find the difficulty or obstacle that happened while learning; analyzing curriculum for a mathematic lesson in grade seven of secondary; analyzing the similar studies to consider the activities that were done in classroom; designing (HLT) and instrument for teaching, such as lesson plan, students' worksheet, teacher's guidance book; and testing validity and reliability of the instrument used. After that, we implemented the HLT by doing learning activities in the classroom, divided into three cycles. The first cycle was done by doing the learning according to the HLT and instruments that were prepared. The activities were continued by revising either the HLT or instruments for implementing later in the second cycle. The same thing was done in the second cycle, where the results of the revision of HLT and instruments in the second cycle were used as guidance for the third cycle. The learning activities were arranged in HLT. HLT was used as guidance for doing the activities in the classroom.

This study's data were obtained from the students' worksheet and post-test, observation of discussion activity, journal, and video of the learning activity—the verification of the data done by doing technical and source triangulations. Students' critical thinking is collected through students' worksheets, post-test, and observations during the learning process. The data were analyzed through some steps, which were:

- Watching all recorded learning video
- Making a general transcript
- Marking the attractive segment especially the moment that showed a crucial learning process
- Completing transcript to make the detail
- Looking for confirmation or contradiction of a crucial moment in the learning process
- Discussing the result with colleagues to see either they had the same interpretation with the researcher or not

The result of the analysis was discussed with mathematics teachers in grade VII to check the teachers' agreement with the result found. Students' works were compared qualitatively to explain how learning design and instruments were used to increase mathematical critical thinking ability. Besides that, the result of observation and student's works while learning was marked to see the new attitude that showed the students' character development.

D. Findings and Discussion

The finding of initial observation and interview with mathematics class teacher revealed that the students still faced problems in dealing with types of numbers (identifying) and were still confused with symbols $<$, $>$, \leq , and \geq . The students were not active in learning and using the source (book) they had. They only focused on what the teacher wrote on the board, and later, they copied it into their notebook. That gave the result of the discussion between the researcher and the

teacher to involve little problems related to numbers and the symbols in the learning process, which resulted in the problems in students' worksheet that will also use little topic about numbers and symbols.

The steps of learning used in the main activities were observing and relating the problems given, comparing the answer with the counter information given and giving an argument to that, finding the correct information and confirming the conclusion, and making a conclusion and solving the problems given.

In the first cycle were found some interesting things while learning. Student A stated that a set is a group of objects that has similarity to each other. Besides that, students at the first two meetings believed that all the counter information was given the correct answer to the problems. And also, at the Venn diagram, students made a mistake by drawing the elements that were not formed as a set into a curved inside the box. In the third meeting, student E said

"This counter-information was sometimes wrong. I felt like you lied to us."

Students thought they needed to find another sets that were its elements were the same or the same with the "bigger" set for the sub-topic subset. For the power of a set, they found it by writing all the elements of the subset. To decide that two sets are equal, they looked at the same elements that both of the two sets had. However, there was also the different way they used to find the subset, which was by finding the parts of the elements in the "bigger" set. Moreover, for the power of a set, some students used the keyword "have all parts" to decide the elements of the power of a set. For the set's operation, students quickly comprehended the union of two sets only to gather all the elements of the two sets.

Meanwhile, for the complement of a set and complement of two sets, students had trouble understanding the meaning. They thought if there were two sets in the same universal set, A and B, so the complement of A was B and vice versa. Also, for the complement of two sets, they sometimes switched the meaning of it. Example $A - B$ were understood as all elements of B, which were not the elements of A. For intersection A and B, some students got it mixed by including the elements which were not the elements in both A and B into the answer. The last about the set's operation properties is that students could find the operation results involving the properties. Students made an analogy of commutative, associative, and distributive properties with the operation properties in number. In the process, students took a long time to make a set in the worksheet given. Besides that, the students who used the book got a problem understanding the new terms that the book used. Another exciting thing was that students comprehend and understand the operation of sets quickly using the Venn diagram.

The post-test result showed that students used various ways to solve the problem. To answer the question related to the set's operation, a student answered using the formula directly. Also, a student was learning it by using logic to describe the way he/she thought. Logically, the student compared the information given in the problem and matched it with the result she/he got. It seemed like making a trial error.

Another exciting thing was how students answered the problem related to the properties of the set's operation. Students did not use the properties, but they directly expanded the operation until they got the answer. Also, a student was answering it by using a Venn diagram. He drew all the sets, and from that Venn diagram, he found the answer.

Later on, from the result of the first cycle, the HLT and the instruments were revised. The revision was applied in the second cycle. The revision that was made was:

- Giving sets for the problems in the worksheet so that the student can work efficiently
- Giving students a general review of the topic before the activities started
- Using Venn diagram as counter information in the subtopic of the set's operation
- Introducing the terms used in the book was included in learning activities

In the second cycle, some impressive results were found. Students started to give vary answered as if they had a different point of views. One of the problems given was as follows.

From 5 objects that is given. Give a name to that group, so the group becomes a set.

The answers that the students gave were: a set of objects that had the shape of a rectangle and a set of the objects which were in the classroom. There were also students facing difficulty in understanding it by still including properties of "red-colored" (the definition of red-colored is not a clear and correct definition) as the name of the set. The name of the set given was a set of the objects which were red-colored in the classroom or a set of the objects that had a zipper and red-colored. Students seemed confused about deciding the definition they would use. The student also

was found to drawing the Venn diagram in the wrong way. The student drew the Venn diagram in a different rectangle box for each set.

Meanwhile, it all could be drawn in the same rectangle box. This problem was solved by giving counter information to be compared with their answer and choosing which one was the correct way to draw the Venn diagram. After that, they gave an argument about why it was correct or vice versa and rewrote the correct answer to the problem given.

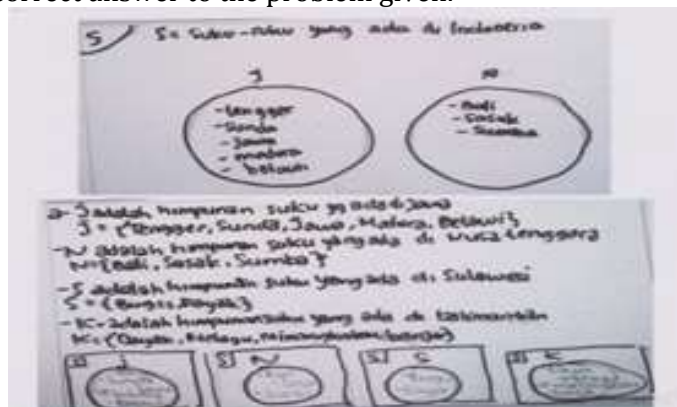


Figure 2. Student's work on Venn diagram



Figure 3. Venn diagram is given as counter information

After the students compared it and decided which one was the correct information, they concluded by explaining how to represent sets into the Venn diagram. To confirm that the students understood how to draw the Venn diagram, the following is the conversation that was done to check the students' comprehension at representing sets into the Venn diagram.

Conversation 1. Draw rectangular box and circles for the sets

- Researcher (R) : Why do you make the diagram into different boxes for sets J and N?
 Student (C) : That is what I see in the book, Miss.
 (R) : Well, let's see. Where is the book? Show it to me. Do J and N lie in the same universal set?
 C : Yes, Miss. It is the same.
 (R) : If it is the same, why don't you try to draw it into the same rectangular box? Well, the universal set of it is the same anyway.
 C : Yeah, it can, Miss.
 (R) : So how do you think it is supposed to? If two ways can draw both of them, so it means both of them are correct.
 C : Ah, the one that is drawn in the same rectangular box is the correct one. I read and looked at the information on the book carefully; here, there is in the book exactly. I missed reading it.
 (R) : Okay, now, what do you think the Venn diagram is?
 C : Venn diagram is to draw the sets into the diagram. We use a rectangular box and circles for the sets.

Another thing appeared on the result of the post-test. Students in this cycle tended to follow the formula or the rule that was used in a topic. Students did not use to give a different argument based on the problem given. This result was discussed later with a mathematics class teacher to find clarification. From the discussion, the teacher stated that these students were the passive ones compared to the other class used as a subject in this study. The teacher suggested to be more focused on the learning process and not to accept the result of the post-test. The students in this

class did not like to explain the process even if it asked. They preferred memorizing the formula directly and applying it right away. Even though the results in post-test students showed a quite reasonable effort in answering. The students were responsible and worked hard to give out their best into their work. Because if we compared it with how the students answered the problems, usually before the study was held, they tended to give short answers and only wrote the result of the final answer that might be the only number or could be "Yes or No."

The revision done based on the result of the second cycle was to encourage the students in the beginning in the lesson to actively use the book they had and make more counter information based on the mistake that happened during the second cycle.

The learning process in the third cycle was not much different from the first and second cycles. In this cycle, the preparation to minimize the possibilities of student's mistake was better.

There was an interesting conversation that happened in this cycle. Mostly it was about how the students thought about the concept they were told. The conversations below happened in the learning process.

Conversation 2. As if it is a ghost

- Researcher (R) : Let us observe, can you see the air in this room?
 Student (all) : No Miss,
 (R) : However, is there air or not?
 A : Yes, there is Miss. If there is not, we all are dead.
 (R) : So, just pretend that the empty set is the same as the air. Do you think the empty set is in other sets?
 Student (all) : (silent)
 (R) : Come on, who wants to answer?
 B : If it's like that, so yes, there is an empty set in another set, Miss, even though it is invisible.
 (R) : If I ask, "is an empty set a subset of a set?" What will your answer?
 B : Yes, it is because it is the same as the air.
 A : Even though it is invisible, it exists.
 (R) : Yes, that is correct, like what A and B said. So, now who can tell the relation between the empty set and subset?
 B : The empty set is a subset also.
 (R) : Whose subset?
 Student (all) : (silent)
 (R) : Okay, the air is everywhere, isn't it? So now, what about the empty set? The empty set ... it has to be in every what?
 B : The empty set is in every subset of any sets, and the set can be anything.
 (R) : How about the others? Can you all find the relation? The empty set is like the air so that it can be everywhere. If I have sets A, B and C. So, the empty set is in A, B, and C. The empty set is a subset of A, B, and C.
 Do you get it?
 Student (all) : Yes Miss,
 E : As if it is a ghost, Miss. They are everywhere, but it is invisible.

At first, the teacher gave the analogy of the empty set as the air. However, a student said that the empty set could be a ghost. It showed that the student was used to seeing a thing or a concept differently. They used the condition or situation that they used to know to help them understand the concepts of the problems given.

Conversation 3. What is subtracting with?

- J : Oh my, why did you write it wrong? It asks for $A - B$. That the answer for $B - A$.
 A : Ahh, what do you mean? I do not get it. If it's like that, then you do it.
 J : No, I answered for the intersection. We shared the task to make it faster. You should do it.
 A : Okay, just let me know the correct answer.
 J : Look, for $A - B$, we found the elements of A, which is not the elements of B. Same as when you work on $6 - 2$, which one is subtracted, 6 or 2?
 A : 6 of course, it is $6 - 2$
 J : That it! It is the same thing. For $A - B$, which one is subtracted?
 A : A?
 J : Yup, the element of A is subtracted. You need to find the same elements from both A and B first, and then you take away the same elements in A.

A : Oh, I see, Okay I redo it again.

Form the result of the conversation above, and it showed that J was able to see the complement between two sets as a difference or subtraction operation. The ability to comprehend it showed that J had a great analysis of the concept compared with the other students. He was able to give another interpretation that showed by "-" sign itself. J showed an excellent critical thinking ability by expanding his point of view towards a concept.

Meanwhile, in the learning process from the first cycle until the third cycle, the steps of the learning process that became the main of this design study included discussion activity and checking the initial result, giving counter-information, teacher intervention, and creating the last conclusion. From those four steps in the learning process of this design study, it obtained about how the students thought and understood a concept. We can also see the development of the student's positive attitude and critical thinking ability in learning.

Table 1. How the students think to comprehend set topic after using the learning design

Subtopic	How students think
The concept of the set	A group of things or objects that has a definite similarity (a precise definition)
Universal of set	A set that can cover all sets
Venn Diagram	The way to draw it by making a rectangular box as a universal set and circles inside the box as the place of the place for the elements of the other sets.
Set cardinality	The number of set's elements, which can be determined by counting the number of the set's elements.
A subset, Empty set, power of set and equality of two sets	<ul style="list-style-type: none"> - The empty set is a set that has no element, or the cardinality of the set is 0 - The subset is a set in which the element is parts of the main set. It can be determined by listing all cardinality of the sets and the elements of it. - The power of set is a set that the elements are all subset of its main set. - Equality between two sets can be checked by comparing the elements of those sets; check all the elements that have to be the same and have the same cardinality.
Operation of sets	<ul style="list-style-type: none"> - The complement of set A is found by determining the elements that are in the universal set but not in A - Unions of two sets can be determined by collecting/uniting all the elements of those two sets. - The intersection of two sets can be determined by finding the same elements which are owned by both of those two elements. - The complement of two sets ($A - B$) can be determined by finding the elements of A that are not B. <p>*Mostly, students can understand it better by using Venn diagram illustration.</p>
The properties of the set's operation	<ul style="list-style-type: none"> - Idempotent: operate (union and intersection) a set with the set itself, and the result is the set itself. - Identity: operate (union and intersection) a set with an empty set. - Commutative: operate (union and intersection) in vice versa, will give the same result - Associative & Distributive: it is the same as the operation in number.

E. Conclusion

Learning trajectory of this design study has steps as follows: (1)Comprehends the concept of set; (2) Comprehends universal set and Venn diagram; (3) I know the means of cardinality terms inset and empty set by giving an analogy, (4) Imagine the elements of a subset, power of the set and when the two sets are called equal, (5) Imagine the elements of the result from set's operation such as union, intersection, the complement of a set, and complement of two sets, (6) Comprehends of operation inset. All those steps were helped by giving counter-information and guided-question, which aimed at resolving the cognitive conflict that occurred in students cognitively. The characteristics of the learning that were arranged are observing and relating, comparing and arguments, constructing, concluding, and solving problems.

The order of the set topic's learning is started by introducing the concept of a set with "naming the group" activities. It is followed by introducing the cardinality of the set and universal set. Since the students know about the universal set, the concept of a Venn diagram can be introduced. Using the Venn diagram, the operation of set and the set's operation properties can be easily taught. The

concept of set and cardinality of the set can be used to teach about the empty set, subset, power of set, and the equality of sets. Which is all of those were learned by giving counter-information and guided questions during the learning process.

F. Acknowledgment

The author would like to acknowledge the contribution and supervision of Prof. Dr. I Nengah Suparta, M. Si. and Prof. Dr. Phil. I Gusti Putu Sudiarta, M.Si. for supervising this paper. Also, for the students and teachers involved in this research. Lastly, for my family for the financial support for this research.

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