

Syllogistic Reasoning and Cognitive Bias of Senior High School Students in Ambon, Indonesia

Johanes Pelamonia¹ and Aloysius Duran Corebima^{2*}

¹Elementary School Teacher Department, Pattimura University, Ambon, Indonesia;
pelamonia_janes@yahoo.com

²Biology Department, State University of Malang, Malang, Indonesia;
durancorebima@yahoo.com

Abstract

Students need the reasoning skill as an important part of intelligence. The purposes of this study were to map and illustrate syllogism-based reasoning and cognitive bias related to the concepts of science. This study was conducted by qualitative design with phenomenology approach. Samples of this study were 20 students from 5 senior high school in average 15-16 years old (formal reasoning level). Instruments of this study were essay test to analyse the structure of syllogistic reasoning and interview to identify the cognitive bias. This study deduced that (1) a syllogism reasoning was an inherent part of the development of human's thinking order, (2) the smoothness of syllogisms reasoning process relied heavily on individual comprehensive understanding of materials analysed, (3) a valid reasoning process was begun from meaning interpretation and premise truth, (4) a cognitive bias within syllogism reasoning was a confirmation bias. Someone accept the premise truth as an a priori without confirming the existing mental model or knowledge structure. Based on the findings, teachers need to empower and increase the students' reasoning skill in science lesson. Further research is need to uncover more information related.

Keywords: Cognitive Bias, Reasoning, Senior High School, Students, Syllogism

1. Introduction

Reasoning was one of important thinking skill needed to evaluate arguments, hypotheses, collect evidence, draw conclusions, and make decisions in daily life¹. In² author stated that thinking or reasoning involved several cognitive processes, such as induction, deduction, analogy, and causal reasoning'. A reasoning skill might facilitate an individual to either process an information, as well as to make a decision or predict a particular event in the future based on present facts or condition³. The urgency of reasoning role has been adopted as one of the purpose of globaleducation. One of purposes of education globally is to educate students to be able to reason well based on the principles of logic and systematic thinking. School is one of places to activate the reasoning skills. Activating students' reasoning is an inevitably process for several studies

showed that reasoning ability cannot develop merely following a child's growth. The reasoning development needs a strict learning intervention and training program. Referring to Piaget, a child's thinking level might reach formal reasoning at the age of 11 to 12 years old⁴. Piaget theory guarantees that a scientific reasoning will reach formal level or perfect level within secondary school period. The findings of a study by Tajudin et al.,⁵ suggested that most of students in Malaysian Public Institute were in concrete operational reasoning level and only a few of them reach formal operational level. Similarly, Corebima stated that the reasoning quality of most of students in State University of Malang while taking genetic course was low⁶. This reveals that reasoning development of people does not occur anytime along with their growth. This verifies Khun and Pearsall's argument that scientific reasoning could not develop completely when students

* Author for correspondence

grew into adults⁷. This shows that various studies of reasoning quality as an indicator of thinking development have been conducted globally yet such study has never been or rarely been conducted in Ambon. The thinking development indication that reaches formal reasoning level is indicated by the mastery of deductive reasoning. Students are categorized in formal reasoning level when they are able to deliver an argument in deductive reasoning pattern⁸. Many experts believe that deductive reasoning is the most crucial part of intelligence system, even though people often make mistakes in practicing deductive reasoning⁹.

Deductive reasoning is a process of creating a new information based on the existing premises and aims at creating valid conclusions¹⁰. One of kinds of deductive reasoning is syllogism or hypothesis syllogism. After being introduced by Aristotle (330 BC), syllogism is a core point of logic and draws many attention of psychologist to be examined¹¹. Okoro and Uyanga explained that syllogism reasoning was key of a good reasoning capability¹². Syllogism is a process of drawing new conclusions from 2 premises. The development of literature of syllogistic reasoning brings up 2 contrast theories. These theories are mental logic and mental model^{13,14}. The basic difference of these two theories lies on the description of syllogistic reasoning. The mental logic theory emphasizes that an individual who do reasoning possesses basic knowledge of the role of logical and language terms and utilize this knowledge in drawing conclusions. On the other hand, mental model theory emphasizes that an individual who do reasoning possesses knowledge related to a meaning of a particular logical and language term and utilize the knowledge to construct or find an alternative scenario. Thus, an internal representation provides a certain structural form of proposition condition¹⁵.

A disputation in syllogistic reasoning researches is caused by distinction of factors that determine the fluency of a certain syllogistic reasoning process. Johnson-Laird et al.,¹⁶ explained that there were three views of syllogistic reasoning. First, syllogistic reasoning is heavily determined by the understanding of inferential mechanism. Second, the success of certain syllogistic reasoning is determined by the understanding of specific rules on reasoning content or materials. In this case, this view focuses on the material requirements of particular reasoning. Someone will be able to deduce correctly if the material learnt is understood. Third, the success of certain reasoning process depends heavily on the

semantic procedure to interpret. An individual can draw a valid conclusion if the semantic meaning of the given syllogistic claims is understood. The correctness of a certain syllogistic reasoning is determined by formal and material provisions. The formal provision is related to the correct syllogism patterns while the material provision is related to the proposition correctness proposed. The proposition given as the antecedent should be correct so that it can produce proper conclusions. Many people might feel difficult in constructing an initial mental model to raise the proposition. The main difficulty in constructing the initial mental model is organizing the valid proposition. Proposition is a connection between concepts having semantic meaning. The mistakes occurred in syllogistic reasoning process are mainly caused by cognitive bias. The cognitive bias will influence the raised proposition validity.

Studies related to the structure of syllogism reasoning in sense of science and biology learning are rarely conducted in Indonesia especially in Mollucas. A reasoning skill is extremely needed by students for it is the most important part of human's intelligence system and as the core of many scientific thinking forms such as critical thinking, creative thinking, arguing, problem-solving, and decision-making. Besides, studies of the structure of syllogism reasoning in the world are frequently conducted quantitatively, yet detail discussion in qualitative way is not commonly done. Hence, it is needed a comprehensive study to discuss syllogism reasoning and cognitive bias phenomena of senior high school students in Ambon. Through a proper study, the empowerment effort of syllogistic reasoning in learning might be more comprehensive.

2. Method

2.1 Subject of the Study

The data of the present study were senior high school students chosen randomly out of 5 upper secondary schools in Ambon. There were 4 students from each school used as the subjects of the study. Thus, there were total 20 students used as the subjects of the study. The subjects of the study were eleventh grade students enrolling in science classes who were never been taught syllogism reasoning before. The age of the study subjects were about 15-16 years old theoretically being at formal reasoning level.

2.2 Data Collection Procedure

The data of syllogism reasoning were obtained through 2 data collection techniques, namely written test and interview. The material used in the written test of syllogism reasoning was biology material taught to both tenth grade and twelfth grade students. In the written test, the subjects of the study were given test items in form of syllogism presented in Table 1.

Table 1. The items of syllogism reasoning test

Sl. No.	Major Premises	Minor Premises	Conclusions
1	DNA lies in the cell nucleus	A prokaryote cell does not possess nuclei	A prokaryote cell possesses DNA
2	Plants need sun light to conduct photosynthesis	<i>Lamun</i> plants can grow in sea water until 20 m depth	<i>Lamun</i> plants do not need sun light
3	The deeper the sea, the colder the water	Echinodermata creatures do not live in deep sea	Echinoderma-ta creatures cannot live in low tempera-ture
4	All plants cannot live in high salini-ty areas	<i>Lamun</i> plants can live in sea water	<i>Lamun</i> plants can survive in a high salinity environment
5	Energy moves from one tropic level to another tropic level	A sea anemone eats lamun leaves detritus	A sea anem-one has more energy

The subjects were asked to write an analysis on a piece of paper sheet. After that, the subjects of the study were interviewed by the researchers. An in depth interview process was conducted by delivering questions related to explanations that need further clarification.

2.3 Data Analysis

The data obtained from the essay test written by the students while analysing the given syllogisms were interpreted qualitatively in order to obtain meanings based on the focus of the study. The students' answers were analysed by entangling the syllogistic pattern contained. The analysis process of syllogistic reasoning structure was referred to the syllogistic guides stated by Markovits and Barrouillet as follow:

- If P, then Q
- Q is correct
- Therefore, P is correct⁸

Beside seeing the structure of the syllogistic reasoning, the researchers also describe the syllogistic reasoning stages based on the interview. The interview conducted was restricted only on syllogism of the existence of DNA in prokaryotic cells. The syllogistic reasoning was analysed based on Bara et al.,¹¹ statement which consists of 3 stages, namely: First, a reasoner constructs a mental model of a premise by making a more explicit number of minimum information. Second, a reasoner uses this model to draw conclusions showing a relationship which is not mentioned by the premises. Third, in order to test the validity, a reasoner will find an alternative model from the premises which reiterate the conclusions or widen the initial model to be more explicit.

3. Findings and Discussions

3.1 The Syllogistic Reasoning

3.1.1 Pattern 1

The researcher carried out interview to examine the syllogism and mental model process used by the informants in reasoning the existence of DNA in prokaryote cells. The validity of the stated syllogism should meet the formal requirement in the sense of the structure and the material requirement in the sense of the learning materials. The description of the reasoning pattern of the informant DN can be seen clearly in Table 2.

Table 2. The syllogism structure of the informant DN

Syllogism Structure	Syllogism	Type
Major premis	Each cell has DNA., DNA is located inside of <i>nuclei</i> ,	Conditional syllogism
Minor premis	Prokaryotic cells pos-sess <i>nucleus</i>	Ponens modus
Conclusion	Automatically, the prokaryote cell <i>nucle-us</i> contain DNA	

The informants used 3 proposition in the syllogism process, namely major premise, which is universal that each cell has DNA contained inside the nucleus, and minor premise telling that prokaryote cells have nucleus. Based on those two premises, the informants deduced that automatically there is DNA contained inside the nucleus. The informants made the syllogism by using a major term, that is nucleus, which appears in the minor premise and the conclusion. The informants perceived

the nucleus as the universal term possessed by each cell. Regarding the universal term, the informants stated too that prokaryote cells had nucleus so that the DNA lied inside the prokaryote cells' nucleus automatically.

Based on the mapping of the syllogism structure in Table 2, it can be said that the syllogism stated by the DN meet the formal requirement, related to the syllogism structure and also material requirement, supporting the truth of each premise. The major premise is valid since basically a prokaryote cell does not have any nuclei membranes yet it has a certain structure like nuclei called nucleoid containing DNA. A prokaryote cell does not have a real nuclei yet the DNA is covered in a structure called nucleoid. The following excerpt is the interview result with informant DN.

- Researcher : Do you think a prokaryotic cell does not have nucleus? Please elaborate.
- DN : A prokaryotic cell does have a nucleus yet it does not have a nuclear membrane. The nucleus associate with cytoplasm so several literatures mention that a prokaryotic cell does not have a nucleus while in fact it does have a nucleus.
- Researcher : So, what do you think? Does it have a nucleus?
- DN : Yes, I think it does possess a nucleus.
- Researcher : Does a prokaryotic cell possess DNA?
- DN : Each cell has DNA. The DNA is located inside the cell itself. Since a prokaryotic cell has a nucleus then it must have DNA inside the nucleus.

The interview excerpt shows that before constructing a syllogism, the informant interpret the major premise truth said. According to the informant, a prokaryote cell does have a nucleus yet it does not have a nuclear membrane. The nucleus associates with adheres to cytoplasm so several literatures mention that a prokaryotic cell does not have a nuclei. Based on this initial interpretation the informant create a syllogism saying that a prokaryote cell does possess DNA inside the nucleus.

In the next syllogism, the informant exhibit different response. The informant gave a short answer and different conclusion method. The informant did not provide syllogistic explanation instead contrary concluding principle. The reasoning description of the informant DN can be clearly seen in Table 3.

Table 3. The syllogism structure of the informant DN

Response	Reason	Type of Concluding
Incorrect conclusion	Because all plants need sun light to conduct photosynthesis	Contrary (if A is correct, the E is incorrect)

The informant analysed the propositions truth used as the major and minor premises as well as decided that by using *tolensmodus* the stated conclusion was incorrect. The reason stated is that all plants need sun light to conduct photosynthesis. The response shows that the informant know well that the role of sun light for plants. Therefore, the informant answered that the conclusion was not suitable with the given premises and thus it was wrong. Moreover, when the informant was given a syllogism related to the impact of temperature on Echinodermata, the informant provided answer in similar pattern. The response was shorter and only provided resistance based on the incorrect proposition. The reasoning pattern of the informant DN is presented in Table 4.

Table 4. The syllogism structure of the informant DN

Response	Reason	Type of Concluding
Incorrect minor premise	Since Echinodermata cannot live in low temperature areas	Contrary (if A is correct, then E is incorrect)

The informant provided response that the minor premise was incorrect since "Echinodermata could not live in low temperature areas". The informant did not provide the proper explanation related to the response, instead the informant changed the proposition of the minor premise to a conclusion. In the next syllogism, the informant still used the same concluding pattern, namely providing resistance. In the syllogism related to the effect of salinity on plants, the informant provided response even shorter and only provided the resistance based on of the wrong proposition. The description of the reasoning pattern of the informant DN is presented in Table 5.

Table 5. The syllogism structure of the informant DN

Response	Reason	Type of Concluding
Incorrect major premise	Since <i>lamun</i> plants live in sea with high salinity level	Contrary (if A is correct, then E is incorrect)

The informant argued that the major premise was

incorrect since *lamun* plants lived in sea with high salinity level. The informant did not provide detail reasons related to why *lamun* plants could live in a high salinity environment. The informant only used contrary reasoning as a concluding method. The similar pattern can also be found in a syllogism of energy movement in Table 6.

Table 6. The syllogism structure of the informant DN

Response	Reason	Type of Concluding
All are correct	Since a sea anemone eats the <i>lamun</i> leave detritus, the tropic moves to other level.	-

The informant provided response that all proposition given in both the premises and the conclusion were correct. The explanation stated by the informant showed neither the syllogism pattern nor a particular conclusion. The response stated did not describe the purpose of the syllogism related to the presence of the higher energy in *lamun* plants or sea anemones as well. The informant only stated that there was an energy movement when a sea anemone eated *lamun* leave detritus.

3.1.2 Pattern 2

The phenomena of concluding pattern of the informant DN seemed different from that of informant GL. The informant GL provided explanations showing the syllogism pattern well formally yet based on the material requirement the explanation could not besaid as valid. The description of the reasoning pattern of the informant GL can be seen in Table 7.

The informant used 3 propositions in the syllogism process, namely major premise which was universal in nature that DNA was located inside nucleus. Minor premise stated that prokaryotic cells did not have nucleus. Based on the two mentioned premises, the informant concluded that DNA was not contained in prokaryotic cells. The informant made the syllogism by using major term namely nucleus, which also appeared in the minor premise and the conclusion. The informant

Table 7. The syllogism structure of the informant GL

Syllogism Structure	Syllogism	Type
Major premis	DNA is located inside nucleus	Conditional syllogism Ponens modus
Minor premise	Prokaryotic cells do not have nucleus, yet only have nuclear membranes	
Conclusion	Therefore, DNA is not contained in a prokaryotic cell since they do not have <i>nucleus</i>	

made the nucleus as the universal term containing DNA. Considering the universal term, the informant added that the prokaryote cells did not have any nucleus so that automatically, DNA was not contained in a prokaryotic cell. Furthermore, the researcher conducted an interview to the informants to know further their understanding or the existing mental model of the informant memory related to prokaryote cells and DNA. The following excerpt is the mental model illustration used by the informant GL in reasoning the existence of DNA in prokaryote cells.

- Researcher : Does a prokaryotic organism have no DNA? Please elaborate.
- GL : Every nucleus has DNA, while a prokaryotic cell has only a nuclear membrane not a nucleus, therefore DNA is not contained in a prokaryotic cell.
- Researcher : What is the difference of prokaryotic and eukaryotic cells?
- GL : An eukaryotic cell has pseudo nucleus since it has a nuclear membrane. Whereas a prokaryotic cell does not have a nucleus yet it has a nuclear membrane.
- Researcher : If I say that a prokaryotic cell does not have a nucleus yet it has DNA. What is your opinion?
- GL : I think a prokaryotic cell does not have a nucleus and thus it neither has DNA
- Researcher : Does every living thing have DNA?
- GL : Of course, every living thing has DNA, and DNA carries the genetic material.
- Researcher : Is a prokaryotic cell a living thing?
- GL : Yes, blue green algae and bacteria are two examples of prokaryotic organisms
- Researcher : If a prokaryotic cell is a living thing, does it have DNA?
- GL : I think it still does not have DNA,.

The mental model illustrated in the above excerpt revealed that the informant did not have proper knowledge related to the structure of prokaryotic cells.

The informant did not interpret the given premise within the questions but kept reiterating the syllogism. The informant knew that all living things had DNA since it bequeathed the characteristics to the new generations and prokaryotic organism was one of living things. The informant mentioned two groups of prokaryotic organisms, blue green algae and bacteria. However, the informant kept on his/her stance that a prokaryotic cell did not have DNA. The informant seemed showing reasoning bias by omitting the other existed facts in the structure of knowledge and accepting the syllogism given in the questions. The difficulty of the syllogistic reasoning the informant had is that the informant could not confirm the given premise truth based on his/her knowledge. If the informant knew that all living things had DNA and a prokaryotic cell belonged to living things, then it should also possess DNA. The difficulty of the syllogistic reasoning process the informant GL had is the incapability to interpret the meaning of the given premise in the questions.

In the next syllogisms, the informant GL provided some explanations that showed particular patterns of conclusion. In the syllogism related to the effect of sun light to *lamun* plants, the informant raised a syllogism stating that the given conclusion in the statement was incorrect. The description of the reasoning pattern of the informant GL can be seen in Table 8.

Table 8. The syllogism structure of the informant GL

Syllogism Structure	Syllogism	Type
Major premis	All plants either on land or in sea conduct photosynthesis	Condi- tional syllogism
Minor premis	Photosynthesis process needs sun light	Ponens modus
Conclusion	Therefore, <i>lamun</i> plants need sun light	

Table 9. The syllogism structure of the informant GL

Syllogism Structure	Syllogism	Type
Major premise	The deeper the sea, the colder the water	Conditional syllogism
Minor premise	Echinodermata do not live in deep sea	Ponens modus
Conclusion	Echinodermata cannot live in low temperature environment	

The informant GL raised a universal proposition that all plants, either on land or in sea depend heavily on sun light to conduct photosynthesis. It is the basic knowledge to draw a conclusion that a conclusion stating *lamun* plants do not need sun light is wrong. The similar pattern can be seen in the syllogism related to the effect of temperature on Echinodermata shown in Table 9.

In the next syllogism related to the effect of temperature on Echinodermata, the informant also used ponem modus conclusion pattern to explain that the deeper the sea, the lower the temperature. The informant argued that all propositions in the questions were correct. The informant understood that the given syllogisms were valid both formally and materially. In the next syllogism related to the effect of salinity on plants, the informant also showed that the explanation used ponem modus. The description of the reasoning pattern of the informant GL can be seen in Table 10.

Table 10. The syllogism structure of the informant GL

Syllogism structure	Syllogism	Type
Major premise	Most plants will die in a high salinity environment	Condi- tional syllogism
Minor premise	<i>Lamun</i> plants can reduce the high salinity	Tolen modus
Conclusion	<i>Lamun</i> plants can survive in a high salinity environment	

The informant draw a conclusion that all the given syllogism related to the effect of salinity on plant were correct. The informant provided an explanation that the higher salinity, the more plants might die, yet *lamun* plants could survive since they could lower the high salinity. This syllogism pattern is very different from the syllogism pattern of energy flow. The informant provided a non-valid explanation related to the energy flow. The description of the reasoning pattern of the informant GL is presented in Table 11.

Table 11. The syllogism structure of the informant GL

Syllogism Structure	Syllogism	Type
Major premise	A sea anemone eats <i>lamun</i> leave detritus	Conditional syllogism
Minor premise	A sea anemone needs more energy so it eats <i>lamun</i> leave detritus	Modus Ponem
Conclusion	More energy contains in a sea anemone	

The informant explained that a sea anemone needed more energy so it eats *lamun* leaves detritus. This is not in line with the concept of the energy flow that a certain organism eats another organism to fulfil its energy need. Hence, it seemed that the informant misinterpreted the meaning and the purpose of the given syllogism.

3.1.3 Pattern 3

A different pattern also can be seen in the explanation stated by IM, a student of Siwalima Senior High School Ambon. The informant IM provided some explanations that showed good syllogism patterns formally, yet the material requirement of the explanations was not valid. The description of the reasoning pattern of the informant IM can be seen in Table 12.

Table 12. The syllogism structure of the informant IM

Syllogism Structure	Syllogism	Type
Major premise	DNA is a genetic material carrier	Condition- Tolens- al syllogism modus
Minor premise	It is impossible that a prokaryotic cell does not have DNA	
Conclusion	A prokaryotic cell must have DNA even though there is no nucleus	

The informant used three propositions in the syllogism process, namely major premise which was universal that DNA was genetic material carrier. It seemed that the informant started the syllogism by defining that DNA was genetic material carrier. Based on the definition, the informant stated the positive minor premise that it was impossible that a prokaryotic cell did not have DNA. Considering that premise, the informant concluded that a prokaryotic cell must have DNA even though there was no nucleus. The following excerpt is the mental model illustration used by the informant IM in reasoning the existence of DNA in a prokaryotic cell.

- Researcher : Does prokaryotic cells do not have DNA? Please elaborate.
- IM : I am not sure, but it is impossible that prokaryotic cells do not have DNA because DNA is genetic material carrier. Prokaryotic cells must have DNA even though there are no nuclei
- Researcher : Prokaryotic cells do not have nuclei, so where can the DNA be found in prokaryotic cells?
- IM : I think prokaryotic cells do have nuclei
- Researcher : Given prokaryotic cells do not have nuclei, do it have DNA?
- IM : Prokaryotic cells stills have DNA

The mental model illustration seen in the above excerpt is the simple model. However, the above excerpt shows that the informant interpret the premise truth in the given syllogism by making a universal proposition saying that DNA is genetic material carrier, so it is impossible that prokaryote cells do not have DNA. It seems too that the informant IM also did not have a proper mental model related to prokaryote cell structure. The informant’s reasoning was based only on the universal term saying that DNA was genetic carrier which should be possessed by all living things, not excluding prokaryote cells.

In the next syllogism, the informant reiterated the syllogism of the given item. The informant used premises in the syllogism to negate the proposition that all plants needed sun light to conduct photosynthesis. The informant argued that *lamun* plants living in 20 m under the sea water surface without any sun light, verified that not all plants needed sun light to conduct photosynthesis. The description of the reasoning pattern of the informant IM is clearly presented in Table 13.

Table 13. The syllogism structure of the informant IM

Syllogism Structure	Syllogism	Type
Major premise	<i>Lamun</i> plants can live in 20 m undersea water surface	Condition- Tolens- al syllogism modus
Minor premise	There is no light in 20 m under sea water surface	
Conclusion	Not all plants need sun light to conduct photosynthesis	

The above statement of the informant IM showed a syllogism patter of tolens modus. It means that the formal requirement of the statement is valid. However, the material requirement of the statement cannot be considered as valid. The presence of *lamun* plants in 20 m under sea water is not related to the absence of sun light. The sun light still reaches the bottom of the sea. Regarding

the explanation in the syllogism of the effect of temperature on Echinodermata, the informant deduced that statement B was wrong. The description of the reasoning pattern of the informant IM is pictured in Table 14.

Table 14. The syllogism structure of the informant IM

Syllogism Structure	Syllogism	Type
Major premise	The deeper the water, the colder the environment	Conditional syllogism
Minor premise	Echinodermata are impossible to live in deep sea water	Ponen modus
Conclusion	Echinodermata cannot live in low temperature	

The informant thought that the deeper the sea water the colder the temperature. Therefore, Echinodermata might not live in a low temperature environment. The informant used ponen modus pattern to explain the effect of temperature on Echinodermata phenomena. A different pattern was used to explain the syllogism related to the effect of salinity on plantation. Table 15 describes the reasoning pattern of the informant IM.

Table 15. The syllogism structure of the informant IM

Response	Reason	Type of Concluding
The major premise is incorrect	Since not all plants cannot live in a high salinity environment, such as <i>lamun</i> and sea weed	Contrary (If A is correct, then E is incorrect)

The informant claimed that the major premise is wrong. Thus, he/she claimed that there was any group of plants that could live in a high salinity environment. The informant used contrary concluding pattern to state that a particular plant might survive in a high salinity environment. In the next syllogism, the informant deduced that all proposition given were valid. The informant affirmed it by explaining that consumers might get more energy. The reasoning pattern of the informant IM can be seen in Table 16.

Table 16. The syllogism structure of the informant IM

Response	Reason	Type of Concluding
All are correct	Since the real energy flow occurs when the eaters get more energy	-

Based on the results of the qualitative data analysis

stated before there are different syllogistic reasoning patterns on each subjects studied. The analysis result on pattern 1 shows that the syllogistic reasoning process was begun with an interpretation. This pattern is in line with a syllogistic reasoning pattern proposed by¹¹ saying that is the key stages of a syllogistic reasoning is an interpretation of premises, formulation and validity test. Johnson-Laird et al.,¹⁶ stated that a reasoning depended heavily on the conclusion rules, specific rules, and semantic procedures. The premises interpretation involves the activation of an individual existing long term memory and mental model^{11,13}. The meaning interpretation and proposition validity involve a linguistic ability. Polk and Newell verified that a linguistic process in a codification and recoding activities was a core of deduction¹⁷. If the reasoner has a well-structured mental model, the explanation will be more comprehensive, vice versa. It is different from the pattern 1, the responses delivered by subject 2 on pattern 2 show an invalid syllogism process materially. The informant accepted the propositions as an apriori without interpreting the truth. Formally, the syllogism process stated by informant in pattern 2 is correct, yet the mistake lies on the material requirement stating that one or two out of the three proposition is/are invalid. If the antecedent of a certain proposition is invalid, the conclusion inferred is also invalid. The syllogism process on pattern 3 is different from the two previous patterns; it looks very simple. The informant provided explanations showing a good syllogism pattern formally yet the material requirement of the explanation could not be considered as valid. The findings of this study show that the syllogistic reasoning should be viewed from both the formal and material requirements. The formal requirement of a syllogistic reasoning is an individual should be able to demonstrate syllogistic reasoning appropriately and utilize the accurate propositions materially¹⁰. The findings of this study confirm that the subjects of the study commonly understand and are able to utilize the syllogistic reasoning well. The difficulties faced by the informants occurred in relation to material requirement, that is the proposition truth used as the antecedent to emerge the consequences. Materially, if the correctness of the antecedent proposition cannot be proven then the consequence might also be invalid, vice versa¹⁸.

The findings of this study also confirm that a syllogism reasoning is an inherent part of the development of human's thinking order. Various references in the field of cognitive psychology mention that an individual

might reach formal reasoning level when he/she can demonstrate a syllogistic reasoning well. According to¹⁹, when we assume that a Hipotetico Deductive reasoning pattern has been possessed by people since they were born, then the development of intellectual including an awareness development of well reasoning and reflection will improve in sense of where the patterns are possible to be implemented. Hamill²⁰ suggested that a logic competence was inherited by a person since birth, therefore it was claimed that there was no a single human that ever made errors in logic. This opinion is different from Wetherick and Gilhooly's argument saying that a person was not trained to have a little or even no competence in creating a syllogism conclusion²¹. Bara et al.,¹¹ stated that an individual who has never been taught in logic might comprehend the basic principles of validity, yet not always was able in creating a valid deduction. Another study by Kwon et al.,²² found that the maturity of lobus prefrontal was associated to the enhancement of the relational reasoning ability.

The results of the analysis reveal that each pattern indicates similar phenomena that a syllogistic reasoning is influenced by material comprehension. Carey²³ claimed that an intellectual development did not depend on the structural change of a mental architecture rather on a knowledge acquisition. The informants could answer one of the items given well, yet felt difficulties in others. The subjects are difficult in providing syllogistic explanation for items number 2 to 5. These difficulties are caused mostly by the lack of understanding of the material analysed. This phenomenon is in line with the mental model theory proposed¹³. This study also verifies^{24,25} findings saying that the difficulty in syllogistic reasoning was caused by the lack of mental model of material analysed. Cordero and Labra

argued that the key weakness of mental model theory was the failure to decide how any one found an alternative explanation to draw a conclusion in syllogism²⁶. The mental model is closely related to a knowledge structure of a person to make an abstraction of a particular object or phenomenon. A working memory might make a mental model to recognize a particular object or phenomenon confronted^{25,27,28}. Children and adults might build a mental model to recognize a certain phenomenon^{13,29}. A child's mental model may be built based on a concrete experience and is very limited yet well-structured (theory)^{30,31}. The success of an abstraction process extremely depends on the number and the structure of a mental model delivered by the working memory²⁸. During the reasoning process, a mental model is needed when a reasoner construct a semantic interpretation of the proposition raised. A meaning interpretation is a linguistic process related to a codification and recoding activities. The process is the core of the overall series of deductive reasoning¹⁷. The meaning interpretation will determine the material validity of the proposition raised in the syllogistic reasoning process. The findings of the present study also confirm that even the subjects not taught before can deliver their argument by using syllogistic reasoning. It is in line with Johnson-Laird¹³ statement saying that an unexercised person can use his/her deductive logic well.

3.2 The Cognitive Bias

A cognitive bias is a pure deficiency or limitedness of mind or a judgment weakness caused by a memory error, a social attribution, and a miscalculation (such as a statistical mistake or a mistake in the sense of probability). A cognitive bias is generally called as the main source of mistakes in reasoning. A memory limitedness frequently

- Researcher : Does a prokaryotic cell have DNA? Please elaborate.
 HAH : A prokaryotic cell does not have a nucleus so it does not have DNA.
 Researcher : Do every living thing have DNA?
 HAH : I think DNA is only for human, animal, and plant.
 Researcher : Is a prokaryotic cell a living thing?
 HAH : No, it is not.
 Researcher : What is the difference between a prokaryotic and eukaryotic cell?
 HAH : A prokaryotic cell does not have a nucleus and a eukaryotic cell has a nucleus.
 Researcher : If I say that a prokaryotic cell has DNA even though it does not have a nucleus because its DNA is spread out in its cytoplasm? What do you think?
 HAH : That's impossible. Based on the literature I read, DNA is located in a nucleus so I don't think that a prokaryotic cell has DNA since it does not have a nucleus.

occurs during the proposition revelation used in the syllogistic reasoning. In the present study, the researcher has conducted an interview to examine the mistakes in students' syllogistic reasoning and the cognitive bias factors accompanying it. The following description is the interview excerpt of an informant HAH, a student of Islamic Senior High I School Ambon related to the existence of DNA in a prokaryotic cell.

The above excerpt shows that the informant creates a syllogism that a prokaryotic cell does not have DNA for it does not have a nucleus. The informant made an error in his/her syllogistic reasoning due to the improper cognitive structure of either a prokaryotic cell structure or a cell genetic. Based on the excerpt, the informant knows that the difference between a prokaryotic and a eukaryotic cells is in the existence of a nucleus. The basic premise used to draw a conclusion is that a prokaryotic cell does not have a nucleus. Although the informant had been told that a prokaryotic cell's DNA is located in its cytoplasm, yet it was ignored. The informant kept arguing that DNA is only located in a nucleus while RNA is located within cytoplasm. In the previous part, the informant also mentioned that DNA was only possessed by human, animal, and plant, while a prokaryotic cell does not belong to living thing. Therefore, these reasons make the informant to conclude that a prokaryotic cell does not have DNA.

The above excerpt shows that the informant accepted the minor premise that "DNA is located in a nucleus" and the conclusion that "A prokaryotic cell does not have DNA" without trying to interpret the meaning and the validity of the premises in the syllogism. Even though the researcher has led the informant's understanding to

another fact that a prokaryotic cell also has DNA inside its cytoplasm, the informant omitted the given fact. It indicates that there is a cognitive bias named confirmation bias. The informant does not confirm the fact that a prokaryotic cell also has DNA inside its cytoplasm.

Similarly, the same syllogism reasoning pattern was also stated by JL, a students of Senior High School 10 Ambon. The following is the excerpt of the interview.

The above excerpt shows that the informant used an invalid mental model syllogistic reasoning. The mistake in the syllogistic reasoning happened because the informant accepted the given proposition within the questions without analysing whether the major and the minor premises stated as the supported conclusion are correct and based on the material requirement or not. The above excerpt shows too that the informant knows that a prokaryotic cell does not have a nucleus and an eukaryotic cell has a nucleus. The informant also knows that all living things must have DNA and prokaryotic organisms belong to living things. Even though contrary facts have been given to the informant as well as the informant possessed a mental model of characteristics of living things, he/she kept mentioning that a prokaryotic cell did not have DNA since it did not have a nucleus. The interview excerpt shows that the informant accepts the minor premise that "DNA is located in a nucleus" and the conclusion that "A prokaryotic cell does not have DNA" without trying to interpret the meaning and the validity of the premises in the syllogism. Even though the researcher has led the informant's understanding to another fact that a prokaryotic cell also had DNA inside its cytoplasm, the informant omitted the given fact. It indicates that there is a cognitive bias named confirmation bias. The informant

- Researcher : Does a prokaryotic cell have DNA? Please elaborate.
 JL : A prokaryotic cell does not have a nucleus so it does not have DNA.
 Researcher : What is the difference between a prokaryotic and eukaryotic cell?
 JL : A prokaryotic cell does not have a nucleus and an eukaryotic cell has a nucleus.
 Researcher : Do every living things have DNA?
 JL : I think all of living things have DNA except virus (it only has either DNA or RNA).
 Researcher : Are prokaryotic organisms living things?
 JL : Yes, prokaryotic organisms are living things.
 Researcher : So, does a prokaryotic cell have DNA?
 JL : No since a prokaryotic cell does not have a nuclear membrane.
 Researcher : So, what's your conclusion?
 JL : The conclusion is a prokaryotic cell does not have a nucleus so it does not have DNA since DNA is located in a nuclear membrane.

did not confirm the fact that a prokaryotic cell had DNA since it was a part of living things. The informant also could not link the existed mental model and the syllogism process analysed.

The errors in the syllogism reasoning process are mostly caused by the errors in the cognitive structure or caused by is a cognitive bias. The responses analysis stated by the subjects during the interview showed that the difficulty in the syllogistic reasoning was related to the incapability in confirming the proposition truth within the mental model questions given. Basically, the informants did not confirm the knowledge when they were given contradictive new facts and found other possible information, rather than focussed on the accepted propositions before as an apriori. Evans et al.,¹⁸ stated that one of factors influenceing the syllogism reasoning related to the initial knowledge phenomenon was belief bias. An initial knowledge often acts as a key factor causing bias in a scientific reasoning³². Thomson and Samboangga explained that an initial knowledge was an incomplete knowledge and might contribute misunderstanding, but it often acted as an inhibition factor in obtaining new information³³. Many students use their initial knowledge in a concluding process.

An initial knowledge also often shifts into a belief called Epistemological belief which tends to be used by students when they have to face improper evidences. It can be seen from a study conducted by Chinn and Brewer that any one tends to keep his/her previous belief by ignoring or distorting the improper evidences³⁴. A thinking process might be more effective if a person can evaluate the validity of the initial knowledge or belief³⁵. According to⁷ the essence of a scientific reasoning is the coordination between theories and evidences. Skills involved in the coordination process occurred between theories and evidence are recalled coding and representing processes. It means that a scientific reasoner will try to find the differences between theories and evidences or find and construct a particular connection model between theories and evidences. The success of this process relies heavily on the ability to see any possibilities of other explanation and evidence inconsistencies. In addition, there is a cognitive base difference of a scientific reasoning between a child and a scientist. Hogan and Maglienti stated that a scientist tended to evaluate knowledge based on data while a student or non-scientist one tended to use his/her personal opinion³⁶. A child and a non-scientist adult also often use their intuition and epistemological

belief in reasoning so it might cause bias in reasoning³². Khun³⁷ found that students and non-scientist adults might distort the improper experimental findings to fit their own hypotheses or theories. Khun et al.,³⁸ mentioned the evidences distorting process in order to fit with the existed theories as “faulty scientific thinking”.

4. Conclusions

Regarding the results of the data analysis and the discussions, it can be concluded that: Syllogism reasoning is an inherent part of human's thinking level development. It is based on the data that the subjects of the study, senior high school students in Ambon, can utilize valid syllogism reasoning patterns formally without being taught before. The fluency of syllogism reasoning depends heavily on the comprehensive understanding of material being analysed. If the understanding of a particular material has been constructed within a complex mental model, the reasoners will be able to draw conclusions. The valid reasoning process is mostly begun by interpreting the meaning and truth of premises. In interpreting, the subjects utilized the existing mental model or knowledge structure related to the materials analysed. The success in interpreting premises determines the validity of the conclusions. In the other words, if the premises are correct, the conclusions will also be correct. The cognitive bias following the syllogistic reasoning is called confirmation bias. A reasoner might accept the premises truth as an apriori without confirming the existing mental model or the prior knowledge structure.

5. References

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