Empowerment Scientific Reasoning in Science Learning for Junior High School Students in Ambon City

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Abstract
Awareness of the importance of scientific reasoning as the main goal of science learning is increasing. This increase is indicated by increasing research in the field of psychology and education on scientific reasoning over the past decade. Scientific reasoning skills are considered very important for a person to be able to adapt to an environment that is increasingly filled with complex problems. In addition, scientific reasoning is also an essential skill in encouraging science literacy. Reasoning is the most essential and essential in everyday knowledge. Reasoning is useful for evaluating arguments, testing hypotheses, gather evidence, make inferences and make decisions in everyday life. Research has been done to see the reasoning process in junior high school students in Ambon City. This research uses the type of qualitative research with phenomenology approach to describe the quality of junior high school students' reasoning in science learning. The data in this study were collected using the written test technique. This study concludes that (1) reasoning occurs when a person is able to create a mental model that is compatible with reality. (2) The reasoning skills a person possesses when birth and the development of reasoning are also influenced by the development of knowledge. (3) The structure of knowledge depends on the working memory capacity to understand the verbal meaning of a concept and relate it to other concepts.

Keywords: scientific reasoning; science learning; junior high school

Introduction
Reasoning is the most essential and essential in everyday knowledge. Reasoning is useful for evaluating arguments, testing hypotheses, gather evidence, make inferences and make decisions in everyday life (Metallidou et al., 2012). Simply put, Etkina et al., (2006) uses the term hypothetico-deductive as the equivalent of scientific reasoning defined as an understanding of the difference between hypothesis and prediction. A hypothesis is a general explanation and a prediction is a description of an experimental result that should occur if the hypothesis proves true. Lawson et al., (2000) tend to define scientific reasoning as a process that includes stages in scientific investigation. According to him, scientific reasoning is a skill to express and test hypotheses that are characteristic of scientific investigation. From that sense, Lawson then called scientific reasoning as hypothetico-deductive reasoning. Reasoning is the most essential and essential in everyday knowledge.

Students who have good reasoning will easily be able to change the initial conception before learning well. Park & Han (2002) also concluded that deductive reasoning has an important role in conceptual change. There is early research evidence that has found involvement of scientific reasoning in encouraging conceptual change. Lawson & Worsnop's (2003) study in Liao & She (2009) found that high school students with good reasoning tended not to maintain an early conception before learning about evolution and creation. Scientific reasoning is an important skill for students to have. This is almost seen from the opinions expressed by Silk (2009), Eskin & Bekirodu (2009), Lawson (2010), Zeinnedin & Khalik (2008). They explain that one of the objectives of science learning in the era of technological and information development is to help to reason rationally or scientific reasoning and be able to communicate his knowledge to others.

In the last few decades, studies that explain the phenomenon of reasoning in humans elicit the opposite conception. The mental theory of logic and mental models are two different views about the process of penalarna in humans. Thesis: the reasoning determined is the mastery of the inference mechanism. This theory is better known as mental logic or mental logic. The mental-logic-theory emphasizes that the reasoner has
knowledge of the meaning of a logical and language term and uses that knowledge to construct or find alternative scenarios. Thus, the internal representation provides a structural form of the conditions stated in the proposition (Goel et al., 2000). Therefore, reasoning difficulties are caused more by two factors: (1) the number of rules used to reach the conclusion, and (2) the complexity of applying each rule. That is, a person is able to reason well if able to master the various rules of reasoning. Antithesis: reasoning is determined by the ability to construct a mental model. This theory is better known as mental model. Model mental theory emphasizes more on the assumption that the ability to construct and manipulate mental models (Johnson-Laird, 1983; Johnson-Laird & Byrne, 1991). This theory consists of 3 important stages of model construction, abstraction of temporary conclusions and apply it to a certain condition. This dialectical position requires a more comprehensive study to prove the truth of the assertions of each theory.

Research on the development of scientific reasoning, especially in science learning is still very rare in Indonesia, including in Maluku. The process of learning science tends to be done by requiring students memorize facts or concepts of science. As a result, there is a wide disparity between science as a concept and a real-life context. Students can not apply these concepts in the context of everyday life. Learning science should be able to develop thinking ability high level. The emphasis of learning on scientific reasoning will trigger students to understand science in depth. The search for information relating to scientific reasoning further mentions empowerment through the application of learning strategies. Research related to mapping and characterizing the development of reasoning scientific has not been done. Thus, comprehensive research is needed to reveal scientific reasoning skills in primary school students.

Based on the descriptions presented above, the urgency of this research are: 1) The importance of doing scientific quality reasoning study on junior high school students in science learning.(2) The need for research to reveal students' cognitive arithmetic in scientific reasoning indicators.

Method

The research was designed qualitatively with phenomenology approach. In general, the research focus includes the cognitive architecture and the students’ scientific reasoning structure. The research focus is based on L. Lawson's argument (2003) that thinking is a process involving the manipulation of operational knowledge in the context of cognitive systems. Therefore, the scope of this study is to map the operational knowledge in the context of the cognitive system used by students to reason the given science phenomena. Subjects in this study were elementary students taken randomly from 4 junior high schools in Ambon City. From each school, 4 students were taken as research subjects. The subjects used in this study are grade V II students who have never been trained to use the rules of reasoning. The syllogistic reasoning data is obtained by using data collecting technique that is written test. The material used in the written test for reasoning is a science-learning material that has been taught to grade V II students. In a written test, the subject of the study was given the reasoning test listed in Table 1.

<table>
<thead>
<tr>
<th>No</th>
<th>Statement</th>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
</table>
| 1  | Phenomenon: A tubular aquarium. In the aquarium are placed several types of organisms such as fish, snails and aquatic plants. | What happens if the aquarium's mouth is closed so the air can not get in? | a. The organisms inside will remain alive  
b. The organisms in it live only briefly until the oxygen is depleted  
c. Organisms in it will die instantly  
**Why so:** |
| 2  | Statement A: Humans and animals breathe by taking O 2 and removing CO 2  
Statement B: Plants take CO 2 for photosynthesis  
Conclusion: The plant is not breathing | The A statement is incorrect  
Statement B is incorrect  
Incorrect conclusion  
Everything is correct  
All wrong | Please explain your answer choice: |

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3 **Statement**: Planaria is a type of worm that lives in clear water.

**Conclusion**: If the planaria is not in the sewer water, then ..........

**Answer**: a. The sewer water has been polluted
b. Planaria does not live in sewer water

**Why is that? Please explain!**

4 **Statement**
- One of the characteristics of living beings is to grow and develop
- Growth is a biological process that occurs in living things in the form of irreversible size changes.
- Plants will grow continuously throughout his life.

**Question**
Do humans and animals also grow throughout their lives?

**Answer**
- a. Yes
- b. No

**Why is that?**

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**Results and Discussion**

**Cognitive Architecture**

Analysis of students’ cognitive structure is needed to find out the cognitive systems students use when scientific reasoning. In this study, subjects were taken as many as 5 students in each school and only 2 students representing the subject of each school. The cognitive structure of students is analyzed through students’ argumentation of the given phenomenon. The following will explain the cognitive structure of reasoning in elementary school students. Analysis of cognitive structure is performed on scientific reasoning indicators. The following data exposure results cognitive structure analysis.

**Analyze Ability**

The ability to analyze is one of the indicators of scientific reasoning. Questions related to analytical skills are students confronted with the phenomenon of a tubular aquarium. In the aquarium are placed several types of organisms such as fish, snails and aquatic plants. After that, students are asked to do the survival analysis of living things when the cap aquarium is closed.
Table 2. The cognitive structure of FL informants

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Basic Unit</th>
<th>Organizing Principle</th>
<th>Inference Mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Answer</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. The organisms inside the aquarium live only for a moment until oxygen runs out</td>
<td>- Fish</td>
<td>- Habitat</td>
<td>- Air</td>
</tr>
<tr>
<td><strong>Reason</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Because fish and plants that live in the sea do not really need air, even though he is in a closed tank though.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Code:</strong> FL/MTs-N</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Cognitive Architecture**

![Causal Reasoning Diagram]

**Figure 1. The cognitive structure of FL informants**

Source: data processed

The result of mapping the cognitive structure of FL informants shows that the argumentation made with the basic unit is a concept consisting of 3 concepts, namely fish, habitat and air. The informant also organizes with causal argumentation patterns and the inference mechanism is predicted. The informant uses a pattern of causal reasoning to explain the phenomenon of organisms in a closed aquarium. The informant identifies the oxygen demand of the aquatic organism and proposes a conditional proposition to make a decision about the event to occur. The informant identifies that fish and plants that live at sea do not really need air. Therefore, the organism in the aquarium will live for a while until the oxygen is exhausted then the organisms will die.

**Indicator II (Making the Conclusion of 2 Premises)**

Making the conclusion of 2 premises is also one of the essential indicators of scientific reasoning. The ability to draw conclusions from two premises enables an individual to foresee events that will occur or bring up new concepts that have not existed before. In this study, has been tested to determine the ability to make conclusions and the following is the exposure of cognitive architecture.
Table 3. The cognitive structure of FL informants

<table>
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<tbody>
<tr>
<td>Answer</td>
<td>- Breathe</td>
<td>Concept</td>
<td>Complete the concept</td>
</tr>
<tr>
<td></td>
<td>- Stomata</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Lenticle</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Reason**

Because plants breathe through the stomata or the mouth of the leaf and also through the lenticel that is the mouth on the stem so that we can say that plants can also breathe.

**Code:** FL/MTs-NG

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**Cognitive Architecture**

![Diagram](https://via.placeholder.com/150)

**Figure 2. The cognitive structure of FL informants**

Source: data processed

The result of mapping the cognitive structure of FL informants shows that the argument made with the basic unit is a concept consisting of 3 concepts of breathing, stomata, and lenticel. The informant also organizes with grouping argument patterns and the inference mechanism is complete the concept. Informants first do or i entasi and explain the respiratory equipment in plants such as stomata and lenticel. After that the informant put forward the opposition's reasoning to make a decision about the respiratory pattern on the plant. The informant explained that plants can also breathe because they have stomata and lenticels.

**Making a Generalization of the Phenomenon**

The generalization of phenomena is one of the important scientific reasoning indicators. Generalization relates to the inductive reasoning of drawing universal conclusions from particular events. Here is an analysis of cognitive architecture of students in making generalizations.

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Table 4. The cognitive structure of FL informants

<table>
<thead>
<tr>
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<th>Inference Mechanism</th>
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</thead>
<tbody>
<tr>
<td>Answer a. Sewer water has been polluted</td>
<td>- Habitat planarian</td>
<td>Concept</td>
<td>Complete the concept</td>
</tr>
<tr>
<td></td>
<td>- Pollution</td>
<td>Grouping</td>
<td></td>
</tr>
</tbody>
</table>

Reason

Because planarian worms do not like dirty and polluted places, this is what makes these worms have been used as animals to detect contaminated areas, especially in sewer and river

Code: FL/MTs - NG

Cognitive Architecture

![Induction Reasoning Diagram]

Planarian

Habitat

Planarian does not like dirty places

 Been used as an animal to detect contaminated areas

Decision

Answer a. Sewer water has been polluted

Figure 3. The cognitive structure of FL informants

Source: data processed

The result of mapping the cognitive structure of FL informants shows that the argument made with the basic unit is a concept consisting of two concepts, namely planarian habitat and pollution. The informant also organizes with grouping argument patterns and the inference mechanism is complete the concept. The informant identifies the phenomenon that is the actual habitat of the planarian worm and suggests that the sewage water has been contaminated.

Analyzing And Correlating Two Similar Phenomena

Analyzing and correlating two similar phenomena is one of the scientific reasoning indicators. In this study, students are exposed to two similar phenomena and students are asked to analyze both phenomena and make conclusions. Here is an analysis of cognitive informant architecture related to the ability to analyze and correlate two similar phenomena.
Table 5. The cognitive structure of FL informants

<table>
<thead>
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<th>Inference Mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Answer</td>
<td>- Age of growth</td>
<td>Concept</td>
<td>Grouping</td>
</tr>
<tr>
<td>a. No Reason</td>
<td>- Cell activity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Because growth will stop at certain ages like humans, the growth period will stop if they are 40 or 50 years old. There, cells that function for growth will stop (die).

Code: FL/MTs - N

Cognitive Architecture

![Causal Reasoning Diagram](image)

Figure 4. The cognitive structure of FL informants

Source: data processed

The result of mapping the cognitive structure of the FL informant shows that the argument made with the base unit is a concept consisting of two concepts, namely growth age and cell activity. The informant also organizes with grouping argument patterns and the inference mechanism is complete the concept. The informant identifies that growth will stop at certain ages like humans, the growth period will stop if they are 40 or 50 years old. Therefore, the cells that function for growth will stop (die). Thus, humans do not experience continuous growth.

Phenomenon of reasoning in humans, until recently, is still controversial. There is a view that as a procedural skill, one must master the mechanisms of reasoning well. The argument is clear, mastering the procedure of making inference means being able to show a smooth process of reasoning. Reasoning seems
to be a very simple and alogarithmic skill. On the other hand, there is a sharply criticizing view of the inference mechanism. This conception poses the opposite view. Conceptual semantic mastery is more important for a person to reason well. The reason, reasoning would be easier to do if someone has a semantic structure relevant to reality. This study was conducted to examine in more detail the phenomenon of reasoning in humans.

Another part that is not less controversial is there is a difference in the pattern of reasoning in children and adults. On the one hand, there is a presumption that the development of reasoning in a person is influenced by biological factors. Maturity of parts of the brain is a good reasoning precondition. Several neurocognitive studies with brain imaging methods have been performed to validate the theory. On the other hand, there is the view that the development of reasoning can not happen automatically. Reasoning must be encouraged through rigorous learning in addition to high level cognitive motivation and control as another prerequisite. Reasoning is assumed to be the slowest growing type of thinking. Two opposite theories have been put forward with regard to the structure of human knowledge. The first position is that children and adults (at least have entered the formal thinking phase) have a compact knowledge structure. This structure is used to recognize and interpret reality beyond the mind. Another view is that children's thinking structures have not yet been fully formed. Pieces of information still not well connected. The apparent structure is semi-structured or better known as p-prim . This study was also conducted to find the truth of the dialectic. If children do not have a compact structure of thinking then it will be illustrated in the argument about an object or a science phenomenon.

In this study, students' cognitive structures were analyzed through answers, arguments or explanations given by the students on the test sheet. Analysis of students' cognitive structure is needed to find out the cognitive systems students use when scientific reasoning. Analysis of cognitive structure includes the identification of basic elements in cognition (basic elements), organizing principles and inferential mechanisms (inferential mechanisms) (Van Geenen & Witteman, 2006). Basic elements can be either cognitive concepts (concept), event (event) or both.

Mapping cognitive architecture means breaking down the mental models used by reasoners in recognizing phenomena, creating abstractions and formulating inferences. Cognitive architecture in this study is the structure of knowledge as a result of sensory perceptions of phenomena or objects of science. The cognitive architecture is formed by working memory to recognize and explain the phenomenon. Analysis of cognitive architecture is needed to know how the mind forms a temporal spatio structure when confronted with a particular phenomenon or object.Cognitive architecture reflects how the mind creates temporal structures based on concepts that are activated in long term memory. It can be said that cognitive architecture is a semantic structure that represents declarative knowledge about a particular object or phenomenon (Van Gennen & Witteman, 2006). Architecturally, the built mental model has constituent elements such as concepts or phenomena. The architectural validity of the mental model is evident from the interrelationships of the elements used as well as the interrelationships of the elements.

This study proves that there are students who have well-structured knowledge in the form of interconnected propositions to form mental models, but there are also students who have a structure of knowledge that has not been structured properly. This structure is highly dependent on the skills of individual reasoning. Complex interconnected structures reflect material understanding and good reasoning methods. Thus, it can be concluded that a reasoner can form a complex and valid semantic network if it has good material knowledge and reasoning skills. If the ability to reason better, then the process of changing the conception will be easier, and vice versa. The scientific reasoning factor is one of the preconditions that determine the process of shaping or changing a mental model (She & Liao, 2009). Model mental theory emphasizes the initial knowledge of the main requirements of reasoning. Penalar is able to recognize and explain a phenomenon or concept if it is able to create and manipulate one or more mental models based on existing knowledge. The better the knowledge of phenomena or objects the created mental model will be more relevant to reality (Bandini et al., 1998; Johnson-Laird, 2010; Khemlani and Johnson-Laird, 2009).

On the basis of exposure of data that has been presented before, in general students are able to argue with the principles of reasoning, although never been trained using inference methods. The argument pattern is arranged according to the syntax of reasoning that is the premise that precedes the conclusion or vice versa. This research reinforces the theory of mental models that early knowledge is a key requirement that a person is able to reason scientifically. Subjects argue with patterns of causal reasoning or complement the concepts. The patterns look different according to the question characteristic of the problem. If it is a matter of causing a cause-and-effect argument, students are able to propose causal claims with valid structures. Similarly, when the question calls for argumentation to classify concepts, the subject is able to propose arguments to support an object or phenomenon categorized into a particular group.
The evidence that mental model theory is more accurate in explaining the phenomenon of reasoning is that students who provide accurate explanations are students who have sufficient knowledge of the phenomenon or object. Thus, the ability of the reasoning process is determined by one's ability to create a mental model for explaining phenomena or objects and making hypothetical or categorical inferences. The ability to create and use mental representations of a scientific phenomenon is a major component of scientific literature (Clement, 2000; Gobert and Buckley, 2000; Coll, 2008). White and Frederiksen (1998) argue that students who do not understand how to create a scientific model are the main problems of reasoning in science learning.

One conclusion from this research is reasoning is the process of creating a semantic model of temporal that is relevant to reality and contains the possibility of a phenomenon or other object that has not existed before. The conceptual definition is the operational reasoning framework which is the sequence of mental activities in the form of (1) creating, (2) applying, and (3) revising the temporary semantic structure of an iterative and continuum phenomenon or object. Reasoning is an inherent part of the system of thinking and processing of information in humans. Reasoning will always happen when a person is exposed to a particular object or phenomenon throughout his life. Thus, cognitive activity in the form of creating, applying and revising the semantic model of temproer is part of the process of human adaptation to its environment.

Conclusion

Based on the results and discussions that have been presented previously, there are several conclusions that can be raised, including: 1) reasoning occurs when someone is able to create a mental model that is compatible with reality. Junior high school students are able to create a well-structured model analyzing scientific phenomena. When faced with scientific phenomena, students create models based on elements of knowledge stored in long-term memory. The elements that are activated properly will be transferred to working memory to create a mental model. Reasoning only really happens when a mental model is created through a system of rational, hypothetical and analytical thinking. The mental model that has been created will be revised if it cannot explain reality completely; 2) a person's reasoning skills when born and the development of reasoning are influenced by the development of knowledge. Primary school students exhibit almost similar reasoning skills. Syntactically, there is almost no difference in reasoning patterns in school students. This means that inference strategies are procedural capabilities inherent in the human thinking system and have been owned from birth. The development of reasoning systems is actually an extension of someone's knowledge structure. The expansion of this knowledge is the accumulation of concept and object acquisitions carried out through perceptions of the real world and learning. Therefore, the argument presented as the findings of this study which is if the broader and complex the structure of someone's knowledge, thus the reasoning system will be good.

References


