An investigation of reasoning ability at the secondary level students

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Abstract. The study aims to investigate students’ reasoning ability of junior high school level. This study is quantitative descriptive research. The sample of the study were 178 students of eighth junior high school in Bandung, Indonesia. The samples were chosen by using stratified random sampling technique. A logical thinking test was used as the instrument of this study which consist of five reasoning aspects and every aspect consist of two items. The result indicates that only several students who have formal reasoning ability. There are many students who lack of probabilistic and correlational reasoning.

1. Introduction
Nowadays, scientific approach, in Indonesia, is commonly implemented to improve higher order thinking and science process skills of the students [1]. The use of scientific learning aims to improve reasoning ability to think both deductively and inductively by using the concepts and principles to explain natural phenomenon and solve problems [2]. Most of Indonesian students’ reasoning ability is still considered at the low level [3]. The new curriculum in Indonesia are expected to enhance students’ reasoning ability.

There are four stages of cognitive developments stated by Piaget. They are: motor sensory, pre-operational, operational, and formal operational [4]. Piaget has described the process where individuals advance from one stage to the next four contributing factors: maturation, experience with the physical environment, social transmission, and “equilibration.” The last item designates an internal mental process in which new experiences are combined with prior expectations and generate new logical operations [5]. Valanides states that there is a relationship between a person's cognitive developmental stage with learning outcomes and reasoning ability. Students with high cognitive development demonstrate better reasoning and learning outcomes than other students [6].

Secondary school students are individuals who enter in adolescence who have an age range between 10-14 years. The intellectual growth of young adolescents differs from individual to another individual, in general this age is characterized by a transition from concrete thinking to abstract thinking. Young adolescents are developing the ability to analyse their own and others’ thinking, and to think about abstract ideas such as justice or equality. They are making the transition from thinking logically about real life experiences to reflecting on and reasoning about abstract concepts and ideas [7].
According to Piaget studies [4], certain rules have been formulated to identify the reasoning patterns as belonging to concrete or to formal thought. In general, reasoning which uses direct experience, concrete objects, and familiar actions is classified as a concrete reasoning pattern, such as serial ordering a set of sticks according to their length. Reasoning that is based on abstractions and that transcends experience is classified as a formal reasoning pattern, such as investigating the effect of fertilizer on clover by setting up several test plantings that are treated alike in all respects except in the amount of fertilizer applied to them [5]

Intellectual development in early adolescence can be used by teachers to train students’ reasoning ability. A teacher can support students’ intellectual development by differentiating in structure; focus on complex thinking skills that ask students to apply their knowledge and skills to worthwhile the task; ask students to make choices and pursue their own interest; provide cooperative learning opportunities, one-on-one feedback, and time for personal reflection; have regular student-teacher conference; and provide the opportunity to create individual projects [7].

A teacher can know how far the intellectual development of students by looking at their formal reasoning abilities. Formal reasoning is closely related to achievements in natural science, mathematics, and other general knowledge [8]. Formal reasoning involves a process of reasoning that guides the search and evaluation process of evidence to support or reject the hypothetical causal proposition. Lawson identifies five reasoning abilities which are relevant to science teaching: proportional reasoning, probability reasoning, variable control, correlational reasoning, and combinatorial reasoning [9]. Lawson develops a written test instrument to assess formal thinking skills for each of the five types of reasoning. In the instrument, students are asked to select answers from the alternative answers provided and students are also asked to write down the reasons for their choice. The problem in Lawson test is that many students are unable to justify their response in a clear written form. Then, Tobin and Capie modify those instruments [10].

Tobin and Capie Test of Logical thinking (TOLT) provides multiple justification, as well as multiple solutions, for each reasoning aspect tested. The test consists of two questions for each of the five reasoning aspects out of 10 items total [10]. The first two items are proportional reasoning, assessing students' ability to work with and understanding the quantitative aspects of science. Students lacking this ability cannot have comprehended, or have difficulty with topics such as the interpretations of equation, the mole concept, stoichiometry, and the gas laws. Controlling variable is the second two items that assessing students’ ability to identify and control variable. This reasoning pattern is one of the most important process thinking skills science instruction seeks to develop.

The third two items are probabilistic reasoning. This reasoning measures students' ability to solve problems using probabilities. The ability to think in probabilistically is crucial for students to understand the need for repeated trials in scientific investigation. The next two items are correlational reasoning, assessing students' ability to identify and verify the relationships between variables in solving problems. This pattern of reasoning is essential in determining relationships between variables from collected data. The last two items are combinatorial reasoning, measuring students' ability to solve problems where the solution involves listing all possible combinations in a set of items [10]. Tobin and Capie report that formal reasoning ability, as assessed by TOLT, is significantly related to achievement in science, as well as retention of integrated science process thinking skills in middle school students [10, 11].

This study aims to investigate the reasoning abilities of eight grade students in Bandung. The students reasoning ability consists of five form of logical thinking (proportional, controlling variable, probabilistic, correlational, and combinatorial reasoning).

2. Method
This study employs a descriptive study. Descriptive study includes studies that provide simple information about the frequency or amount of something. Descriptive research may compare groups of individuals, and often the variable used to classify the groups which is considered independent. The
description is usually in form of statistics such as frequencies or percentages, averages, and sometimes variability. Often, graphs and other visual images of the results are used [12].

This study was conducted in Bandung. The population of this study was the students of eighth grade junior high school in Bandung academic year 2014/2015. Target population is a population that serves the data needed by the researcher [13]. The samples of the data were chosen by using stratified random sampling technique. It is a process of choosing a sample based on a strata or group in a population [14]. The strata of this study were differentiated based on the cluster system of junior high schools in Bandung. The samples of the study were students of junior high schools which were divided into three clusters. Every cluster was represented by 2 schools and every school was represented by one class of students of eighth grade junior high school. The samples of this study were 178 students. The details of the samples can be seen at Table 1.

Table 1. The details of samples every school.

| School | School Code | Cluster | Total Students |
|--------|-------------|---------|----------------|
| 1      | S01         | 1       | 32             |
| 2      | S02         | 1       | 35             |
| 3      | S03         | 2       | 27             |
| 4      | S04         | 2       | 31             |
| 5      | S05         | 3       | 28             |
| 6      | S06         | 3       | 25             |

The amount of students in each class is regulated in the Ministerial Regulation where the maximum students in class is 36 students [15]. Based on Table 1, it can be seen that the amount of student in every class is relevant with the ministerial regulation.

The instrument in this study was Test of Logical Thinking (TOLT) proposed by Tobin and Capie. The TOLT was used to measure students' reasoning ability. The TOLT consists of five reasoning aspect and every aspect consists of 2 items. The total of TOLT are 10 items. The score for each item is 1. Test score from 0-1, 2-3, and 4-10 were used as a basis for classifying subject as a concrete, transitional, and formal reasons [6, 16].

3. Result and discussion

3.1. Students’ reasoning ability

A teacher can investigate how far the intellectual development of students by looking at their formal reasoning abilities. The ability of formal reasoning is an important mediator to observe student’s cognitive achievement. According to Piaget, intellectual development that occurs in adolescent stage is not the same between one and the other, this study determines students with faster or slower intellectual development compared with other students.

The finding of this study is students’ reasoning ability based on TOLT scores. The students who have followed the TOLT test were classified into three categories of reasoning, concrete, transitional, or formal. Student’s reasoning category is presented in Table 2.
Table 2. Students’ reasoning ability.

| Reasoning category | Total (student) | Percentage (%) |
|--------------------|-----------------|----------------|
| Concrete           | 97              | 54.5           |
| Transitional       | 49              | 27.5           |
| Formal             | 32              | 18             |
| Total              | 178             | 100            |

Based on Table 2, it can be seen that most students were in concrete reasoning ability. It means that the students lack of reasoning ability. On the other hand, only several students that possess formal reasoning ability.

The eighth grade students are individuals who are entering the age of 11 or 12 years’ old who, according to Piaget, should have started to enter formal operational phase. However, only several students who have formal reasoning ability. This shows that there are still many eighth grade students who are unable to think abstract and conduct a hypothesis.

By investigating students’ reasoning ability, it will also reveal students’ reasoning ability of each school. There were six schools participated in this study which were divided into 3 clusters. Each cluster consists of two schools. The result of students’ reasoning ability in each school can be seen in this below figure.

![Figure 1](image-url)  

Figure 1. Percentage of every schools reasoning ability.

Figure 1 is an image showing the percentage of the number of students for each school. Percentages are based on the total number of students who take TOLT. Based on the figure 1, it can be seen that most students with formal reasoning ability is in S01 then followed by S02 and S03. The reverse result is shown by S04, S05, and S06, none of students who have formal reasoning ability in that schools. Otherwise, in those schools, most of the students’ reasoning ability is in a concrete level.

One category of clustering system used in Bandung is the cognitive level of students at the selection of new admissions through the score of national test students. Cluster 1 is a school whose students have good academic performance, followed by cluster 2 and cluster 3. The results of this study is accordance with the system cluster. These results show that cognitive ability is related to the level of student reasoning as stated by Lawson which states that formal reasoning is closely related to achievements in the fields of natural science, mathematics, and other general knowledge [8].
3.2. Students’ ability on every aspect of reasoning

The other findings are known the students score in every items of TOLT. From 178 students who answer 10 items of TOLT, only obtained 18.4% correct answered. From five aspects of reasoning, shows that most correct answers are in proportional reasoning items, probabilistic and correlational is the most items were incorrectly answered. The comprehensive students’ answer can be seen in Figure 2.

The Figure 2 shows that most correct answers are in proportional reasoning items. The average of item 1 and 2 is 30%. Proportional reasoning assesses students’ ability to work and understand the quantitative aspects of science. Without this ability, the understanding of derivation and use of functional relationship is impossible. The students who can answer correctly of items 1 and 2 means have ability to comprehend or interpret equations, the mole concept, stoichiometry, the gas laws, velocity, acceleration and density. Otherwise, the students who lack in this reasoning cannot do that.

Figure 2. Students’ correct answer in each item.

According to Figure 2, probabilistic and correlational is based on TOLT items that the most items were incorrectly answered. The average correct answer for each those items is only 8%. It means only 8 from 178 students who answer correctly.

Probabilistic reasoning was designed to measure students’ ability to solve problems using probabilities. Students who lack this reasoning, cannot fully comprehend concept and identifying the probability of events involving one or more variable. Based on the result, it can be seen that many students cannot solve problems using probabilities.

The same result is shown in correlational reasoning items. Correlational items were designed to assess students' ability to identify and verify the relationships between variables in solving problems. This pattern of reasoning is essential in determining relationships between variables from collected data. Such reasoning ability is required in comprehending relationship between the types of bonding and the ionization energies involved in forming molecules from atoms, and the interpretation of displacement-time studies. From the result, it can be regarded that many students cannot to identify and verify the relationships between variables in solving problems.

The use of TOLT is strongly recommended to distinguish students based on their reasoning abilities. The resulting data will be beneficial to investigate the relationship between students' reasoning with their accomplishments, investigating the relationship of reasoning ability with teachers, determining the effect of teacher and student variables or others. According to Valanides findings, a
person who has formal reasoning ability will be better at solving problems of reasoning than other reasoning levels [6].

4. Conclusion
The study indicates that only several students who possess formal reasoning ability. Most students were still categorized at the concrete reasoning levels. The students from cluster one is dominated by the student with formal reasoning ability. On the other hand, the students from cluster two and three are mostly dominated by the people with concrete reasoning ability. From the total five aspects of reasoning, proportional reasoning is an aspect of reasoning which is mostly answered by the students. There are still many students who lack of probabilistic and correlational reasoning.

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