Identify Students’ Scientific Reasoning Ability at Senior High School

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Abstract. This study aims to identify students’ scientific reasoning ability in SMAN 3 Surakarta. The ability of scientific reasoning is an important factor to encourage students' thinking ability in learning. The method used in this study is a descriptive method with 88 students 11th-grade taken at random. The data of scientific reasoning obtained through written test using the Lawson classroom test of scientific reasoning (LCTSR), instrument test that used consists of 12 items two tier multiple-choice that contains 6 scientific reasoning domain 1) Conservation of Mass and Volume (CMV), 2) Proportional Thinking (PPT), 3) Control of Variables (CV), 4) Probabilistic Thinking (PBT), 5) Correlational Thinking (CT), and 6) Hypothetical-deductive Reasoning (HDR). The domains are used as the basis for grouping students' scientific reasoning abilities into three levels: concrete reasoning, transitional, and formal reasoning. The results showed that 51.14% of the students were at the level of concrete reasoning, 42.05% at the transitional level, and 6.81% at the formal reasoning level. This can be a reflection of whether the physics learning that has been implemented is able to encourage students' scientific reasoning ability. The information can be used as a consideration in the selection of appropriate models, methods, and physics learning media.

1. Introduction
Scientific reasoning ability is a much needed of students in the 21st century. Students need to develop important competencies of 21st century learning outcomes through empowering scientific reasoning as a provision for survival [1]. An understanding of the 21st century learning paradigm is important to be applied as a pedagogical framework in the learning process [2]. Schools need to implement competencies that not only focus on subject, but also develop a deeper understanding of a knowledge content, such as scientific reasoning ability [3]. Scientific reasoning needs to be instilled early on at the level of educational unit that is affirmed with Permendikbud No 59 of 2014 [4] about the structure of curriculum, mentioned that the competence that must be achieved by students high school through physics learning is the ability of reasoning.
Reasoning ability students are needed in all disciplines as a key to the effective ability for learning [5]. In his research, Colleta, et al [6] mentions that scientific reasoning is one of the factors that affect student achievement in science and physics. Scientific reasoning contributes to academic achievement, cognitive ability, decision making and problem solving [7]. Scientific reasoning is the ability to use cognitive aspects at concrete operational level into abstract and hypothetical situations [8]. From the perspective of science literacy, scientific reasoning is the cognitive ability needed to understand and evaluate scientific information that involves understanding and evaluating theoretical, hypotheses, statistical and causal [9]. From a research Zimmerman [10] explain that scientific reasoning is defined as reasoning and problem solving ability in result, testing and revising hypotheses or theories. Scientific reasoning is the end of the developmental ability of the characteristic of intellectual maturity, so it is important to be invested in the level of secondary education, scientific reasoning is said to be suitable if given to middle-level students [11].

Piaget [12] classifies the thinking ability of children into four stages: motor sensory (0-2 years), pre operational (2-7 years), concrete operational (7-11 years) and formal operational (11 years and over). The highest scientific reasoning rate is formal operational reasoning [11].

The reasoning ability is not an innate ability, but reasoning is influenced by many factors. So it is with scientific reasoning. One of the factors that can influence the development of scientific reasoning is the approach, models and teaching methods used by teachers. The students’ scientific reasoning ability can be trained through physics learning using a scientific approach [13]. Scientific reasoning involves activities to produce, test, and revise hypotheses and help decision-making in solving problems. One way the teacher does to improve students’ scientific reasoning abilities is to carry out learning using the experimental method and free inquiry learning and modification inquiry.

Based on the above description, knowing the scientific reasoning ability of each student is important to do. This can be a reflection of whether the physics learning that has been implemented is able to encourage students’ scientific reasoning ability. The information can be used as a consideration in the selection of appropriate models, methods, and physics learning media. This study aims to identify students’ scientific reasoning ability 11th-grade in SMA N 3 Surakarta the academic year of 2017/2018. The results obtained are expected to be used as a reference in the selection of models and methods of physics learning appropriate, in order to train and develop students’ scientific reasoning ability. In this study, students’ scientific reasoning ability were identified using scientific reasoning tests from Lawson Classroom Test of Scientific Reasoning instrument [14].

2. Research Method
The method used in this research is descriptive, to identify students’ scientific reasoning ability. Researcher do not provide treatment in the form of learning in advance to students, this descriptive research is research that aims to investigate students’ scientific reasoning ability to obtain information level of students' scientific reasoning ability. Research subjects were 11th-grade students in SMA N 3 Surakarta the academic year of 2017/2018. The sample of the study consists of 88 samples taken at random.

The instrument used in this study is the Lawson classroom test of scientific reasoning (LCTSR) instrument consists of 12 two-tier multiple choice questions. Each question has a choice of answers and a choice of reasons underlying the answer. Score 1 if the answer and reason are correct, and score 0 if the answer or reason is wrong, or both are wrong. Examples of instruments can be seen in Figure 1.
At the right are drawings of three strings hanging from a bar. The three strings have metal weights attached to their ends. String 1 and String 3 are the same length. String 2 is shorter. A 10 unit weight is attached to the end of String 1. A 5 unit weight is also attached to the end of String 2. The strings (and attached weights) can be swung back and forth and the time it takes to make a swing can be timed.

Suppose you want to find out whether the length of the string has an effect on the time it takes to swing back and forth. Which strings would you use to find out?

a. only one string
b. all three strings
c. 2 and 3
d. 1 and 3
e. 1 and 2

Figure 1. example of question in instrument LCTSR

The division of scientific reasoning indicator on the instrument of scientific reasoning test is shown in table 1. The test data obtained is then analyzed to identify the students' scientific reasoning level, while also analyzing the achievement of each indicator. The students' scientific reasoning level is determined based on the test scores obtained, Lawson [5] classifies the 0-4 score as the concrete operational reasoning level, the score 5-8 as the transitional level, and the score 9-12 as the operational reasoning level formal (formal operational).

| Scientific reasoning indicator                | Question number |
|-----------------------------------------------|-----------------|
| Conservation of Mass and Volume (CMV)         | 1,2             |
| Proportional Thinking (PPT)                   | 3,4             |
| Control of Variables (CV)                     | 5,6,7           |
| Probabilistic Thinking (PBT)                  | 8,9             |
| Correlational Thinking (CT)                   | 10              |
| Hypothetical-deductive Reasoning (HDR)        | 11,12           |

Table 1. Scientific reasoning indicator

3. Result and Discussion

Based on the research that has been done by using Lawson classroom test of scientific reasoning (LCTSR), the result shows the level of students' scientific reasoning. The scoring system and the determination of the scientific reasoning level refers to the scoring system from Lawson [5]. The results of the students' level of scientific reasoning analysis are shown in Table 2.

| Scientific reasoning level                  | Percentage     |
|---------------------------------------------|----------------|
| Concrete operational                        | 45 (51.14 %)   |
| Transitional                                | 37 (47.72 %)   |
| Formal operational                          | 6 (1.14 %)     |

Table 2. level of students' scientific reasoning

Based on Table 2 it can be seen that the percentage of the number of students with scientific reasoning for the level of concrete operational in the first place, while the level of formal operational is at the lowest order. This result is incompatible with Piaget's cognitive development theory which states that children aged 11 years and over should have had scientific reasoning ability at formal operational level [12]. As many as 51.14% of students are still at the level of concrete operational reasoning.
Scientific reasoning level can also be analyzed based on the achievement of each indicator. Data on achievement of each student's scientific reasoning indicator for the level of concrete operational reasoning is shown in Figure 2.

![Figure 2. Achievement of indicators at the level of concrete operational reasoning](image)

It can be seen that at the level of concrete operational reasoning, students can answer well on question number 1 to 4 (indicator 1 and 2), it is in accordance with Lawson [5] that indicators 1 and 2 consists of questions 1 to 4 represent the characteristics of concrete operational reasoning.

![Figure 3. Achievement of indicators at the level of transitional reasoning](image)

From Figure 3 it can be seen that at this level of transitional reasoning, students can answer well on question number 1 to 9, but have not been able to answer well on question number 10, 11 and 12. This indicates that at the transition level, students can answer well the initial indicators of formal operational level (indicators 3 and 4), but have not been able to answer well the final indicators of formal operational level (indicators 5 and 6).

![Figure 4. Achievement of indicators at the level of formal operational reasoning](image)

Based on Figure 4 for the level of formal operational reasoning, students can answer well on all indicators. In indicators 1 and 2 (questions 1 to 4) almost all students answered correct, indicators 3 to
6 (questions 5 to 12) can be answered well by students. This is in accordance with Lawson [5] which states that indicators 3 to 6 represent the characteristics of formal operational reasoning.

Based on the results of the data analysis of students' scientific reasoning scores, it can be seen that the students of 11th-grade students in SMA N 3 Surakarta the academic year of 2017/2018 with age range of 16-17 years are still in the scientific reasoning ability level of concrete operational (51.14%) and the transition level (47.72%). While students who are at the level of formal operational reasoning is lowest (1.14%). This result is not in accordance with the theory of child cognitive development which states that children aged 11 years and over have formal operational reasoning ability [12] characterized by having the ability to identify and control of variables, probabilistic thinking ability, thinking correctional ability and hypothetical-deductive reasoning [5]. The low level of students’ scientific reasoning ability at the level of formal operational can be used as a benchmark that the physics learning that has been implemented has not been able to encourage students' scientific reasoning ability. For that teachers should attention to the selection of models and methods of physics learning appropriate, in order to train and develop students' scientific reasoning ability.

4. Conclusion and Suggestion

4.1 Conclusion

Based on the result of the study it can be concluded that the average of students' scientific reasoning ability is at the level of concrete operational reasoning (51.14%), at the level of concrete operational reasoning, students can answer the problem well on conservation of mass and volume indicators, and proportional thinking. Following the level of transition reasoning (47.72%), for the level of transition reasoning, students were able to answer all questions on conservation of mass and volume, proportional thinking and some questions on formal operational reasoning indicators (control of variables and probabilistic thinking). While the lowest is the level of formal operational reasoning (1.14%), at the level of formal operational reasoning, students are able to answer the problem well all the questions of scientific reasoning. The low ability of formal operational reasoning of high school students is perhaps influenced by the learning process that has not been classified well to encourage students' scientific reasoning ability. The results of this study are used as teacher references to determine the learning method to be used, adapted to students scientific reasoning ability. Thus, by providing learning that is oriented to students scientific reasoning ability, it can improve scientific reasoning ability according to the age classified by Lawson.

4.2 Suggestion

In this study did not pay attention to gender characteristics of respondents, furthermore can be explored the influence of gender on students' scientific reasoning ability, besides that interesting to investigated is the relationship between scientific reasoning ability with student learning outcomes.

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