Students’ scientific reasoning and argumentative abilities through levels of inquiry models based on socio-scientific issue

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Abstract. Scientific reasoning and argumentative abilities are one of the purposes of science education. The way to involve students in reasoning and arguing activities is to provide a science learning activity that integrates the practice of inquiry using scientific methods in Socio-Scientific Issue (SSI). To create this environment, one of the learning models that can be used is the Levels of Inquiry model. The stages of Levels of Inquiry used in this study are discovery learning, interactive demonstration, and inquiry lesson. In every stage of Levels of Inquiry has five learning syntax, namely observation, manipulation, generalization, verification and application. The purpose of this study was to know the changes in scientific reasoning and argumentative abilities of junior high school students after the implementation of the Levels of Inquiry model based on SSI in the science learning at global warming material. The method used is the weak experiment with the one group pretest-posttest design. The subjects of this study were seventh grade students at junior high school. The instrument used is a scientific reasoning test and scientific argumentation test. This study resulted in a gain of 0.43 for changes in students’ reasoning abilities and 0.39 for changes in students’ argumentative abilities. Based on the paired sample t-test analysis, there is a significant difference between the results of the pretest and posttest.

1. Introduction

Scientific reasoning ability is one of the purposes of science education. Scientific reasoning is defined as the process of investigation by individuals in which they revise and reconstruct theories by involving reasoning skills in conducting experiments, evaluating evidence, and making conclusions aimed for scientific understanding [1]. Students’ reasoning abilities are developed through scientific practice. Through scientific practice, students know how they obtain scientific knowledge in accordance with the procedures used in finding, evaluating, revising, and communicating the knowledge. Therefore, the students can be actively involved in meaningful learning. The aspects of scientific reasoning measured in this study are control of variables, proportional reasoning, correlational reasoning, inductive reasoning, and hypothetical-deductive reasoning [2].

In addition to scientific reasoning, the argumentative ability is also the purpose of science education. The scientific argumentation is defined as the activity of dialogue discussing evidence and theory to produce an explanation, model, prediction or evaluation [3]. Argumentation is not used to convince other students from another student’s point of view, but rather as a way of finding some possible explanations for a case. Toulmin developed a structural framework that could be used to...
develop skills in producing arguments and analyzing the quality of arguments [4]. The parts of the Toulmin model are claim, data, warrant, backing, qualifier and rebuttals.

One way to involve students in argumentative practice is to provide a learning environment with Socio-Scientific Issue (SSI) [5]. Integration of SSI into science learning can create conditions for students to actively participate in lessons. Socio-scientific issues are issues of various scientific concepts and problems, controversies that occur, and public discussions that are heavily influenced by social politics. However, students who participate in the SSI debate are considered to have fewer opportunities to engage in authentic scientific practice through variable manipulation, designing experiments, and collecting data to match the evidence [6].

To answer and overcome these shortcomings, it is necessary to integrate the practice of inquiry using scientific methods with SSI in order to increase student involvement with scientific reasoning and argumentative practice. One of the methods is using Levels of Inquiry a learning model based on Socio-Scientific Issue. Levels of Inquiry is a unipolar series of inquiry which consists of six levels beginning with the basic level to the highest level, sorted by students’ intellectual abilities and the controller [7]. These levels are discovery learning, demonstrative interactive, lesson inquiry, lab inquiry, real-world application and hypothetical inquiry. In the model, students can use reasoning skills to collect and analyze data to obtain evidence in supporting their claims so that it will strengthen the students’ scientific argumentative abilities. Levels of Inquiry also has five learning syntax in every level or stage, namely observation, manipulation, generalization, verification, application [7]. This learning syntax emphasizes student actions that are consistent and stronger than teacher actions.

![Figure 1: The Syntax of the Levels of Inquiry Learning Models](image)

In accordance with the basic competencies of the science curriculum, one of the materials given to seventh grade of Junior High School students is global warming. Global warming is one of the science materials that has many links with social, economic and other issues, for example the impact and efforts to combat global warming so that this material is considered appropriate to be used in SSI-based science learning. Therefore, science learning using the SSI-based Levels of Inquiry model on global warming material is expected to change students’ reasoning and scientific arguments. So, this research aims to provide an overview of changes in scientific reasoning abilities and scientific arguments of junior high school students in science learning using the Levels of Inquiry model based on Socio-Scientific Issue Global Warming Material.

2. Methods
This study used the weak experiment method. In this study there was only one class that received treatment, namely SSI-based level of inquiry learning. The research design used in this study was One-Group Pretest-Posttest Design. In One-Group Pretest-Posttest Design, one group was measured before and after treatment, without a comparison group. This research was conducted at junior high school with a population of all seventh-grade students in the even semester of the 2018/2019 academic year. The samples taken from the population were students of class VII B, amounting to 34 students.

Levels of Inquiry based on learning occurred for three meetings. Each meeting lasted for 2x40 minutes. At the first meeting, teacher used Discovery Learning stage. In the syntax of observation, the teacher gives several articles on social issues about the phenomena that are the effects of global
warming, for example “Tikus Island, the marine tourism area, is threatened to sink”, “Tidal floods that always inundate the coast of the city of Pekalongan”, and “The ice on the Antarctic Continent continues to melt rapidly”. The teacher asks students to describe the article given. In the syntax of manipulation, students conduct group discussions to compare and identify the cause of the phenomenon. Furthermore, in the syntax of generalization, students identify the relationship between global warming, melting of ice in the Antarctic continent and rising sea levels and drawing conclusions. Then in the syntax verification, the teacher and students provide justification for the concepts that are not quite right. At the end of learning in application syntax, students identify and describe other phenomena which are impacts caused by global warming.

At the second meeting, the stage of inquiry conducted was Interactive Demonstration. At the beginning of learning in the observation syntax, the teacher again presents an article on "CO₂ Levels in the Atmosphere Reaching the Highest Level in 800 Thousand Years", then asking questions of problems that will become the core of learning. The second syntax is manipulation in which the teacher performs a demonstration to help students understand a "The Greenhouse Effect" phenomenon. The teacher also asks students to write down predictions and possible explanations to support the predictions. After that, students group share predictions and general explanations on the generalization syntax. Then in the syntax verification, the teacher does a demonstration again to show the phenomenon of the greenhouse effect in a clear manner. Students compare the initial predictions of the group with the results of the demonstration that has been done. At this stage students draw conclusions from some demonstration and prediction data. At the end of learning in application syntax, students determine what can be other causes of global warming and the greenhouse effect.

At the inquiry meeting, the inquiry stage carried out was the Inquiry Lesson. At the beginning of learning in observation syntax, the teacher displays an article about the government's efforts to tackle global warming, namely "The Earth is Getting Hot, the Government Planted Trees in 800 Thousand Ha Land". Then the teacher raises guiding questions for investigative activities regarding the effect of tree planting on reducing the effects of global warming. In the manipulation syntax, students identify what variables can be related in the investigation. The teacher guides students to design and explain a series of experiments to investigate the problem. After designing the experiment, students are asked to do the experiment. In generalization syntax, students describe the observed relationship between independent and dependent variables. The teacher provides verification of the results of the experimental design and the results of the experiment in the verification syntax. After that, the teacher guides students to determine other efforts made to tackle global warming.

The test instruments used in this study were test instruments of scientific reasoning abilities in the form of multiple choices and tests of the ability of scientific arguments in the form of essays. Both tests were given twice, before (pretest) and after (posttest) learning. Pretest and posttest data were analyzed using the Paired Sample T-test to find out if there were significant differences between the pretest and posttest results. In addition, each data is also calculated using the N-gain formula and grouped according to the N-Gain value. This value has been interpreted according to the normalized gain score criteria that listed below.

| Gain score \( (g) \) | Criteria     |
|----------------------|--------------|
| \( 1,00 \geq (g) > 0,70 \) | High         |
| \( 0,70 \geq (g) > 0,30 \) | Moderate     |
| \( 0,30 \geq (g) > 0 \)   | Low          |

### 3. Result and Discussion

#### 3.1. Changes in scientific reasoning abilities

Scientific reasoning abilities was seen based on students’ pretest and posttest average scores. First, the data of the pretest and posttest scores were tested using the normality test and the results were normally distributed. Furthermore, the data were analyzed using paired sample t test with SPSS 25.
The results of the analysis produced Sig. (2-tailed) of 0.000. If we compare with the value of Sig. (2-tailed) < 0.05 (confident interval percentage 95%), its meaning that there are significant differences between the results of the students' pretest and posttest scientific reasoning abilities.

| Table 2. Pretest and Postest Average Score and N-Gain |
|-----------------------------------------------|
| Student Reasoning Ability                     |
| Test      | Xideal | Xmin | Xmax | Average | <g>  |
| Pretest   | 100    | 20.00| 45.00| 43.38   | 0.43 |
| Postest   | 100    | 60.00| 90.00| 68.68   |      |
| Improvement Criteria                          | Moderate                    |

| Table 3. Number of Students based on N-gain Category at Scientific Reasoning Abilities |
|-----------------------------------------------|
| N-gain Category | Number of students | Percentage |
| Low              | 9                  | 26.5%       |
| Moderate         | 20                 | 58.8%       |
| High             | 5                  | 14.7%       |

Based on the Table 2 above, students' scientific reasoning abilities experience positive changes, which increase by 0.49 and are in the moderate category, whereas Table 3 presents the number of students based on the N-gain category of students' overall scientific reasoning abilities. The highest achievement of N-gain is in the medium category which is 58.8% of the total number of students. This shows that the application of the SSI-based Levels of Inquiry model to Global Warming material can improve students' scientific reasoning abilities.

Significant changes occur due to the effect of inquiry learning that can encourage students to think actively and engage continuously in the investigation process [8], [9]. Important stages in inquiry learning will help students develop clearer and deeper knowledge about science concepts and processes. Developing reasoning abilities can be done through a series of learning designs that facilitate students using their reasoning abilities [10]. For example, students study inquiry-based science and mathematics in order to help develop reasoning abilities.

The application of inquiry learning model must be in accordance with the level that can guarantee the occurrence of teaching and learning process. The design process for the application of inquiry learning models must be planned and systematic. The level of inquiry used in this study is adjusted to the condition of students' intellectual intelligence and to go to the next level must pay attention to the readiness of students to receive inquiry learning. Therefore, this research begins with the most basic level of discovery learning with the teacher still playing an active role in guiding students to find concepts and shape student understanding based on student experience. Next, the level used is interactive demonstration. At this level the teacher still plays an active role in learning but there has been a reduction and dominance of control by the teacher in learning. The last level is Inquiry Lesson. At this level, teacher guidance decreases and the role of students increases. The ability of student inquiry is also expected to be in the intermediate stage because at this stage students are directed to hone their ability to experiment.

This finding is in accordance with the results of previous studies which state that the inquiry learning model has an effect on improving the results of students' reasoning abilities and mastery of concept concepts. Students who are accustomed to learning Levels of Inquiry based on SSI will have an effect on their reasoning abilities. Reasoning ability is an important component in learning because if students have good reasoning, students will show good results also in ongoing learning[11]. Students' reasoning abilities shows an increase after a number of times given exercises and assignments that require reasoning abilities to answer or complete the assignments and exercises[12].
SSI-based learning also supports the development of scientific reasoning abilities. SSI learning is useful in developing students using their scientific reasoning to build competent learning groups in participating in all forms of inquiry objectively[13]. Karpudewan & Roth's research confirms that the implementation of SSI activities can encourage students to improve their reasoning abilities[14]. SSI-based learning offers a learning context that includes conceptual connections to science and structured problems that involve discussion, critical thinking, and decision making [15].

3.2. Changes in the abilities of scientific argumentative

Scientific Argumentative abilities was seen based on students' pretest and postest average scores. First, the data of the pretest and posttest scores were tested using the normality test and the results were normally distributed. Furthermore, the data were analyzed using paired sample t test with SPSS 25. The results of the analysis produced Sig. (2-tailed) of 0.000. If we compare with the value of Sig. (2-tailed) < 0.05 (confident interval percentage 95%), its meaning that there are significant differences between the results of the students' pretest and posttest scientific argumentative abilities.

| Test   | Xideal | Xmin | Xmax | Average | <g> |
|--------|--------|------|------|---------|-----|
| Pretest| 100    | 16.67| 35.00| 46.32   | 0.39|
| Postest| 100    | 78.33| 93.33| 68.48   |     |

Table 4. Pretest and Posttest Average Score and N-Gain Student Argumentative Abilities

| Improvement Criteria | Number of students | Percentage |
|----------------------|--------------------|------------|
| Low                  | 10                 | 29.4%      |
| Moderate             | 21                 | 61.8%      |
| High                 | 3                  | 8.8%       |

Table 5. Number of Students based on N-gain Category at Scientific Argumentative Abilities

Based on Table 4, there is a change in the average value of students' argumentation abilities at the pretest and posttest with the normalized gain average score of 0.39. If the gain score is converted in the category of normalized gain average score <g> then it is included in the moderate category. Then, Table 5 presents the number of students based on the N-gain category of students' overall scientific argumentative abilities. The highest achievement of N-gain is in the medium category which is 61.8% of the total number of students. This shows that the application of the SSI-based Levels of Inquiry model to Global Warming material can improve students' scientific argumentative abilities. Students who get inquiry learning reach far higher levels of achievement in aspects of knowledge, reasoning ability, and argumentation [16].

This significant change in students' scientific argumentative abilities is caused by the application of the SSI-based Levels of Inquiry model. In the learning process carried out, students carry out a series of active processes in each stage of SSI-based inquiry that trains the ability of scientific argumentation. This is consistent with [5] research which states that incorporating the practice of scientific inquiry into SSI issues has the potential to improve the quality of their argumentative abilities. During scientific argumentation, students reflect on their own ideas and learn about the ideas of others. Their basic ability to identify ethical issues in the context of science and their skills affect the ability to recognize and build scientific arguments themselves [17]. Therefore, the ability of argumentation helps to correct misunderstandings and ensure meaningful learning experiences [18]. This is also consistent with the results of Dawson & Venville's study which states that students who are trained to argue and be active in argumentation classes are better able to produce rational written arguments [19].
In addition, Dawson & Carson's research also revealed that learning science by raising SSI problems can support students’ argumentative abilities[18]. With the Levels of Inquiry stage in SSI learning, students still have the opportunity to engage in scientific practice through manipulating variables, designing experiments, and collecting data to match evidence. Inquiry learning also has the potential as an effective platform for formulating arguments while conducting various types of experiments [20]. Therefore, students can produce the best arguments by considering all alternatives and inserting relevant and supporting evidence explicitly.

The other research results also show that the results of students’ argumentation abilities after applying the Argument Driven Inquiry (ADI) learning model can improve students’ argumentation abilities in the claims, data, and justification components increase in the moderate category, but an increase in the support component increases in the lower category.

4. Conclusion
Based on the results of data analysis and discussion, it can be concluded that students’ scientific reasoning and argumentative science learning experienced a significant change after the implementation of Levels of Inquiry model based on Socio-Scientific Issue in Global Warming material. The changes of students’ scientific reasoning and argumentative abilities included in the moderate category. The highest achievement of N-gain of students’ scientific reasoning and argumentative abilities is at the moderate category too.

5. References
[1] Andersen C and Garcia-Mila M, 2017, Scientific Reasoning During Inquiry, in Science Education, K. S. Taber and B. Akpan, Eds. (Rotterdam: SensePublishers), p. 105–117.
[2] Lawson A E, 1985 A Review of Research on Formal Reasoning And Science Teaching 22, 7 p. 569–617.
[3] Duschl R A and Osborne J, 2008 Studies in Science Education Supporting and Promoting Argumentation Discourse in Science Education September 2013 p. 37–41.
[4] Toulmin S E, 2003 The Uses of Argument Cambridge: Cambridge University Press.
[5] Nam Y and Chen Y C, 2017 Promoting argumentative practice in socio-scientific issues through a science inquiry activity Eurasia J. Math. Sci. Technol. Educ. 13, 7 p. 3431–3461.
[6] Cavagnotto A R, 2010 Argument to Foster Scientific Literacy: A Review of Argument Interventions in K-12 Science Contexts Rev. Educ. Res. 80, 3 p. 336–371.
[7] Wenning C J, 2004 Levels of inquiry: Hierarchies of pedagogical practices and inquiry processes p. 175–176.
[8] Chen C T and She H C, 2014 The Effectiveness of Scientific Inquiry With/Without Integration of Scientific Reasoning Int. J. Sci. Math. Educ. 13, 1 p. 1–20.
[9] Lazonder A W and Kamp E, 2012 Bit by bit or all at once? Splitting up the inquiry task to promote children’s scientific reasoning Learn. Instr. 22, 6 p. 458–464.
[10] Bao L et al., 2009 Physics Learning and Scientific Reasoning Science 323 p. 586–587.
[11] Frosch C and Simms V, 2015 Understanding the role of reasoning ability in mathematical achievement in EuroAsianPacific Joint Conference on Cognitive Science.
[12] Lawson A E Clark B Cramer-Meldrum E Falconer K A Sequist J M and Kwon Y, Jan. 2000 Development of Scientific Reasoning in College Biology: Do Two Levels of General Hypothesis-Testing Skills Exist? J. Res. Sci. Teach. 37, 1 p. 81–101.
[13] Tal T and Kedmi Y, 2006 Teaching socioscientific issues: Classroom culture and students’ performances Cult. Stud. Sci. Educ. 1, 4 p. 615–644.
[14] Karpudewan M and Roth W, Feb. 2018 Changes in Primary Students’ Informal Reasoning During an Environment-Related Curriculum on Socio-scientific Issues Int. J. Sci. Math. Educ. 16, 3 p. 401–419.
[15] Klosterman M L and Sadler T D, May 2010 Multi-level Assessment of Scientific Content Knowledge Gains Associated with Socioscientific Issues-based Instruction Int. J. Sci. Educ.
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