Effectiveness of Argument-Driven Inquiry Model on Student’ Generic Science Skills and Concept Mastery

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Abstract. Chemistry lessons not only transfer knowledge from teacher to student, but also rather than how to foster interest and experience through experimental work, therefore chemistry lessons become more authentic and enjoyable. Argument-Driven Inquiry (ADI) is a model that integrates practical activities with classroom learning. The purpose of this research is to find out how the effectiveness of Argument-Driven Inquiry (ADI) learning model is compared to guided inquiry towards understanding the concepts and students’ generic science skills. The method used is quasi-experimental using non-equivalent Pre-Test and Post-Test Control-Group design. The results showed that the ADI model is more effective in developing students’ generic science skills and conceptual understanding, except in the sub-indicators concept formation no significantly difference with guided inquiry.

Keywords: Argument-Driven Inquiry; Generic science skills; Conceptual understanding, Chemistry.

1. Introduction
To support 21st Century skills, the Indonesian government through the 2013 curriculum has designed and prepared Indonesian people to have the skills and knowledge needed in the current era. At this time, it is expected that learning science in high school (especially chemistry) is not only for the transfer of knowledge and skills, but for increasing interest and developing generic science skills through practicum [1] [2]. Thinking skills are also called generic science skills. Generic science skills can be used to learn various concepts and solve problems in science [3]. Therefore, generic science skills are used generally in a variety of scientific work and can be used as a basis for conducting laboratory activities.

However, integrating laboratory activities in learning will create new problems. Many factors as difficulties in laboratory activities, including the implementation time, laboratory facilities, expected results, and activities that are not develop students’ skills [4]. This is quite alarming, because if laboratory activities are separated from classroom learning, there will be an impact on changes in students’ understanding of the material, the development of scientific reasoning, understanding of complexity and ambiguity towards empirical problems, work skills (practice), understanding of the nature of science, and growing interest in chemistry and chemistry learning [5].

Argument-Driven Inquiry (ADI) is one of the learning models developed by integrating laboratory activities with classroom learning [6]. The ADI learning model consists of seven stages of learning, namely identifying assignments and asking questions, designing experiments and collecting data, producing tentative arguments, conducting argumentation sessions, making investigative reports, conducting peer reviews, and revising and collecting investigative reports. The results of previous studies explained that learning with the ADI model is able to improve understanding of concepts,
develop science process skills, high order thinking skills, and positive attitudes of science [7] [8]. Therefore, this paper presents a study with the aim to examine how the effectiveness of the ADI model on the generic ability of science and the understanding of the concept of high school students.

The rest of this paper is organized as follow: Section 2 describes the proposed research method. Section 3 presents the obtained results and following by discussion. Finally Section 4 concludes this work.

2. Research Method

This study used the quasi-experimental method with the Non-equivalent Pre-Test and Post-Test Control-Group Design [9]. The experimental class (N = 25) used the ADI model and as a comparison is called the control group (N = 25) using a guided inquiry model. The research participants were high school students of grade XI science on the topic solubility product constant. Each group will be given two different worksheets but the objectives were the same. The independent variable in this study was the ADI learning model and guided inquiry, the dependent variable is the generic science skills, and the control variable is the allocation of time and subject matter. Before learning, each group was given a pre-test to find out how the initial ability of students and after learning will be given a post-test to see the effects of the application of each model. Furthermore, the score of pre-test and post-test were analysed using statistics of SPSS 22.

To see the increasing in understanding of concepts and students’ generic science skills used normalized gain <g> and then <g> was interpreted according to the normalized gain level category (see Table 1) [13].

| N-gain       | Category |
|--------------|----------|
| g < 0.30     | Low      |
| 0.7 > g ≥ 0.30 | Medium  |
| g ≥ 0.7      | High     |

2.1 Data Collection

Research data was obtained through written tests. The test developed is multiple choices with reason of 20 items. Two of items are categorized as invalid, therefore only 18 items using in this research. The open reasoning is used to know how students build a conceptual understanding of the options they choose. For generic science skills data, 14 items from 18 items were used. Validity test based on judgement of expert of chemistry education and chemistry and reliability test is 0.767. This test is given before and after learning, wherein the student's answers are converted into scores. The score is then analysed based on needs. This following is the test scoring rubric (see Table 2).

| Objective | Argument | Score |
|-----------|----------|-------|
| Correct   | Correct  | 3     |
| Correct   | Correct  | 2     |
| Correct   | False    | 1     |
| False     | Correct  | 1     |

Table 2. Scoring Rubric
3. **Result and Discussion**

This section presents the obtained results and following by discussion.

### 3.1 Students’ Generic Science Skills

The data in this study were obtained from students' scores on generic science skills. The pre-test is given to determine students' initial ability in each group towards generic science skills. The results of the pre-test showed that the two groups had generic science skills that were not much different. In the experimental group students' pre-test scores were 4.86% and the scores of students in the control group were 5.81%.

After the learning process is carried out, each class was given a post-test. The post-test score in the experimental group was 74.67% while the acquisition score in the control group was 47.62%. This shows that the implementation of the ADI model is better at developing generic science skills than the guided inquiry model. The results of the pre-test and post-test generic science skills in the control and experimental group can be seen in Figure 1.

![Figure 1. The Result of Pre-test, post-test, and \( \bar{x} \) N-gain on Generic Science Skills](image)

Furthermore, statistical tests were conducted to find out whether there were significant differences in pre-test scores in the experimental and control groups. The results of the statistical analysis can be seen in Table 3.

| Indicator          | Group     | Mean±SD | Shapiro-Wilk \(^1\) | Detail         | Z     | Sig. | Mann-Whitney test for Significant Differences \(^2\) |
|--------------------|-----------|---------|----------------------|----------------|-------|------|---------------------------------------------------|
| Generic Science    | Experimental | 4.855±3.53 | 0.008 | Normal            | -0.94 | 0.35 | No difference                                    |
|                    | Control    | 5.807±3.08 | 0.126 | Normal            |       |      |                                                   |
| Concept Mastery    | Experimental | 6.44±3.43  | 0.06   | Not Normal        | -1.47 | 0.14 | No difference                                    |
|                    | Control    | 7.33±2.70  | 0.020  | Not Normal        |       |      |                                                   |

Where:

1\(^1\) = *Shapiro-Wilk test* (Normal: Sig>0.05)

2\(^2\) = *Uji Non-Parametric Mann-Whitney* (Sig. Difference<0.05)
The Mann-Whitney non-parametric test results showed that there were no significantly difference between students in the experimental and the control group on generic science skills. Then, the analysis continued on changing the generic ability of students’ science after the application of learning using pre-test, post-test, and N-gain, \(<g>\). Based on the test results, the average N-gain of students in the experimental and control group was 73.4% and 44.3% (Figure 1). The experimental group is in the high category, while the control group is in the medium category [11]. Furthermore, statistical analysis is performed on the average N-gain between the experimental and the control group. The results of the statistical analysis can be seen in Table 4.

Table 4. \(<g>\) in the Experimental and Control Group

| Indicator          | Group      | Normality test Shapiro-Wilk\(^1\) | Levene test utk Homogeneity of Variance\(^2\) | t-test for Significant Differences\(^3\) |
|--------------------|------------|-----------------------------------|----------------------------------------------|------------------------------------------|
|                    |            | Mean±SD              | Sig.    | Detail | F      | Sig.    | Detail | t      | Sig.    | Detail |
| Generic Sains Skill| Experimental| 0.734±0.08         | 0.818   | Normal | 0.85   | 0.36    | Homo.  | 11.23  | 0.000   | Sig. Difference |
|                    | Control    | 0.442±0.09         | 0.799   | Normal |         |         |        |        |         |        |
| Concept Mastery    | Experimental| 0.725±0.06         | 0.072   | Normal | 0.74   | 0.39    | Homo.  | 11.49  | 0.000   | Sig. Difference |
|                    | Control    | 0.493±0.07         | 0.483   | Normal |         |         |        |        |         |        |

Where:
\(^1\)= Shapiro-Wilk test (Normal: Sig>0.05)
\(^2\)= Levene’s test (Homogen: Sig>0.05)
\(^3\)= Uji Independent Sample T test (Sig. Difference<0.05)

The independent sample \(t\)-test results show that there is a significantly different in the average N-gain between the experimental class and the control class, namely the higher experimental class (\(M = 0.734; SD = 0.08\)) compared to the control class (\(M = 0.442; SD = 0.09\)). Furthermore, an analysis of the mastery of generic science skills from the sub-indicators is carried out. Based on the results of the analysis, the highest average N-gain value in the experimental class was obtained in the mathematical modelling sub-indicator (86.5%), followed by the causal law (78.3%) and symbolic language (77.2%). These three sub-indicators are classified in the high category. However, building a concept (47.3%) is the lowest sub-indicator that can be achieved by students and classified as being in the medium category [11]. The results of the recapitulation of the average N-gain from each sub-indicator can be seen in Figure 2.
Where
1 = Causality
2 = Symbolic Language
3 = Mathematical Modelling
4 = Concept Formation

Based on the findings and statistical analysis of the generic ability of science, it can be said that the ADI learning model is better than guided inquiry in the legal sub-indicators of causality, symbolic language, and mathematical modelling. Whereas students’ gain of concept formation sub-indicator of guided inquiry learning model is not significantly different in the ADI model.

The results of the data analysis showed that the ADI learning model was effective in improving students’ generic science skills compared to the guided inquiry model. Students begin to hone their generic science skills starting from the first stage of ADI. When doing the practicum, students will be asked to work with colleagues to identify and skillfully use causal laws to answer the problems faced, so they find solutions to answer these problems. For example: when two solutions containing salt ions are difficult to dissolve mixed little by little, a precipitate will emerge from the mixing of the two solutions, why does the precipitate not appear at first? Why does the precipitate appear after a few ml is mixed? Through the ADI model too, students will practice recognizing symbolic language from practicum, the process of building arguments, to writing investigative reports, for example, the Ksp symbol to state the solubility product constant, to indicate the solubility of a salt, to $s$ and $aq$ to indicate substance phase.

Integration of Students’ generic science skills with ADI indirectly have honed their generic skills, conceptually these skills will also help them to understand their strengths and weaknesses when facing problems and help them solve them based on their own strengths [12]. Moreover, ADI learning models also provide opportunities for students to find various mathematical relationships during learning activities, which are then formulated in mathematical equations / mathematical modelling. This is according to Ling’s research, which states that acid-base titration activities can improve generic science skills [2].

Compared to the three KGS sub-indicators above, concept building is the most difficult to improve generic science skills. This proved to only produce an N-gain of 47.5%, the lowest among other KGS sub-indicators. This is because in the ADI model the teacher only acts as a facilitator and must refrain from giving explicit direction, so that understanding and knowledge are actually built and developed by students from practicum activities, followed by constructing tentative arguments, then arguing to the final writing investigative report [10].

3.2 Students’ Concept Mastery

The results of the pre-test showed that the two classes had an understanding concepts that were not much different in solubility product constant. In the experimental class students’ pre-test scores were 6.44% and the scores of students in the control class were 7.33%.

Furthermore, given a post-test after the implementation of each model. The post-test score in the experimental group was 74.30% while the score in the control group was 53.04%. This shows that the implementation of the ADI model is better in improving students’ understanding of concepts compared to the guided inquiry model. The results of the pre-test and post-test understanding of students’ concepts in the control and experimental groups can be seen in Figure 3.
Furthermore, statistical tests were conducted to determine whether there were significant differences in student pre-test scores. The results of the Mann-Whitney non-parametric test showed that there was no significant difference in concept understanding between students in the experimental class and the control class. Then, the analysis continued on changing students' conceptual understanding after the application of learning using pre-test, post-test, and N-gain. Based on the test results, the average N-gain of students in the experimental group and the control group was 72.5% and 49.2% (Figure 3). The experimental group is in the high category, while the control group is in the medium category [13]. Furthermore, statistical analysis is performed on the average N-gain between the experimental and the control group. The results of the statistical analysis can be seen in Table 4. The independent sample t-test results show that there is a significant difference in the average N-gain between the experimental and the control group, namely the higher experimental group (M = 0.725; SD = 0.06) compared to the control group (M = 0.493; SD = 0.07). Furthermore, an understanding of the concept of each concept label is analysed. Based on the results of the analysis, the highest N-gain in the experimental group was obtained by the concept label of the constant solubility (Ksp) (74%), followed by Qc (71.3%) and solubility (65.8%). The sub-concept of the solubility product and Qc results are classified into the high category while the sub-concept of solubility in the medium category (see Figure 4).

The results of data analysis showed that in general the two groups studied had an increase in concept understanding on each concept label, but the increase in the experimental class was higher than the control class. Because, starting from the first step, students have been required to carry out deep learning by generalizing and analysing data, then will be used as a basis for constructing valid and scientific arguments. This is parallel with the walker and Sampson research which says that each stage
of ADI is intended to enable students to develop skills and knowledge to collect data needed for scientific inquiry [13]. Furthermore, the results of N-gain analysis on each concept label. The label of the Solubility concept, the solubility product constant (KSP), and the Qc in the experimental class showed a significant difference from the control group. From the three concept labels the solubility (65.8%) is the lowest concept label, but when compared to the control class (30.5%) the label of the concept of solubility is the biggest concept of the difference. This is because the ADI learning model provides an opportunity for students to build knowledge based on experience experienced [4], in addition to the existence of tentative argument building stages and argumentation activities that contribute greatly to the process of understanding concepts [14].

4. Conclusion
This paper has presented a study with the aim to examine how the effectiveness of the ADI model on the generic ability of science and the understanding of the concept of high school students. Based on data analysis, it can be concluded that learning with the Argument-Driven Inquiry (ADI) model is more effective in developing generic science skills and students’ understanding concepts. The highest N-gain of the generic science skills sub-indicator is mathematical modeling (86.5%) and the understanding concept is obtained by the solubility constant product (74%). The lowest N-gain of the generic science skills sub-indicator is concept formation (47.3%) and the understanding concept is obtained by the solubility (65.8%).

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