The effect of argument-driven inquiry on chemistry reaction-rates to enhance pre-service chemistry teachers critical thinking skills

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Abstract. This research aims to determine the effect of using the Argument Driven Inquiry (ADI) learning model on the critical thinking skills of pre-service chemistry teachers on the topic of reaction rate. The study participants comprised of 20 pre-service chemistry teachers enrolled in a School Chemistry 1 unit. This research uses quasi experiment with one group pretest-posttest design method. The data collected through two-tier multiple choices test which refers to the indicator of critical thinking skills by Ennis before and after with Argument-Driven Inquiry model. Pretest and posttest result data were analyzed using Wilcoxon's nonparametric statistical test. The results showed that there was an influence of the application of the Argument Driven Inquiry learning model to the critical thinking skills of students as indicated by the sig value. of 0.000 at a 95% confidence level. based on these results, it can be concluded that the implementation of Argument Driven Inquiry model effective to improve the critical thinking skill of pre-service chemistry teachers. Critical thinking skills in each sub-indicator were analyzed using normalized gain and the results obtained n-gain values for the indicator determine an action 0.73 (high), focus questions: 0.69 (medium), analyze arguments: 0.56 (medium) and to make deductions and consider the results of deductions: 0.40 (medium). These N-gain results indicate that ADI learning can improve pre-service chemistry teachers' critical thinking skills on these four indicators.

1. Introduction
Critical thinking is a skill needed in 21st century education [1]. Critical thinking skills are needed by each individual to be flexible to adapt and better in processing the information received [2]. Individuals who think critically have better meanings of ideas, are open to various approaches and points of view and determine for themselves what to believe or what to do [3]. Critical thinking skills have the potential to promote the quality of human beings, because these skills are very important in helping students to solve problems.

Critical thinking is recognized as a valuable set of skills for college graduates. However, based on the results of research by Irwanto involving 220 prospective chemistry teachers at one of the state universities in the Yogyakarta area shows that the average score of students' critical thinking skills is still considered low [4]. This is supported by another research which shows that the critical thinking skills of chemistry education students at one of the state universities in Pontianak are in the less skilled category, but based on academic data, these students have an average GPA of 3.3058 which is in the very satisfying category [5]. These data show that there was no guarantee that students with high GPA will have high critical thinking skills, and vice versa.
The results of these studies are supported by the results of a survey conducted by Goeden, Kurtz, Quitadamo & Thomas shows more than 80% of scholars believe that their learning experience generates critical thinking, but the test results use the California Critical Thinking Skills Test (CCTST) shows that only 5% have critical thinking skills, with more than 80% showing no skills [6]. Based on these facts prove that most college students have not mastered critical thinking skills. Critical thinking is a cognitive activity of someone by involving rational thinking and skilled in reasoning an idea [7]. Critical thinking is evaluative thinking and related to arguments. critical thinking can be contained in the form of oral and written arguments [8]. The ability to analyze and construct an argument is one of the things needed in critical thinking skills [9, 10].

The initial survey was conducted by researchers involving 100 respondents consisting of pre-service chemistry teacher and in-service chemistry teacher showed that the topic of reaction rate was one of the topic that was still difficult for pre-service teachers to understand. The topic of reaction rate is considered as one of topic that is difficult to study because it covers the basic concepts of chemistry [11]. The reaction rate is a complicated topic because it brings together various mathematical visualizations, accessing conceptual and contextual [12]. Teachers concept mastery plays an important role in students' understanding of concepts, therefore, helping prospective teachers in building understanding of concepts is very important in teacher education.

One effort to improve critical thinking skills and concept mastery is to apply an argument-based learning model, namely Argument-Driven Inquiry (ADI) [13]. ADI is an argumentation based learning model with inquiry laboratory experiments. In experimental activities students are able to express scientific arguments from research questions that have been given, and can answer hypotheses, change methods, and a trade-off of what has been done during experiments. So that through these labs experimental activity they can build higher-order thinking skills (HOTS) [14].

The stages of ADI include (1) identifying tasks that aim to frame the objectives of class activities in an effort to develop, understand and evaluate scientific explanations for a phenomenon or solution to a problem; (2) collecting and analyzing data that aims to involve students in the investigation; (3) produce tentative arguments aimed at encouraging students to learn how to produce arguments that provide explanations for research questions as part of the inquiry process; (4) argumentation session; (5) make an investigation report; (6) peer review and (7) revision that aim to provide opportunities for students to learn how to propose, support, evaluate, revise ideas through discussion and writing in a more productive manner, creating a class community that values evidence and critical thinking and encourage students to take control of independent learning [15, 16].

The ADI model provides opportunities for students to actively participate in scientific argumentation and peer review. The opportunity to formulate arguments gives students the opportunity to construct their understanding of the basic concepts of chemistry which are then used in the process of learning about reaction rates. When students are asked to build and maintain their answers, students are guided to think critically and reach higher levels of abstraction [17]. Through a combination all of these activities, the Argument-Driven Inquiry learning model is expected to improve the critical thinking skills of prospective chemistry teacher students. Therefore, in this study used Argument Driven Inquiry learning to improve the critical thinking skills of pre-service teachers on the topic of reaction rates.

2. Methods

The method used in this study is a quasi-experimental method using one-group pretest-posttest design. The subjects of this study were 20 students who were enrolled School Chemistry 1 unit at one of the State Universities in Bandung. Due to the outbreak of the covid-19 pandemic, ADI learning was implemented online classroom. A two-tier multiple choices test consisting of 11 questions adjusted to four sub-indicators of critical thinking skills according to Ennis (analyzing arguments, focusing questions, determining an action and determining considering the results of deduction). This test is given before and after learning and then the students' answers are converted into scores. The pretest and posttest scores were analyzed using SPSS 22 statistics.

Critical thinking skills data obtained from the pretest and posttest were then analyzed using N-Gain which aims to see improvement after treatment. Then the N-gain value obtained is interpreted based on the criteria listed in Table 1.
Table 1. N-Gain Level Category

| N-gain       | Criteria |
|--------------|----------|
| \((g) \geq 0.70\) | High     |
| \(0.30 \leq (g) > 0.70\) | Medium   |
| \((g) < 0.30\)         | Low      |

3. Result and Discussion
Critical thinking skills were measured before and after learning the reaction rate with the Argument Driven Inquiry learning model. The initial test aims to determine the students’ critical thinking skills before participating in learning the reaction rate with the ADI learning model. The average value of the pretest results is 61.28. The initial test results are then compared with the final test results to determine the effect of learning the reaction rate with ADI learning on pre-service chemistry teachers’ critical thinking skills with the help of statistical tests. Statistical test results are presented in Table 2 and Table 3.

Table 2. The Average value of pre-test and post-test and normality test result

| The Average value of pretest and posttest | Saphiro-Wilk Normality Test Results |
|------------------------------------------|------------------------------------|
| N            | Average value | N-gain | Sig | Criteria |
| Pretest      | 20            | 61.28  | 0.65 | 0.831 | Normal |
| Post-test    | 20            | 86.28  | -3.922 | .000 | Not normal |

Based on the results of the Saphiro-Wilk test it was found that the pretest value data were normally distributed while the post-test value data were not normally distributed so that the next test conducted was a non-parametric test. Because the method used is one group pretest-posttest, the non-parametric test used is the Wilcoxon test.

Table 3. Wilcoxon Non-parametric Test Results

| Scores   | N  | Mean Score | Sum of Scores | Z       | Asymp. Sig. (2-tailed) |
|----------|----|------------|---------------|---------|------------------------|
| Posttest-pretest Negative Scores | 0 | .00 | .00 |         |                        |
| Positive Scores | 20 | 10.50 | 210.00 | -3.922 | .000                   |
| Ties | 0 |         |               |         |                        |
| Total | 20 |         |               |         |                        |

Wilcoxon non-parametric test results as shown in Table 3 show that there is a significant difference between the pretest and posttest values. In the table there are negative scores which show the difference (negative) between learning outcomes for the pretest and posttest is 0, both on the value of N, Mean score, and sum score. This value of 0 indicates no decrease from the pretest value to the posttest value. Positive scores show the difference (positive) for the pretest and posttest. In the positive scores column it can be seen that the value of N indicates that 20 pre-service teachers have improved learning outcomes from pretest to posttest with an average increase of 10.50. Ties show the similarity of the pretest and posttest scores, because the ties value is 0, it can be concluded that there is no similar score between the pretest and posttest scores.

Next is an analysis of mastery of critical thinking skills on the critical thinking skills sub-indicator. Sub indicators analyzed include analyzing arguments, focusing questions, determining an action, and deduction and considering deduction result. The highest N-gain score is on the sub-indicator deduction and considering deduction result obtained a score of 0.73 with high criteria. Then in the sub-indicator focusing the question, analyzing the argument and determining an action the N-gain score is successively 0.69; 0.56 and 0.40 are included in the medium category. The results of the pretest posttest and N-gain scores for each sub-indicator can be seen in Table 4.
Table 4. Results of Analysis of Critical Thinking Skills for Students on each sub-indicator

| Critical Thinking Skills Sub-Indicator | Average value | Criteria |
|---------------------------------------|---------------|----------|
|                                       | Pretest  | Posttest | N-gain  |          |
| Analyze arguments                      | 46.25    | 76.25    | 0.56    | Medium  |
| Focus the question                     | 46.25    | 83.12    | 0.69    | Medium  |
| Determine an action                    | 83.44    | 90       | 0.40    | Medium  |
| Make deductions and consider the       | 48.125   | 86.25    | 0.73    | High    |
| results of deductions                  |           |          |         |          |

Based on the analysis of the results of the study it can be argued that Argument Driven Inquiry learning can improve students' critical thinking skills in the topic of reaction rate. From the results of the pretest and posttest on the reaction rate learning using the Argument Driven Inquiry model, the average N-gain value is 0.65 with the medium category. Even though they are in the medium category, the analysis of the average difference in critical thinking skills generally shows that there is a significant difference between the pretest and posttest scores shown in the Table 3. This proves that the ADI learning model can improve students' critical thinking skills on the topic of reaction rate.

Increased critical thinking skills in the four sub-indicators can be understood because starting from the stage of identifying the task, analyzing data, designing arguments to writing reports, students have used their critical thinking skills. This means that with the ADI learning model students are continuously trained and demanded to use their critical thinking skills to solve the problems presented. ADI learning model is able to help students to develop critical thinking skills [18]. This is also supported another research which says that the ability to think critically is influenced by various factors, especially the structure of someone's thinking. This structure of thought can be expressed through language, both oral and written, which is then referred to as argumentation. Thus, the application of the ADI model enhances students' critical thinking skills [14].

The application of the ADI Model is based on constructivist learning theory. Constructivist learning theory is a learning theory that conceptualizes learning as a result of constructing meaning based on experience and prior knowledge [19]. Based on this theory, the application of the ADI model will train students' argumentation skills in the process of making, revising and evaluating arguments. The argumentation skills of students trained through the ADI Model will be stored and will be used when these argumentation skills are needed. When students are active in the ADI learning process, students will experience making and evaluating arguments so they can improve their argumentation and critical thinking skills [20]. The stages carried out in learning are explained below.

At the beginning of learning, students are reminded again about the definitions and characteristics of chemical reactions and then students are asked about the definition of reaction rates that they already knew at high school so students will recall the knowledge they already have. After that students are instructed to read phenomena and direct questions about the collision theory and the factors that affect the rate. This stage is in accordance with one of critical thinking skills indicator that is focusing questions. The category of focusing questions is Identifying or formulating questions and identifying or formulating criteria to consider possible answers [7]. At this stage, teacher connects students' initial knowledge with knowledge that will be obtained after learning so that students will be interested and motivated to carry out learning. [21].

In the stage of generalizing and analyzing data, students are asked to watch a demonstration video that the researcher has prepared about the collision theory and the factors that influence the reaction rate. After watching the video, students were required to fill in the observation table and analyze data from the results of the experiment in the demonstration video. At this stage one indicator of critical thinking skills that can be trained on students is the indicator determining action. The categories of indicators determining action are defining the problem, selecting criteria for making solutions, determining what needs to be done temporarily and monitoring implementation. At this stage students have the opportunity to conduct scientific investigations such as interpreting research results and analyzing data. [21]
In the stage of making tentative arguments and carrying out arguments, students are asked to formulate their arguments about the collision theory and the factors that influence the rate of reaction and then students are asked to present their arguments to their other colleagues. This stage corresponds to one of critical thinking skills namely analyzing arguments. The categories of analyzing arguments are identifying stated and unstated reasons, looking for similarities and differences, identifying and dealing with irrelevance, finding the structure of arguments, and summarizing. This stage aims to make students able to build good quality arguments that include claims, data, warrant and backing. After that students can compare the arguments that have been built with the arguments of other peers so that students can consider which arguments are better and more reliable [21]. The various ideas put forward by students at this stage can make learning more meaningful and interesting [22].

At the report making stage, students are asked to make a learning report that has been done with the format: objectives, hypotheses, theoretical basis, observations, data analysis, conclusions and bibliography. The stage of making a report gives students the opportunity to express their findings, ideas and supporting reasons that they obtained during learning in a scientific paper so that students can strengthen their mastery of concepts and improve their writing abilities [21]. Learning how to write can help students understand the content being investigated because the writing process encourages metacognition [23].

At the peer review and revision stage, the reports that are collected are then reviewed by other groups. Each group was given a peer review sheet to determine whether the report reviewed was acceptable or needed to be revised. Besides that, on the peer review sheet students are also asked to provide feedback to the group being reviewed in order to improve the quality of their report. At this stage students can get feedback about the scientific work that has been done, train students to determine the quality of scientific work and train students to appreciate the ideas and critical thinking expressed by other students in the class [21,16]. At the stage of making reports, peer reviews and revisions, one of the critical thinking skills that can be trained is making and considering the value of decisions.

Based on the explanation above, ADI learning can improve students' understanding of the concept of reaction rate and can provide opportunities for students to practice scientific methods and engage in argumentation so that students can develop their critical thinking skills. Individuals who think critically must be able to ask accurate questions, gather relevant information effectively and efficiently, have logical reasons from certain information, and draw conclusions that are consistent and reliable [8]. This is also reinforced by the results of another research which showed that students' argumentation skills were positively correlated with students' critical thinking skills [24].

Table 4. shows that the increase in critical thinking skills with ADI learning varies on each sub-indicator that is in the category of medium to high. This variation in the increase in the sub-indicator of critical thinking skills shows that the ADI learning model provides a positive response to the improvement of students' critical thinking skills. This is because ADI learning does not only carry out practical activities but is also integrated with discussions, lectures, writing and reading. Based on research that has been done previously laboratory learning with SWH and discussion methods can improve critical thinking skills [25, 26].

Compared to the other 3 sub-indicators, the sub-indicator determines that an action has the lowest N-gain score, this is because the initial test results obtained by students are good with an average pretest score of 83.44, in the sub-indicator determining an action a student is given a problem regarding the mathematical resolution of determining the law of the rate and order of reaction. Since students have studied reaction rates in high school and physics chemistry courses, it can be understood if students can take initial tests on sub-indicators to determine an action very well.

4. Conclusion
The process of knowledge construction in arguing with the Argument-Driven Model in students can improve critical thinking skills as indicated by the value of N-gain obtained from the students' pretest and posttest scores (<g> 0.65). Based on the Wilcoxon test results it can be concluded that the implementation of the Argument-Driven Inquiry model can improve students' critical thinking skills. Argument Driven Inquiry learning can improve students' critical thinking skills on indicators of deduction and considering deduction result, focusing questions, analyzing arguments and determining
an action. The highest increased of students critical thinking skills on the indicator deduction and considering deduction result (<g> 0.73), while the lowest in the indicator determining an action (<g> 0.40).

5. References

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