The implementation of Argument Driven Inquiry (ADI) learning model to improve scientific argumentation skills of high school students

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Abstract. This study aims to describe the implementation of the ADI learning model on physics learning of Newton's laws, the skills of scientific argumentation of students after learning, and the patterns of scientific argumentation students. This research method used explanatory sequential mixed method design. Data collection methods used in this study were tests, documentation and observation. This research was conducted in Surabaya, East Java, Indonesia. Eighty-five of ten grade students on three classes and one teacher participated in this study. This study applied a scientific argumentation level framework developed by Erduran to determine the level of scientific argumentation skills that can be achieved by students. The results showed that ADI learning model was carried out very well for 3 classes with an average percentage of feasibility for Science Classes 1, 2, and 3 as a whole involving 86.67%, 87.08%, and 88.75%. Scientific arguments of students show a significant increase, with a significance of n-gain values obtained in the medium category. The pattern of changes in the skills of scientific argumentation of students from levels 1 and 2 in the pre-test increased to levels 3 and 4 in the post-test. The reason for the skills of scientific argumentation of students is in accordance with the scientific argumentation skills verbally. Based on these results it can be concluded that the application of the ADI learning model improve scientific argumentation skills of students.

1. Introduction
The 2013 Indonesia’s curriculum learning contains 21st century skills that are considered capable of strengthening social capital and intellectual capital. The 21st century skills referred to are the 4C capabilities, namely communication, collaboration, critical thinking and problem solving, and creativity and innovation [1][2][3]. Kivunja states that the fundamental ability that must be achieved by students is the ability to think critically [4] [5]. There are several indicators in critical thinking, one of them is stated students are able to think critically if they are able to analyse, understand and evaluate argument statements in a learning.

According to Duschl & Osborne [6], it is stated that an explanation of reasoning for a solution related to the substance of claims, evidence, and support is called an argument while something related to the process of obtaining and organizing these components is called argumentation. Based on research conducted by Roshayanti [7], the results show that learning outcomes and student performance through argumentative activities can increase. This is supported by the results of Erduran’s research [8], which states that to strengthen self-understanding, a student needs an argument in each lesson. Therefore, it is very necessary to have activities to train and develop students' argumentation skills in each learning.
Research conducted by Mahardika found that in physics learning, out of 21 high school students only 7 students had high level argumentation skills [9]. This shows that the ability of scientific argumentation of students in learning physics is still in the low category. According to the Ministry of National Education [10], physics is one of the subjects that is a means to develop the ability of analytical thinking inductive and deductive in explaining various natural events and solving various problems both quantitatively and qualitatively. Qualitatively solving problems in physics learning can certainly be trained through argumentative activities. However, based on observations during the Learning Management Program activities, it was found that in physics learning, the exercises given to students tended to be mathematical problems that did not yet contain indicators of practicing argumentation skills. For this reason, there is a need for argumentation-based physics learning.

Argument Driven Inquiry (ADI) learning model is a laboratory-based learning model that is able to encourage students to engage in experimental activities as well as scientific argumentation activities [11]. The laboratory-based ADI learning model is very relevant to be used in physics learning, because basically physics learning must be laboratory-based to practice the science process skills of students. In addition, by applying ADI learning in physics learning it is expected to be able to practice the students' scientific argumentation skills.

Based on the description above, it is necessary to conduct a study by applying the ADI learning model to practice the students' scientific argumentation skills in learning physics. In this study Newton's Law of Motion material was used. Newton's laws of motion are considered to have real objects that are often encountered by students in daily life so that this will facilitate students in understanding the phenomena displayed and facilitate students in designing scientific activities.

Another reason that supports the choice of Newton's laws of motion material is that researchers assume that in learning physics with this material, debates will emerge that can stimulate students to argue. This happens because, according to research conducted by Muna, the results are obtained that students have an understanding that where objects do not move means there is no working force [12]. This is raised in learning will bring up some debate. Because in Newton's first law stated about the law of inertia. Through this law, it can be explained that in stationary objects there could be forces work to objects. Thus, in learning physics Newton's law material about motion will emerge a debate that will require students to prepare arguments in order to strengthen their understanding. Based on the explanation of the background above, the researcher will conduct this study to Implement argument driven inquiry (ADI) learning model to improve scientific argumentation skills of high school students.

2. Methods
This research is mix methods study with sequential Explanatory design [13][14]. This research was conducted on February 2019 at a public senior high school in Surabaya, Indonesia. The sample used in the study was determined by a purposive sample technique, that is the research sample was determined based on the consideration of researchers who considered the desired elements already existed in the sample members taken [15]. Thus, one experimental class is used, namely class X MIA 3 with 2 classes of replication, namely class X MIA 1 and X MIA 2 (MIA is mathematics and science class in Indonesia). Data collection methods used in this study were tests, documentation and observation.

The scientific argumentation skills of students is divided into two parts: scientific argumentation skills in writing and orally. Analysis of students' scientific argumentation skills is done with two techniques namely quantitative data analysis and qualitative data analysis. Quantitative data analysis is performed to determine the increase in students' scientific argumentation abilities based on the pre-test and post-test scores. Quantitative data analysis uses statistical analysis with t-test and n-gain test. While qualitative data analysis is carried out to determine the level of scientific argumentation skills that can be achieved by students. The way to determine the level of scientific argumentation skills that can be achieved by students is to use a scientific argumentation level framework developed by Erduran [16], as follows.
3. Result and Discussion

The following are the results of increasing the ability of scientific argumentation achieved by students after Argument Driven Inquiry (ADI) learning model implementation. Increased of students' scientific argumentation skills is based on a comparison of the level of argumentation that students can achieve in the pre-test with the level of argumentation that can be achieved by students in the post-test.

**Table 2. Students scientific argumentation skills in class X MIA-1**

| Subject matter | Question number | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|----------------|----------------|--------|--------|--------|--------|--------|
|                |                | T1     | T2     | T1     | T2     | T1     | T2     |
| Newton's 1st Law | 1              | 5      | -      | 19     | 1      | 5      | 23     | -      | 5      | -      | -      |
| Newton's 2nd Law | 2              | 1      | -      | 11     | 1      | 14     | 15     | 3      | 13     | -      | -      |
| Newton's 3rd Law | 3              | 2      | -      | 18     | 1      | 49     | 20     | -      | 8      | -      | -      |
| Newton's 3rd Law | 4              | 9      | -      | 1      | 16     | -      | 10     | -      | 1      | -      | -      |
| Newton's 3rd Law | 5              | 1      | 23     | -      | 6      | -      | -      | -      | -      | -      | -      |

**Table 3. Students scientific argumentation skills in class X MIA-2**

| Subject matter | Question number | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|----------------|----------------|--------|--------|--------|--------|--------|
|                |                | T1     | T2     | T1     | T2     | T1     | T2     |
| Newton's 1st Law | 1              | 7      | -      | 12     | 2      | 9      | 24     | -      | 2      | -      | -      |
| Newton's 2nd Law | 2              | 7      | -      | 11     | -      | 8      | 7      | -      | 21     | -      | -      |
| Newton's 3rd Law | 3              | -      | -      | 19     | 1      | 8      | 13     | -      | 14     | -      | -      |
| Newton's 3rd Law | 4              | 8      | 19     | -      | 9      | -      | -      | -      | 1      | -      | -      |
| Newton's 3rd Law | 5              | 3      | 28     | -      | -      | -      | -      | -      | -      | -      | -      |
Table 4. Students scientific argumentation skills in class X MIA-3

| Subject matter | Question number | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|----------------|----------------|--------|--------|--------|--------|--------|
| Newton's 1st Law | 1              | 6      | -      | 14     | 1      | 8      | 24     | -      | 3      | -      | -      |
| Newton's 2nd Law | 2              | 8      | -      | 7      | 4      | 9      | 8      | 3      | 16     | -      | -      |
| Newton's 3rd Law | 3              | 5      | -      | 15     | 1      | 4      | 16     | -      | 11     | -      | -      |

Information:

T1 : the number of students who reach a certain level in the pre-test
T2 : the number of students who reach a certain level in the post-test

Based on the results of paired t-test on the value of the pre-test and post-test results achieved by students from all three classes, it was found that the value of t-count in the three classes is greater than the value of t-table. Obtained t-value of class X MIA 1, 2 and 3 in a row that is 13.682; 11.201; and 14.330 with t-table values from class X MIA 1, 2 and 3 respectively 2.048; 2.052; and 2.052. This shows that there is an average difference in the pre-test and post-test results. Next, based on the n-gain test, the average n-gain score for class X MIA-1 is 0.275 with a low category and for class X MIA-2 and X-MIA 3, it is obtained an average of successively 0.349 and 0.427 in the medium category. This shows that there is an increase in the ability of scientific argumentation of students from all three classes.

Based on Table 2 to Table 4 shows that in Newton's 1st Law material most of the scientific argumentation skills of students are at level 2 in the next pre-test, most are able to reach level 3 in the post-test. In Newton's 2nd Law material, most of the scientific argumentation abilities of students are at level 1 to 3 in the next pre-test, most are able to reach level 3 and 4 in the post-test. Whereas in Newton's 3rd Law material in the pre-test most of the ability of scientific argumentation of students is at level 1 and there are most students who are not able to provide scientific arguments appropriately on this material. Next, in Newton's 3rd Law material, most students were able to reach levels 2 and 3 in the post-test.

The students' scientific argumentation skills for each sub-chapter of the material is different. In Newton's 3rd Law material students have the ability to argue in the low category, because most students are not able to provide arguments correctly and most of the scientific argumentation abilities that can be achieved by students on this material are limited to level 1. This is caused by several things including the low understanding of learners on Newton's 3rd Law material. Students have an understanding that gravity and normal forces acting on an object are a pair of action and reaction forces. Students ignore that the action and reaction styles work on different objects, of course with this understanding students are not able to provide scientific arguments appropriately.

The results of the increase in the ability of written scientific argumentation of students above are supported by the ability of scientific argumentation of students orally. Following are the results of the analysis of students' scientific argumentation skills verbally. The following description is a transcript of students' conversation tendencies in responding to the questions in the argumentation session in Newton's 1st Law material.

Phenomenon question:

When you are on the bus in a standing position, suddenly the bus driver stepped on the gas and the bus drove. How is your body responding? Explain your opinion!

Based on the phenomenon questions above the representative students from several groups present their arguments as described below. Group 3 representative, Sinta gave the following statement:
"... When the bus driver steps on the gas, the body's response will be pushed back because our body maintains its initial position, this is the same as Law 1, the same as the Law of Inertia ..."

The statement is a statement of argument at level 3. Students state a simple claim "... when the bus driver stepped on the gas ..." supported by data that is the statement "... the body's response will be pushed back ...", accompanied by an explanation of the relationship between the claim and the data submitted, in the form of a statement "... because our bodies maintain their original position ...". In this statement contains justification with the theory (backing), but the backing provided is very weak.

The following description is a transcript of students' conversation tendencies in responding to the questions in the argumentation session in Newton's 2nd Law material.

**Phenomenon question:**
There are 3 trolleys that are the same but contain different loads, trolley 1 is free, trolley 2 contains a small load, and trolley 3 contains many loads. If the force applied to push the trolleys is the same, Which trolley will be easy to move? Explain your opinion!

Based on the phenomenon questions above the representative students from several groups present their arguments as described below. Group 2 representative, Mala gave the following statement:

"According to our group the easiest is trolley 1 because there is no burden. If according to theory according to Newton's 2nd Law theory because the force is the same and trolley one has no load so it's easier to push trolley number 1"

Based on the quotation, the statement is an argument at level 3. Students are able to provide simple claims accompanied by data accompanied by warrant (statement of the relationship between claims and data). Students also provide backing (justification with theory), but backing is given in the weak category.

The following is a transcript of the tendency of students' conversations in responding to questions in the argumentation session in Newton's Law 3 material.

**Phenomenon question:**
All objects that are on the surface of the earth have a gravity (w) in the downward direction due to gravity and have a normal force (N) in an upward direction, are w and N a pair of action and reaction forces?

Based on the above question, Siti gives the following statement:

"... in our opinion yes, the action of the cardboard squeezed under the floor and the reaction of the N cardboard, is in accordance with Newton's 3rd Law ..."

Statements delivered by students are statements of argumentation at level 1 and the statements given are not appropriate to answer the questions given.

Based on the results of an analysis of the ability of oral scientific argumentation from the students above it was obtained that the ability of students' oral scientific argumentation for Newton's 1st, 2nd and 3rd Law material were respectively at levels 3, 3, and 1. These results support the results of the ability written scientific argumentation of students obtained from the results of the pre-test and post-test. Thus, the applied ADI learning model can be declared able to improve the students' scientific argumentative skills.

4. **Conclusion**
The Argument Driven Inquiry (ADI) learning model is able to improve the scientific argumentation skills of high school students. This is supported by the results of t-test and n-gain calculations which show an increase in students' scientific argumentation skills. Next, based on the analysis of qualitative data it is found that in the pre-test the average skills of scientific argumentation of students is at level 1 and 2 while in the post-test the skills of scientific argumentation of students is able to reach levels 3 and 4. This is supported by the results of the skills analysis oral argumentation of students.
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