Comparison of building understanding of students on newton’s laws with phenomenon-based ADI with assessment formative and ADI models

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Abstract. The Newton's laws cannot be separated from mechanics and real life phenomenon, but research is rarely done on improving understanding of Newton's law through ADI-Phenomenon-AF. The purpose of the research was to compare the effectiveness between ADI-Phenomenon-AF and ADI models in building understanding of Newton's law and describing students' difficulties after the learning process. This study used a mixed method design with an embedded experimental design. The instrument of this study was Newton's law Understanding Test in the form of reasoned multiple-choice questions with a reliability of 0.817. The research data were analyzed by Wilcoxon test, Mann-Whitney U test, N-gain, d-effect, and a description of the reasons for students' answers. The results show that both models are effective in building students' understanding, but the ADI-Phenomenon-AF model is more effective than the ADI model. After the learning process the students of both classes still have difficulty in analyzing the relationship between acceleration, force, and mass. In addition, ADI-Phenomenon-AF class students still have difficulty with the nature of force in Newton's first law, while the ADI class analyzes the application of Newton's first and second laws.

1. Introduction
Newton’s Law covers the concept of force and motion and is one of basic concepts in Physics which is applied on many phenomena in daily lives [1,2]. Newton’s Law has important role in learning concept of Mechanics and in explaining the phenomena in real world [3]. However, Newton’s Law is a fundamental topic which is considered as difficult by students. Students only master around 30% of the concept of Newton’s Law about motion [4]. Students have difficulties in understanding Newton’s First Law, for example, on the case of an object at rest, students assume that gravity works on the object but they don’t understand the presence of normal force. Another example is for the Newton’s Second Law, students assumed that if the net force of an object is not equal to zero, then the object will move at constant velocity. On Newton’s Third Law, students have an understanding that gravity is the reaction force of the normal force [5]. The research which was done by [6], on Newton’s First Law, students assumed that forces will always be needed by an object for it to keep on moving; on Newton’s Second Law, students assumed that the forces which affect an object are equal to the velocity; and on Newton’s Third Law, students assumed that when two objects collide, the object which had higher velocity will produce a bigger force.

Some of learning strategies has been done to address the problem of students’ understanding in Newton’s Laws. In the multi-presentation learning, even though students understand the concepts of...
Newton’s Laws, there are some students which still have misconceptions which are hard to change about Newton’s First, Second, and Third Law [7]. On experiential learning, students hadn’t understood the concept when they finish the implementation of Newton’s Laws [8]. Through physics representation worksheets, a lot of students still haven’t been able to identify all forces which worked on an object [9]. From these previous research, it’s apparent that students hadn’t understood the topic of Newton’s Laws because the learnings hadn’t put urgency to make the students to have an active role. The implemented learning should have created an environment to help students to be active so they can understand the concept and do the science process [10].

Inquiry is the center of science learning where students can be active to ask questions, describe an object of phenomenon, test their ideas with existing theories, communicate their findings. Previous research stated that students’ understanding of Newton’s Laws increased with Inquiry Lesson with LBQ strategy [11]. Other research stated that guided inquiry model can minimalize students’ misconceptions and increase their understanding of concepts better than conventional model [12]. Few research can serve as a proof that inquiry model can increase students’ conceptual understanding in the topic of Newton’s Laws.

One of models of inquiry learning which can increase students’ conceptual understanding is Argument Driven Inquiry (ADI) learning model. ADI is comprised of activities in laboratory in which students work on experiments in groups and get involved in scientific arguments to increase their score in conceptual knowledge [13,14]. It can be seen that ADI learning model is considered to have capability to facilitate students to understand the concepts of science well because the activities put an emphasis on knowledge construction and validation through the process of investigation [15].

Apart to understand the concept in physics, students also need to learn about themselves and the environment, and more about the development process of the application in a phenomenon in daily lives [16]. Therefore, it’s necessary to use phenomena-based ADI learning where phenomena is learned deeply in its entirety, on real world context, and is connected with other knowledge and information [17]. Phenomena which is used in the learning can be a real object which can be observed [18]. The result of the research showed that the result of students’ learning in physics after being taught with phenomena-based learning model yielded a high category while the result of those who were taught with conventional learning model yielded medium category [19]. Therefore, the learning design of phenomena-based ADI learning can be used to increase students’ understanding on the concept of Newton’s Laws.

Aside from choosing the suitable learning strategy, knowing how well the learning program, which is being designed, will go as planned is a necessary aspect to complete the learning itself. Therefore, it’s necessary to use formative assessment which is a process that can facilitate feedbacks to gather the information about how far students are doing in learning and which is the best course of action to do next [20]. The result of the formative assessment can be used by teachers to reflect or perfect the learning program [21]. For the learning participants, formative assessment helped them in learning and in finding best way to learn [22,23]. The result of the research showed that learning with formative assessment yields significant difference in average score of conceptual understanding so that it affects students’ achievements in mathematics [24], and is an important component in learning which can increase students’ achievements [25]. Formative assessment also has an effect towards learning with reflection system [26], and learning which is based on practice and discussion [27,28]. This kind of learning is the characteristic of ADI learning. It’s apparent that phenomena-based ADI learning with formative assessment has a large potential to increase conceptual understanding of Newton’s Laws. However, this learning model is still rarely implemented.

The design of phenomena-based ADI learning with formative assessment can increase the conceptual understanding of Newton’s Laws. This research aims to compare the effectiveness of ADI-Phenomenon-AF model and ADI model in building the understanding of Newton’s Laws and in describing students’ difficulties after the learning process.
2. Method
This study used a mixed method design with an embedded experimental design. The subject of the research: N=26 (M=12; F=14) in Experiment class (ADI-Phenomenon-AF), and N=23 (M=11; F=12) in Comparison class (ADI). The choosing of the research subject used Cluster random sampling method. ADI model has syntax (steps) on its implementation. The steps of ADI model [29] are combined with the dimensions in phenomenon learning [17] and the aspects of formative assessment [30] in the learning to increase the conceptual understanding of C1-C6 [31] as written in Table 1.

| Conceptual Understanding | Steps of Phenomenon-based ADI | Formative Assessment |
|--------------------------|--------------------------------|----------------------|
| Remembering (C1)         | Identifying assignment based on Holisticity | At the beginning of learning |
| Understanding (C2)       | Data gathering and analysis based on Authenticity | Key 1 : Developing Classroom Talk and Questioning |
| Applying (C3)            | 1. Formulating temporary argument based on Contextuality 2. Expressing the argument during learning | Key 3 : Sharing Criteria with Learners |
| Analysing (C4)           | Making report of experiment based on Problem based inquiry learning | Key 2 : Giving Appropriate Feedback |
| Evaluating (C5)          | 1. Working on revisions of report 2. Discussing explicitly and reflectively based on Learning process | During learning |
| Creating (C6)            |                                | Key 4 : Self assessment and Peer assessment |

The instrument of this research is the Conceptual Understanding Test of Newton’s Laws which is comprised of 13 test items of reasoned multiple-choice questions with the reliability of 0.817. Data analysis were done with Wilcoxon test, Mann-Whitney U test, N-gain, and a description of the reasons for students’ answers. A model can be said to be effective in increasing students’ understanding if there is significant different between pre-test and post-test and there is an increase in N-gain in the minimum category of medium. Qualitative data of students’ answers/reasons was analysed with transcript, coding, and conclusion [32]. Students will be deemed to have difficulty on a question item if the distractors are choosen with more than 20% of student.

3. Result and Discussion
The data description and few of data analysis on experiment and comparison class are presented on Table 2.

| Parameter              | Experiment Class | Comparison Class |
|------------------------|------------------|------------------|
|                        | Pre-test         | Post-test        | Pre-test         | Post-test        |
| Mean (SD)              | 21.01 (10.33)    | 69.82 (17.67)    | 23.75 (18.25)    | 55.52 (17.96)    |
| Kolmogorov-Smirnov test | 0.013 (no normal) | 0.002 (no normal) | 0.000 (no normal) | 0.200 (normal)   |
| Wicoxon test           | 0.000 (difference) | 0.000 (difference) | 0.000 (difference) | 0.417 (medium)   |
| N-gain                 | 0.618 (medium)   |                  |                  |                  |

It’s apparent from Table 2 that the pre-test of both classes are similar. However, the post-test of the experiment class is higher than comparison class. As there is data which is not normal, the difference test between pre-test and post-test is done with Wilcoxon test, which is a non-parametric statistical test. The result is that there is significant difference between pre-test and post-test, both in experiment class and comparison class. Meanwhile, experiment and comparison class have the N-gain in medium
category, although the N-gain in experiment class is higher than comparison class. Based on the result of Wilcoxon test and N-gain, the models of both classes are effective to increase the understanding about Newton’s laws. However, as the N-gain of the experiment class is higher than the comparison class, the model in experiment class is more effective to increase the understanding on Newton’s laws.

The result of the research showed that the ADI-Fenomena-AF model is effective to increase the conceptual understanding in the topic of Newton’s laws. This cannot be separated from the learning process which is done on experiment class as presented on Table 1. The learning dimensions of the phenomenon-based learning and the aspects of formative assessment which are combined in ADI model is able to increase conceptual understanding on every level. The result of the research also shows that ADI model is more effective in increasing the conceptual understanding of Newton’s laws. This result supports the finding on other research which states that ADI learning can increase students’ understanding [33], and give better impact than conventional class [34]. Meanwhile, the learning dimensions of phenomenon-based learning and the aspects of formative assessment are able to make ADI-Fenomena-AF model to be more effective to construct the understanding about Newton’s laws than ADI model.

To find out the impact of learning model towards the increase of understanding, difference test of post-test is done. However, the initial condition (pre-test) needs to be checked first. The initial condition test and difference test of post-test need a requirement about normality and homogeneity of data. Data normality and homogeneity test result is presented in Table 3.

Tabel 3. Data normality dan homogeneity test result

| Classes  | Kolmogorov-Smirnov test | Levene Test | Mann-Whitney U Test |
|----------|-------------------------|-------------|---------------------|
| Pre-test | Experiment              | 0.013 (not normal) | 0.078 (homogen) | 0.837 (no differences) |
|          | Comparison              | 0.000 (not normal) |             |                     |
| Post-test| Experiment              | 0.002 (not normal) | 0.760 (homogen) | 0.005 (differences) |
|          | Comparison              | 0.200 (normal)  |             |                     |

It can be seen from Table 3 that the normality test of both pre-test and post-test of both classes result in not normal, even though the homogeneity requirement is fulfilled. Therefore, the difference test of both use Mann-Whitney U test, which is a non-parametric statistical test. The result of initial condition test (pre-test) shows no difference, which means that both classes started from same initial condition. If there is difference about students’ conceptual understanding by the end of the learning process, it is solely as the result of the different learning model which are implemented. The difference test of the post-test data of both classes shows that they are different, which means that the learning model affected the increase of conceptual understanding. As the average of the experiment class is higher than comparison class, it can be said that the ADI-fenomena-AF model is better than ADI model in increasing students’ conceptual understanding on Newton’s laws. This finding supports the result of previous study which stated that phenomenon-based experiential learning can be used successfully to increase the concept acquisition on projectile motion [35], and that learning with formative assessment can increase students’ conceptual understanding in the topic of magnetic field [36].

N-gain test result for each of the subtopic of Newton’s laws is presented in Table 4.

Table 4. N-gain result of each subtopic of Newton’s laws

| Classes       | Friction force (No. 1) | Newton’s I law (No. 2, 3, 4, 5, 13) | Newton’s II law (No. 6, 7, 8, 9, 10, 11) | Newton’s III law (No. 12) |
|---------------|------------------------|-------------------------------------|------------------------------------------|---------------------------|
| Experiment    | 0.381 (medium)         | 0.756 (high)                        | 0.540 (medium)                           | 0.722 (high)              |
| Comparison    | 0.353 (medium)         | 0.489 (medium)                      | 0.298 (high)                             | 0.917 (high)              |

From Table 4, it can be seen that each subtopic on experiment class yielded better N-gain result than comparison class. This is proof that students on AD-Phenomenon-AF class have better conceptual understanding on Newton’s laws than students of ADI class. On the subtopic of friction force, the increase in both classes is similar on medium category. On the subtopic of Newton’s I and II laws, the
increase in experiment class is a level higher than the increase in comparison class. However, on the subtopic of Newton’s III law, both class gained the increase on high category. If the result is compared with the threshold of average N-gain that can be found in active learning at the score of 0.48 [37], experiment class has the subtopic of friction force, and comparison class has the subtopic of friction force and Newton’s II law which are below the threshold.

Based on the answers on pre-test and post-test, students of experiment and comparison class still have difficulties on the questions item number 6, 7, and 8 as written on Table 5.

Table 5. Summary of wrong reason on the distractor on both classes

| Number/Dimension/Indicator of test item | Wrong reason on post-test distractor (%) |
|----------------------------------------|-----------------------------------------|
| No. 6/C4/ Two boxes are put on the smooth floor with same force and students compare the accelerations of both boxes | Students assume that if the force is equal in magnitude, the acceleration of objects are proportional to the mass (Exp = 76.92%; Comp = 68%) |
| No. 7/C4/ Students play baseball, football, and basketball, and compare the force of three balls | 1. Students miscalculate the ratio of forces which are proportional to the mass (Exp = 69.23%)
2. Students assume that if the acceleration is the same, the forces needed is inversely proportional to the mass, and also miscalculate the ratio (Comp = 36%)
| No. 8/C2/ A box is pushed and students determine the acceleration of the box | Students assume that object’s acceleration is proportional to its mass and inversely proportional to its force (Exp = 20%; Comp = 36%)

From Table 5, it can be seen that students of both classes still have difficulty in analyzing the relationship between acceleration, force, and mass. This finding supports the result of previous study which said that students have difficulty in determining the acceleration of objects [38], and the magnitude and direction of the acceleration [39]. Students’ difficulties are mostly identified on determining the forces which act upon an object and the definition of acceleration [4]. Other difficulties which are common among students on Newton’s II law are to find the connection between acceleration, force, and velocity [40]. By using Certainty Respon of Index (CRI), it’s found that students have misconceptions on Newton’s II law regarding the assumption that if an object has big mass then it will have big force [41].

Other than the difficulties which are experienced on both classes, the experiment class still have certain difficulties on the question item number 1 and 3 as shown on Table 6.

Table 6. Summary of wrong reason on the distractor on experiment class

| Number/Dimension/Indicator of test item | Wrong reason on post-test distractor (%) |
|----------------------------------------|-----------------------------------------|
| No. 1/C1/ A box is moving on a slope and students identify the characteristic of friction force | Students assume that the friction force upon a moving object on a slope with friction does not depend on the weight of the object (Exp = 42.31%)
| No. 3/C2/ Students explain Newton’s I law while observing a moving object | Students assume that a pushed table with constant velocity v has the magnitude of net force which depends on the mass (Exp = 26.92%)

From Table 6, it can be seen that students of ADI-Phenomenon-AF class still have difficulty with formula of friction force and normal force on a slope, and the nature of force in Newton's first law. It seems that students still struggle to understand the relation between object’s mass, gravity, and friction because of the abstract nature of the concept [42]. It seems that students only memorise the words of Newton’s laws without understanding the physical or practical meaning of Newton’s laws [43], and students often neglect the use of Newton’s first law of inertia [44].
Other than the difficulties which are experienced on both classes, the comparing class still have certain difficulties on the question item number 4, 9, 11, and 13 as shown on Table 7.

| Number/Dimension/Indicator of test item | Wrong reason on post-test distractor (%) |
|----------------------------------------|-----------------------------------------|
| No. 4/C3/A car driver suddenly push the brake and students use Newton’s I law to analyse and solve the problem | Students assume that the water bottle will stay motionless above the dashboard of the car as the car move with changing velocity (Comp = 20%) |
| No. 9/C2/Regarding Newton’s II law, students can determine the relation between force, mass, and acceleration | Students assume that on the case of a pushed box on flat surface, Newton’s II law is valid, in which the relation between force, mass, and acceleration is the result of net force which acts upon an object and it’s inversely proportional to the object’s acceleration (Comp = 40%) |
| No. 11/C3/Students show how Newton’s II law works on real world example | Students assume that one example of Newton’s II law is when a bus driver suddenly push the brake and the standing passangers are suddenly propelled forward (Comp = 48%), and the hurt which is felt by the elbow when pushing the surface of a table too strongly (Comp = 20%) |
| No. 13/C5/An object falls from a reference point which is moving with constant velocity v relative to other reference point and students are determining the velocity of the object | Students assume that if the falling object from a reference point with constant velocity relative to a motionless reference point is seen from the latter reference point, the object is moving with velocity of zero (Comp = 28%), or velocity of more than 4 m/s (Comp = 20%), or velocity of less than 4 m/s (Comp = 28%) |

From Table 7, it can be seen that students of ADI class had difficulties on analyzing the application of Newton’s first and second laws. This finding is in accordance to the result of previous research which stated that students assume that on Newton’s I law, a moving object always has a force that acts upon it, including objects which are moving on constant velocity [45]. Also, on Newton’s II law, students had difficulties in making a connection between net force, velocity, and acceleration [40], and on determining the magnitude of object’s acceleration [38]. Students still have misconception and difficulties in understanding force and motion [46,47,48]. Therefore, there are still students who has incorrect thinking which is hard to change about Newton’s I, II, and III laws [7]. On Newton’s III law, students had difficulties on defining and understanding the formulation, identifying forces and utilizing free body diagram, and understanding action and reaction forces [49]. This might be caused by the fact that students struggle to make a representation, both mathematically or visually, of forces and motion [50,51,52]. The difficulties experienced by students on the topic of Newton’s laws are indicated to be originated from students’ low conceptual understanding about the topic of force and motion [51,53,54,55].

4. Conclusion

From the result and discussion, few conclusions as follows can be made. The pre-test and post-test of experiment and comparison class were significantly different and had N-gain on medium category. This means that ADI-Phenomenon-AF model and ADI model are effective on increasing students’ conceptual understanding on the topic of Newton’s laws. However, as the N-gain of experiment class is higher than comparison class, the ADI-Phenomenon-AF model is more effective than the ADI model in constructing the understanding the concept of Newton’s laws. After the learning process the students of both classes still have difficulty in analyzing the relationship between acceleration, force, and mass. In addition, students of ADI-Phenomenon-AF class still have difficulty with the nature of force in Newton's first law, while the ADI class analyzes the application of Newton's first and second laws.
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