Scientific method by argumentation design: learning process for maintaining student’s retention

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Abstract. The purpose of this research describes the effect of scientific methods designed by argumentation in maintaining retention of pre-service physics teachers (students) in mechanical concept. This learning consists of five stages including the first two stages namely observing and questioning. While the next three stages of reasoning, trying, and communicating are made of argumentation design. To know the effectiveness of treatment, students are given pre-test and post-test in one time. On the other hand, students were given advanced post-test to know the durability of retention as many as four times in four months. The results show that there was mean difference between pre-test and post-test based on the Wilcoxon test (z = -3.4, p=0.001). While the effectiveness of treatment is in the high category based on normalized gain values (g = 0.86). Meanwhile, the mean difference of all post-test is significantly different based on Analysis of Variance (F = 365.63, p = 0.00). However, in the fourth month, students retention rates began to stabilize based on Tuckey’s HSD (p=0.074) for comparison of mean difference between fourth and fifth post-test. Overall, learning designed can maintain students retention within 4 months after the learning finish.

1. Introduction

As a pre-service physics teacher in the future, students are required to be able reproducing the concepts obtained during lectures to students in school. Reproducing the concepts relates to the ability of student in mastering concepts. This certainly also relates to the ability of students in mastering concepts. The good ability of mastering concepts has to be also supported by the good ability of maintaining retention. Therefore, learning process that is done has to facilitate students have good mastery of concepts and be able to maintain concepts mastered. In other words, learning process has to bridge students have good durability in retention. Retention relates to concept and memory. Retention is the amount of knowledge still remembered or stored in certain time interval [1].

In this research, learning innovation was made by applying scientific method by argumentation design. This innovation was done with purpose that students could achieve good learning outcomes in terms of concept mastery and its durability. Scientific method was chosen because its syntax can facilitate the students in understanding easily and mastering concepts [2]. The application of scientific method by argumentation design also makes students are easier to build concepts, models, theories, and reasoning of science [3-5]. According to Duschl [6], students can achieve scientific learning outcomes as they want by giving them more scientific argument opportunities.
Learning syntax in scientific method include observing, questioning, reasoning, trying, and communicating [2, 7]. Combination with the argument activities is done from the reasoning stage to communicating stage. The activities of argumentation that they are conducted refer to Toulmin Argumentation Pattern (TAP) included the activity of proposing claim, data, warrant, backing, and rebuttal [8].

Referring to association of Indonesia Science Teacher, mechanics is one of the studies that have to exist in the program of science education. Mastery of mechanical concepts is very important for students of pre-service physics teacher because the subject widely contained in the physics curriculum that is taught at the secondary school level in Indonesia. Therefore, students have to master well concepts and maintain its retention as a provision for transferring them when teaching at school. On the other hands, the findings of research show that mechanical concepts are difficult to be understood by students both in undergraduate, master, and even in doctoral level [9, 10]. Finally, this study is conducted with the purpose to get a description of the influence of learning using scientific methods by argumentation design activities on the retention of pre-service physics teacher on the mechanical concepts.

2. Methods
2.1. Participants
This research involved fifteen students of pre-service physics teacher in one of the colleges in Bima, Nusa Tenggara Barat, Indonesia. All students came from different area in central zone of Indonesia. Generally, sample of research activity almost had the same ability in academics. Learning activities in this research were conducted in three times of lectures and one lecture almost spent hundred minutes. Before learning activities were conducted, all of students were given pre-test. After all learning activities using scientific method by argumentation design were finished, post-test was given to student to measure the concept mastery of students in mechanical concepts. During four consecutive months after the learning activity was completed, students were given post-test again with a one-month break for each test. This test was conducted to measure durability of student’s retention after 4 months completing the learning activity. The design of research could be seen in Figure 1.

![Figure 1. Design of research](image)

2.2. Learning Activities
In this research, learning activities using scientific method by argumentation design was conducted in three times of lectures on mechanical concepts. Learning activities performed was supported by using Phet virtual media. One example of learning scenario that was conducted can be seen in Table 1.
### Table 1. Example of learning scenario using scientific method by argumentation design

| Learning Syntax | Learning Activities                                                                                   |
|-----------------|-------------------------------------------------------------------------------------------------------|
| Introduction    | • Reviewing concept of distance, displacement, velocity, speed, and acceleration.                     |
|                 | • Reviewing fundamental concept of constant velocity motion, constant acceleration motion, uniform circular motion, and circular motion uniformly accelerated. |
| Step I: Observing | Conducting virtual demonstration with displaying *Phet Simulation* about people who are moving.       |
| Step II: Questioning | Probing information that exists on demonstration activity for guiding students to propose questions. |
|                 | • Guiding discussion process to answer questions that embark form students with proposing claim, data, warrant, backing, and rebuttal. |
| Step III: Reasoning by argumentation design | Explaining important concepts in front of the class namely deriving mathematics equation for constant velocity motion, constant acceleration motion, uniform circular motion, circular motion uniformly accelerated and applying this in physics problems. |
|                 | • Giving problems to be solved by experiment activity that was guided by using worksheet based argumentation. Problems: |
|                 | 1. Two matters with different mass have the same height from floor is fallen simultaneously without initial velocity. Do you agree that the matter that have bigger mass needs little time to get the floor? |
|                 | 2. When the car pass down the road, its engine is suddenly off and goes out of control. Do you think, which the bigger acceleration of car weather car pass down the road with angel of slope 30° or 60°. |
| Step IV: Trying by argumentation design | • Sharing Student’s worksheet that it is developed by argumentation design for solving the problems. GUIDING THE DISCUSSION PROCESS IN THE CLASSROOM WHERE DISCUSSION IS CONDUCTED WITH EXPLAINING CLAIM, DATA, WARRANT, BACKING, AND REBUTTAL TO PROBLEM GIVEN. |
| Step V: Communicating by argumentation design | Guiding the discussion process in the classroom where discussion is conducted with explaining claim, data, warrant, backing, and rebuttal to problem given. |

#### 2.3. Instrument Test

The instrument test in this research was made in essay form using rubric assessment. This was developed by referring to Bloom’s taxonomy that was revised by Anderson and Krathwohl [11]. There were six abilities in Bloom’s taxonomy (revised edition): remembering (C₁), understanding (C₂), applying (C₃), analyzing (C₄), evaluating (C₅), and creating (C₆). The concept abilities that were measured by these instruments were embarks from remembering (C₁) to evaluating (C₅).

#### 2.4. Procedures of Data Analysis

Analysis of data was embarked by scoring average of pre-test and all post-tests. Then, conducting normality test of data for deciding the difference of mean data was analyzed by using parametric or non-parametric statistics. Test of the difference of mean was conducted for pre-test to post-test and among all post-tests. Student test or Wilcoxon test was used for testing of mean difference of pre-test to post-test and ANOVA (Analysis of Varian) was used for testing of mean difference of all post-tests. Post hoc testing was also used for comparing all scores of post-test. To know the effect of treatment, the data were analyzed by using equation 1 of normalized gain [12]. Criteria of normalized gain was differed in three categories namely high (\( <g> \geq 0.7 \)), modest (0.3 \(<g><0.7 \)) , and low (\(<g><0.3\)). Finally, to analyze durability of retention was performed by counting percentage of durability of retention by using equation 2.

\[
< g > = \frac{<S_{post}>-<S_{pre}>}{<1>-<S_{pre}>}
\]  \hspace{1cm} (1)

\[
\text{% Retention(Posttest2.3.4.5)} = \frac{\text{Posttest (2.3.4.5)} \times \text{Pretest1}}{100}
\]  \hspace{1cm} (2)
3. Result and Discussion
Before determining test of mean difference between pre-test and post-test, and all post-test, both pre-test and post-test data were tested of normality test. In this research, normality test was counted by using Kolmogorov Smirnov. The result of this could be seen in Table 2.

| Test of Normality   | Kolmogorov Smirnov $(N=15, df=15)$ | $p$ | Mean of scores |
|---------------------|------------------------------------|-----|----------------|
| Pre-test            | 0.249                              | 0.01| 19             |
| Post-test 1         | 0.145                              | 0.20| 84             |
| Post-test 2         | 0.201                              | 0.11| 72             |
| Post-test 3         | 0.137                              | 0.20| 59             |
| Post-test 4         | 0.214                              | 0.06| 53             |
| Post-test 5         | 0.172                              | 0.20| 51             |

According to data in Table 2 showed that the pre-test data were not distributed normally. On other hands, all post-test data were distributed normally. Therefore, testing of mean difference that was used for pre-test was Wilcoxon test while all post-test was tested by ANOVA and Tuckey’s HSD. To know effectiveness of treatment was also analyzed by normalized gain. The results of these data could be seen in Table 3, Table 4, and Table 5.

| Test of Normality   | Wilcoxon Test $(N=15, df=2)$ | $p$ | Normalized gain $<g>$ |
|---------------------|------------------------------|-----|-----------------------|
| Pre-test            | -3.4                         | 0.01| 0.86                  |

Based on the data in Table 3 revealed that mean score of pre-test and post-test were significant difference. It showed that increasing of student’s concept mastery was profound difference. In addition, the effectiveness of treatment could be seen by normalized gain ($<g>=0.86$). It showed high criteria that it meant the effect of treatment were very strong in increasing concept mastery. The reason why these results were happened was because scientific method by argumentation design could give meaningful experience to students during learning process.

| df | Mean square | $F$  | $p$  |
|----|-------------|------|------|
| Between groups | 4 | 2937.55 | 365.63 | 0.00 |
| Within groups  | 70 | 8.03   | 365.63 | 0.00 |
| Total          | 74 |        |       |      |

| Scores                | df | Mean difference | $p$  |
|-----------------------|----|-----------------|------|
| Post-test 1 – Post-test 2 | 2  | 12              | 0.00 |
| Post-test 2 – Post-test 3 | 2  | 13              | 0.00 |
| Post-test 3 – Post-test 4 | 2  | 6               | 0.00 |
| Post-test 4 – Post-test 5 | 2  | 2               | 0.074|
On the other hands, the result of ANOVA test showed that mean difference of all post-tests was significant difference. Post hoc test by using Tuckey’s HSD showed that the highest decrease happened between post-test 2 and post-test 3. In contrast, the lowest decrease happened between fourth and fifth post-test. The result described that there was no significant mean difference between fourth and fifth post-test. It meant that the durability of student’s retention began achieving stable condition after learning activity was completed in four months.

![Figure 2](image_url)  
**Figure 2.** Percentage of durability of retention

Like data of concept mastery for all post-tests, the percentage of durability of student’s retention decreased in its trends and had small difference between fourth and fifth post-test. If the sixth post-test was given to students, the prediction of the result would almost have the same mean score with fifth post-test.

The analysis of student’s retention could be connected to scientific method by argumentation design used in the learning process. Because of pedagogical benefits from scientific method by argumentation design in which it was to build concepts, models, theories, and reasoning of science [3-5], the rate of student’s retention decrease reach the fixed condition in fourth week. This situation would be different if the learning process used conventional design without training argumentation activity. There was possibility that student’s retention on mechanical concept would fall over time, because the mechanical concepts were difficult to be understood by students at any level [9, 10]. This condition supported by the result of another research. The research showed that traditional learning method that were not involved the argumentation activities did not develop the reasoning scores that it gave impact to concept mastery indirectly [13].

Argumentation activity made the students were easier to mastery concept and feeling happy during learning activity [2]. Students could achieve scientific learning outcomes as they wanted by giving chances for them to do more scientific argument activities [6]. Therefore, the learning process that combined argumentation activity could maintain student’s retention on mechanical concept (Figure 2).

Based on the previous research, retention was able to be well-maintained if the learning process made students felt happy [1]. Finally, pivotal understanding for decreasing of student’s retention did not have strong correlation with the loss of student’s understanding about mechanical concepts.

4. Conclusion

The conclusion that was given from this research were scientific method by argumentation design could increase the concept mastery, and gave good durability of student’s retention on mechanical concepts. The first suggestion that was taken from this study was the need of further research on
retention as an effort to achieve meaningful learning pre-service physics teachers. The second suggestion for further research was to implement the control group in the research so that there would be additional research findings.

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