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A LEARNING PROCESS BASED ON CONCEPTUAL CHANGE APPROACH TO FOSTER CONCEPTUAL CHANGE IN NEWTONIAN MECHANICS

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Abstract. *The purpose of this research was to investigate the effectiveness of conceptual change learning approach based on conceptual change model over traditional instruction on the improvement of physics education undergraduate students' conceptual understanding in Newtonian mechanics. A quasi experimental research method with pre-test and post-test control group design was employed. The sample chosen based on purposive technique sampling comprising of 73 students was in two groups selected randomly each as experimental and control group. Predict-Observe-Explain-Apply (POEA) and using Conceptual Change Texts (CCT) strategies were implemented in the experimental group. The Force Concept Inventory (FCI) in Indonesian was used to collect data before and after treatments. The results show that the conceptual understandings of students who were taught using strategies under conceptual change approach was significantly better than those of the traditional approach. The research confirmed that only learning based on conceptual change model could improve learners' Newtonian mechanics conceptual understanding.*

Key words: *conceptual change approach, conceptual change texts, predict-observe-explain-apply, Newtonian mechanics.*

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Introduction

Quality of education outcome is still one of the major problems in Indonesia. Reports, such as by PISA and TIMSS, always put Indonesia in the low ranking. Among the reasons of the low educational quality is the science education tend to test-oriented and teachers teach the science as a product to recall (Ministry of National Education of Indonesia, 2007). Students are drilled to solve computational mathematics problems instead of understanding the concepts correctly. It is a consensus among the researchers and science educators that students come to class with their own conceptions. These pre-conceptions are constructed based on their daily experiences far before school (Mann & Treagust 2010). Global studies have found that mostly these pre-conceptions differ substantially from scientific views (Treagust, Mthembu, & Chandrasegaran, 2014). In this study 'misconceptions' term is used referring to this kind of conceptions. Traditional teaching approach in basic science, including in physics, course does not successful increase students' conceptual understanding in the most basic concept (Pundak & Rozner, 2008). The misconceptions are not only highly resistant to change (Clement, 1982) but also could sometime be an obstacle in learning (Mchunu & Imelda 2013). Therefore, it needs special teaching approach to promote conceptual change and to dispel misconceptions. Hewson and Beeth (1993) defined teaching that explicitly aims to help learners experience conceptual change learning and that follows guidelines of conceptual change model as teaching for conceptual change.

Newtonian mechanics is an important topic in physics because almost all of other topics in physics depend on the concepts in this topic. Many studies from many countries are focused in this area and those revealed abundant misconceptions and low conceptual understanding and comprehension in Newtonian mechanics. Among the massive misconceptions held by physics education undergraduate students on Newtonian mechanics in Indonesia are they think that 1) the heavier objects always fall faster, 2) mass of an object can make it stop moving, 3) motion is caused by active force, 4) impetus is supplied by hit, 5) circular motion is also influenced by impetus, 6) position indiscriminate with velocity, and 7) no motion of an object implies no force works on it. Their average conceptual understanding score in Newtonian mechanics was also low, i.e.18.08%. This score is far below Newtonian mastery threshold 85% even entry threshold to Newtonian physics 60% (Hestenes & Halloun, 1995). It is very important to take misconceptions into account for students who have the score below the entry threshold (Hestenes, Wells, & Swackhamer, 1992). This research examined the effectiveness of some conceptual change teaching strategies based on conceptual change approach to foster conceptual understandings in Newtonian mechanics.

Problem of Research

Students' conceptual understandings in Newtonian mechanics are low. They hold some misconceptions. Most of physics education students at Universitas Sriwijaya confused when asked some questions such as 1) which one of heavier and lighter objects will reach the ground first if they fall from the same height, 2) does mass of an object make it stop moving, 3) does an object need a force to keep its motion, 4) is the velocity of two objects the same when they are in the same position, 5) does impetus also occur in circular motion, 6) is the velocity proportional to force and its direction always parallel to force direction, and 7) can a passive object exert a force. In this research, some teaching strategies were used to promote students' conceptual understanding and counter their misconceptions.

Research Focus

Focus of the research is to promote conceptual change in students' mind in Newtonian mechanics by means of developing their scientific thinking. The conceptual change can be shown by increasing of students' conceptual understanding toward the correct – scientific concepts and overcoming their unscientific misconception. POE (Predict-Observe-Explain) and using CCT are among teaching strategies for conceptual change based on cognitive conflict and existing idea (Scott, Asoko, & Driver, 1991). White and Gunstone (1992) proposed three tasks in teaching, i.e. prediction, observation, and explanation to probe students' understanding. Treagust et al. (2014) stated that POE strategy is one of instructional strategies that take into account students' pre-conceptions. These pre-conceptions are an important aspect in conceptual change learning. Researchers have reported successfulness of these strategies to facilitate conceptual change in several science topics. Coştu, Ayas, & Niaz (2012) pointed out that the POE strategy helps learners to achieve better conceptual understanding in condensation topic and enables them to retain the replacing conceptions in their long-term memory. Sreerekha and Sankar (2016) found POE strategy is effective in improving of students' achievement in Chemistry for secondary school. Studies such as by Özmen (2007), Baser and Geban (2007), Ozkan and Selcuk (2015), and Yürük and Eroğlu (2016) on the effectiveness of CCT also found that it significantly improves students' conceptual understanding. The objective of this research was to examine the effectiveness of these selected strategies in improving conceptual understanding and eliminating misconceptions in Newtonian mechanics. The result of the research can be utilized by lecturer of basics physics course in undergraduate level or by physics teacher in upper class of senior high school to improve conceptual mastery in Newtonian mechanics topic.

Methodology of Research

General Background of Research

Increasing of students' conceptual understandings or overcoming their misconceptions means to sift their conceptual understanding from the wrong conceptions toward the correct conceptions. Based on paradigm of theory of conceptual change by Posner, Strike, Hewson, & Gertzog (1982), a process in which learners' central concepts change from one set of concepts to another set that is not compatible with the first concepts can be called as a conceptual change. The misconceptions are highly resistant to change (Clement, 1982), so that how the conceptual change takes place is not a simple thing, and traditional instruction commonly fails to correct them (Baser, 2006). It needs a learning become a process in which a new concept replaces the existing concept or be remodeled from the stable concept that the student has constructed over many years (Clement, 1982).

Posner et al. (1982) explained a general model of conceptual change. They as initiators of Conceptual Change Model (CCM) suggested four important conditions that must be fulfilled in order to conceptual change take place. First, the existing concept must be dissatisfaction for student. Second, the replacing conception must be intel-

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ligible for student. Third, the replacing conception must appear initially plausible for student. Fourth, the student should fill the replacing conception fruitful, have potential to open a new area of inquiry. Teaching approach in conceptual change involves many strategies. Scott et al. (1991) have identified two major groupings of strategies to promote conceptual change, i.e. 1) the strategies based on cognitive conflict and the resolution of conflicting perspective, and 2) the strategies built on students' existing ideas and extend them to a new domain through, for instance, metaphor or analogy. POE and using of CCT which are selected as strategies in this research fulfill these four requirements. In this research, POEA as a variant of POE was used. The additional of Apply (A) phase is to strengthen the fourth step of Posner et al. condition. The relationship between POEA strategy and the requirement of conceptual change is presented in Figure 1.

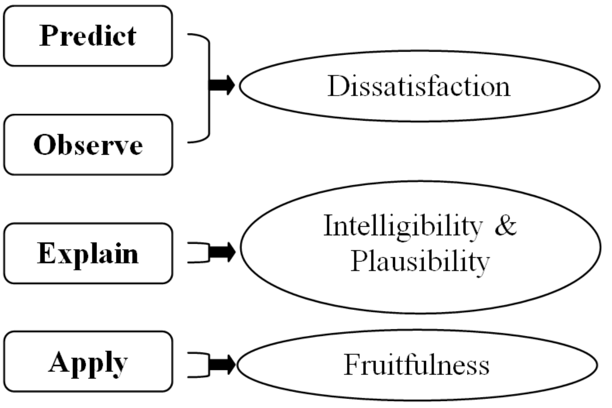

Figure 1: The relationship between POEA strategy and four conditions in the conceptual change model.

Sample of Research

The sample of the research chosen based on purposive technique sampling comprised of 73 first-year undergraduate students (44 students in experimental group and 29 students in control group) of Physics Education Program at Universitas Sriwijaya, Indonesia. One group was randomly assigned as the experimental group and the other group was assigned as the control group. All the sample was graduates from high schools around Indonesia and have had the same opportunity to enroll any class in undergraduate level, so that they were expected to have the same pre-knowledge about Newtonian mechanics concepts.

Instrument and Procedures

A quasi experimental research with pre-test and post-test control group design was implemented to test the effectiveness of the strategies to foster conceptual change. Data regarding students' pre-conceptual understanding and post-learning conceptual understanding was collected by an instrument the Indonesian translated of the FCI. The FCI developed by Hestenes et al. (1992) is a standard conceptual test for kinematics, force and relevant concepts. It was designed to be test of students' conceptual understanding (Hake, 1998) and to probe their misconceptions. This Indonesian version of the FCI have succeeded validation and reliability test process. In the experimental group, the conceptual change approach was implemented. Treatment was conducted in seven lessons. Time allocation for one lesson was 3 x 50 minutes. The pre-test was done one week before the first lesson and the post-test was in the next week after the seventh lesson. The test was completed in 45 minutes. Two teaching strategies based on the conceptual change approach, i.e. POEA and using of CCT were implemented as treatment in the experimental group. A strategy was selected for particular topic based on the characteristic of the materials in the topic. The Newtonian mechanics cover seven topics, i.e. 1) introduction, 2) Kinematics 1, 3) Kinematic 2, 4) Dynamics 1, 5) Dynamics 2, 6) Work and Energy, and 7) Impulse and Linear Momentum.

In the control group, traditional instruction was implemented. The traditional strategies used generally by physics instructor in Indonesia class are: introduction to topic, derivation of equations, giving example for using the equations, and practice computational physics problems. All conditions in experimental and control groups such as time allocated, textbooks used, and assignment to do, were the same, except for the strategy implemented in the learning process.

Data Analysis

The students' conceptual change is a shift of their conceptual understanding before and after a process or a certain time. The effectiveness of the conceptual change approach in fostering the students' conceptual understanding in Newtonian mechanics was measured by using the normalized gain scores (N-gain). The normalized gain was calculated by equation (Hake, 1999):

$$< g >= \frac{\% < postest > - \% < pretest >}{100 - \% < pretest >}$$

The meaning of N-gain (<g>) values are determined by the criteria (Hake, 1998):

High	(<g>)≥ 0.7
Medium	0.7 > (<g>) ≥ 0.3
Low	(<g>) < 0.3

Furthermore, the statistical tests were conducted to investigate how significant the approach in promoting conceptual change. The null-hypothesis is Ho: there is no significant difference of conceptual understanding between students who were taught under conceptual change approach and students who were taught by using traditional one for Newtonian mechanics and for each of six dimension of Newtonian mechanics. Test of the normality of data distribution was carried out by using the Kolmogorov-Smirnov test for α = 0.05 and the homogeneity of data variance was investigated by using Levene's test by F test for α = 0.05. The research hypothesis was test by using independent sample t-test by two side with α = 0.05 and by Wilcoxon test or Mann-Whitney test for the data distribution is not normal.

Results of Research

The analysis results of pre-test scores, post-test scores, and N-gain for the experimental group and the control group are presented in Figure 2 below.

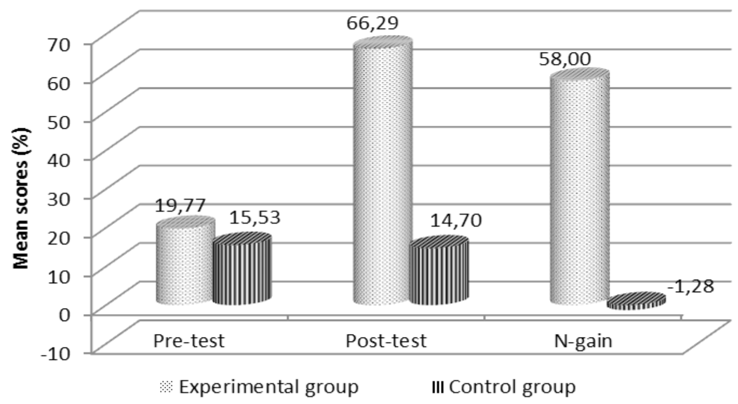

Figure 2: The mean scores of pre-test, post-tests and N-gain for the experimental and the control groups.

Figure 2 shows that the mean pre-test score for the experimental group was 19.77% and the mean pre-test score for the control group was 15.52%. In the other hand, the mean post-test score for the experimental group

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was 66.29% and the mean post-test score for the control group was 14.70%. Therefore, the average N-gain for the experimental group was 58.00% and that for the control group was -1.28%. These showed that there was an increase percentage in the experimental group for students' conceptual understanding toward the correct concepts in middle category, while in the control group there was no increase at all toward the correct concept.

A set of statistical test was conducted to investigate whether the difference in the average N-gain between the experimental and the control groups was significant or not. In the normality test for the experimental group it was obtained D_{calc} = 0.073 while D_{table} = 0.1351, this meant that the data distribution was normal. The normality test for control group obtained that D_{calc} = 0.135 and D_{table} = 0.161, which meant that the control group's data was normally distributed as well. The test of homogeneity showed the significance sig. = 0.588 > α = 0.05, this meant that there was no difference of data variance for the experimental group and the control group or the data variance was homogeneous.

Because the data was normally distributed and its variants were homogeneous, the test of mean difference was done by t-test, with two-tailed test and α = 0.05. The results were $t_{calc.}$ = 22.189 and t_{table} = 1.994. So that $t_{calc.}$ was outside of the reception area of Ho. Thus Ho: there was no difference in the mean of increasing of conceptual understanding of the experimental group and the control group was rejected. The conclusion was there was difference for the means of increasing of conceptual understanding for the experimental group and the control group. The resume of the statistical analysis for the pretest, post-test, N-gain, and conducted statistical tests were shown in Table 1 below.

Table 1. Results of analysis of students' conceptual understanding for the experimental and control groups.

	Pre-test		Post-test		<g>	Normality of <g>	Homo-geneity of <g>	t-test of <g>	p
Group	M (%)	SD	M (%)	SD					
Experimental	19.77	2.69	66.29	2.87	58.00	0.073	0.135	22.189	0.0001*
Control	15.52	1.78	14.70	2.35	-1.28	0.135			

**Significant (p < 0.025)*

Table 1 shows that the average N-gain (<g>) of groups of students who were taught with conceptual change learning and the average N-gain of those who were taught with learning that was not intended for conceptual change with respect to the mastery of Newtonian concepts were significantly different. The significance value *p* was less than α/2 = 0.025 (0.0001 < 0.025), it proved that this difference occurred significantly. The results also revealed that for fostering conceptual change requires learning based on the conceptual change approach. Normal learning, which was not based on the theory might increase knowledge of learners in the Newtonian mechanics topic but could not change or improve their conceptual understanding toward the correct concepts.

Further results of improvement of conceptual understanding of Physics Education Program students on six dimensions of Newtonian mechanics concepts are shown in Table 2 below. Each dimensional refers to several specific item in the FCI.

Table 2. Mean scores and N-gain for each dimension of Newtonian concepts.

Dimensions	Pre-Test	Post-Test	N-Gain	Pre-Test	Post-Test	N-Gain
	Experimental Group			Control Group		
Kinematics	31.49	60.71	41.85	18.23	20.69	1.60
First Law	20.71	60.61	49.15	20.69	19.92	-3.85
Second Law	19.55	34.55	15.98	17.93	13.79	-10.69
Third Law	10.23	97.16	96.59	9.48	8.62	-4.02
Superposition Principle	21.82	51.36	30.53	19.31	17.93	-4.25
Kind of Force	19.23	69.06	60.85	12.47	12.73	-0.65

Table 2 shows that all dimensions for experimental group had positive N-gain with categories high, middle, and low, while for the control group, five dimensions had negative N-gain and one dimension had very low N-gain, namely 1.6%. In kinematics dimension, the mean scores for the experimental group increased two-fold from 31.49% to 60.71% and for the control group, a slightly increase occurred from 18.23% in the pretest to 20.69% in the post-test. The only increase of the control group score was for this kinematics dimension. For the first law, the N-gain for the experimental group was 49.15%, a middle category, while for the control group the N-gain was negative. In the second law the mean scores of pre-test for the experimental group was 19.55%, while the mean scores of the post-test increased to 34.55%. On the contrary, the control group decreased from 17.93% at the pretest to 13.79% at the post-test, thus N-gain of control group was negative. The highest increase of mean scores for experimental group occurred in third law, i.e. from 10.23% in the pre-test to 97.16% in the post-test. When comparing with the other dimensions, the third law had the lowest mean scores in the pre-test, yet had the highest mean scores at the post-test. Similarly, the pre-test of the control group for the experimental group had also the lowest mean scores in the third law. However, like any phenomenon in the other dimensions and in the Newtonian mechanics in general, there was no increase in the conceptual understanding for the control group. The dimension of the third law showed no increase in mean scores from pre-test to post-test for the control group. For the superposition principle there was an increase in the mean scores of the experimental group from 21.82% to 53.36%, whereas those for the control group decreased from 19.31% to 17.93%. the gain of control group for the superposition principle was the second lowest among the six dimensions of the Newtonian concepts. Kinds of force dimension had the highest increase of gain for the experimental group, which was 12.67%. Kinds of force dimensions had the second highest N-gain after the third law dimension.

Furthermore, a set of statistical tests was carried out to investigate the significant difference of the mean N-gain between the experimental group and the control group for each dimension as displayed in Table 3. It shows that the results of normality test gave normal distribution for the data for dimensional kinematics, first law, and kinds of force for the experimental group and kinds of force for the control group. The rest data, i.e. the data for second law, third law, and superposition principle dimensions for the experimental group and all the data for the control group except for kinds of force were not normally distributed. The results of the homogeneity test showed that data for the kinematic, the first law, the second law, the superposition principle and the kinds of force were homogeneous, while the variance of the third law was not homogeneous. Based on this basic assumption, the kinematics, the first law, the second law, the third law, and the superposition principle were administered the mean difference test using the Mann-Whitney test, while for the kinds of force the t-Test was used.

Table 3. The results of statistical test for each dimension of Newtonian mechanics concepts.

Dimensions	Normality Test, α/2 = .025				Homogeneity Test		t-Test or u-Test, α/2 = 0.025	
	P		Explanation		*p*	Expl.	u or t values	*p*
	Exp.	Con.	Exp.	Con.				
Kinematics	0.091	0.000	Norm	Not Norm	0.134	Hom.	u=97.000	0.0001*
First Law	0.169	0.001	Norm	Not Norm	0.853	Hom.	u=51.000	0.0001*
Second Law	0.000	0.000	Not Norm	Not Norm	0.278	Hom.	u=358.000	0.001*
Third Law	0.000	0.000	Not Norm	Not Norm	0.000	Not Hom	u=2.500	0.0001*
Superpos. Principle	0.000	0.001	Not Norm	Not Norm	0.248	Hom.	u=234.000	0.0001*
Kinds of Force	0.200	0.029	Norm	Norm	0.334	Hom.	t=15.576	0.0001*

**Significant ($p < 0.025$)*

Table 3 shows that the significance values for all dimensions were between 0.0001 and 0.001 or sig. < α, which meant that Ho is outside the reception area. Based on the calculation of the value of t it was also obtained the value of $t_{calc.}$ = 15.576 was greater than t_{table} = 1.994, which meant that Ho was rejected. It could be concluded that there were significant differences between the average N-gain of the experimental and control groups for all

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dimensions of mechanics. For the second law dimension, where the acquisition of N-gain was the smallest one for the experimental group and the N-gain difference between the experimental group and the control group had the lowest result, the result still yielded the significance of 0.001. In other words, there were differences improvement of conceptual understanding to the correct concept for all dimensions of the Newtonian mechanics concepts between the experimental group and the control group. It can be concluded that the conceptual change learning is more effective in improving students' conceptual understanding toward the correct concepts. More specifically, based on the pattern of acquisition of N-gain of the experimental and the control groups, it can be concluded that only the conceptual change learning can change students' conceptual understanding towards the correct concepts.

Discussion

Students' Conceptual Understanding and Dominant Misconceptions in Newtonian Mechanics

This research was conducted in three main steps, i.e. analyzing students' conceptual understanding and identifying their misconceptions, implementing conceptual change approach of learning, and analyzing students' post-learning conceptual understanding. Based on the analysis of correct answer of the FCI items, the mean scores of experimental and control groups were 19.77% and 15.52% (Table 1), respectively. These scores were far below the entry threshold (see Hestenes & Halloun, 1995), so that students' misconceptions must be taken into account (Hestenes et al., 1992). Hake (1998) asserted that low score on the FCI indicates a lack of understanding of the basic mechanics concepts. From the analysis of students' wrong answers of the FCI based on *Table of Taxonomy of Misconceptions Probed by the Inventory* (Hestenes et al., 1992, revision 1995), it was revealed students' misconceptions in Newtonian mechanics. The dominant misconceptions held by the students were 1) heavier objects always fall faster, 2) mass makes object stop moving, 3) motion of object implies active force working on it, 4) impetus comes from hit, and 5) impetus also exists in circular motion.

In the item 1 of the FCI, students were asked *time taken to reach the ground by two metal balls that have the same size but one weighs twice as much as the other dropped from the same height at the same instant of time*. There were 46.58% of the students chose option **A**: *about half as long for the heavier ball as for the lighter one,* 39.73% chose **D**: *considerably less for the heavier ball, but not necessarily half as long*, 4,11% chose **B**: *about half as long for the lighter ball as for the heavier one*, and 1.37% chose **E**: *considerably less for the lighter ball, but not necessarily half as long*. It meant that 91.79% of the students held misconception that *heavier objects always fall faster*. Only 8.22% of them had correct scientific concept that *two balls take about the same time* (option **C**). The reality found in this research was the students had ability to solve computational problem in determining time it takes by an object to fall from a certain height by using an appropriate equation easily. So, although the students may have been drilled using the equation many times and have memorized it, but their understanding about the meaning of the equation is still nonsense.

Misconception *mass makes object stop moving* was revealed by the FCI item 27, options **A** and **B**. There were 75.34% of the students who experienced this misconception. Students who held this misconception thought that *a large object moving at a constant speed being pushed by a person with a constant horizontal force will "immediately come to stop"* or *"continue moving at a constant speed for a while and then slow to stop"* instead of *"immediately start slowing to a stop"*. Next, misconception *motion of object implies active force* was experienced by 63.01% of the students. They believed that motion must be caused by active force such as a force being exerted by a person. This was inferred from the students' answer for item 5 when choosing options **C**, **D**, and **E** and item 27 when choosing option **A**. An example of students' answer for the FCI item that revealed this misconception was the answer for item 27 that *the large object will immediately come to stop if a person stops applying a horizontal force*.

Misconception *impetus comes from hit* was revealed by four items, i.e. item 5 (options **C**, **D**, and **E**), 11 (options **B** and **C**), 27 (option **D**), and 30 (options **B**, **D**, and **E**). The general statement believed by students was there is a force working continuously on an object that sustains the object moving and this force was transferred from the object's environment by means of, for example, a hit or a throw. There were 59.93% of them had this misconception. As an example, in item 30 "*A tennis player hit a tennis ball with his racquet in a very strong wind. What force(s) is (are) acting on the tennis ball after it has left contact with the racquet and before it touches ground?",* there were 89.04% of students thought that *force by the hit* also works on the ball, with detail: 8.22% chose *force by the hit and downward force of gravity*; 10.96% chose *force by the hit and a force exerted by the air*; and 60.27% chose *force by the* *hit, downward force of gravity, and a force exerted by the air*. Moreover, this research found that the students held impetus concept strongly because there was no any student who chose *only a downward force of gravity work on the ball*. In conclusion, only 10.96% of the students held correct scientific concept that the gravity force and force exerted by the air work on the ball.

Furthermore, the students also believed that there was impetus in circular motion. As many as 54.11% of them held this belief. Items 5 (options **C**, **D**, and **E**), 6 (option **A**), 7 (options **A** and **D**), and 18 (options **C** and **D**) revealed this misconception. The students thought that there must be a force works on an object in its direction of motion in a circular path to sustain the object moving, and this force still work on the object even if after the object exits the circular path. Item 5 is *A ball is shot at high speed into a frictionless channel in the shape of a segment of a circle. Forces exerted by the air are negligible. What force(s) is (are) acting on a ball when it is within the channel?* There were 80.83% of students chose the answer containing phrase *a force in the direction of motion* that imply they believed about existence of impetus in circular motion. These consisted of 41.10% of the students who chose answer *a force in the direction of motion and a downward force of gravity*; 26.03% who chose answer *a force in the direction of motion, a downward force of gravity, and a force exerted by the channel pointing from the ball to the center;* and *13.70%* who chose the answer *a force in the direction of motion, a downward force of gravity, and a force pointing from the center to the ball*. Moreover, as many as 39.72% of them chose the path of the ball after it exits the channel still constructs a circular path.

Conceptual Change Learning Approach

This research was intended to investigate the effectiveness of conceptual change learning approach to increase students' conceptual understanding and overcome their misconceptions in Newtonian mechanics. General flow of implementation of POEA strategy was, firstly, students were given two or three conceptual problems to discuss in their groups. Then, they reported their answers and reasons in class discussion while teacher probed deeply students' reasons with question: why; why do you think like that; and so on. Next, teacher displayed real demonstration or animation and students saw discrepancies between what they think and what happen. Teacher used this condition to start the lesson and conveyed materials based on syllabus and was aware about students' misconceptions. Whenever teacher arrived at a suitable moment she explained why this concept is correct. The last, students were back to group to discuss two or three novel conceptual cases following by short final class discussion. In this step they apply their new concept. In the end of learning, teacher checked students' conceptual understanding and gave conclusion and follow up. Similarly, general flow of using CCT strategy was almost the same as POEA. The differences were two or three problems for group discussion were taken from CCT and the correct answers were given by teacher when she arrived at suitable materials to explain the concept. In brief, the instruction in the experimental group fulfilled the Posner et al.'s conditions.

Conceptual Change

According to Table 1, the students' conceptual understanding after instruction for experimental group was 66.29%. It meant that the ability of this group, on average, was above entry threshold. In addition, it also inferred the effectiveness of the instruction based on conceptual change approach by means of POEA and using CTT strategies in promoting conceptual change. N-gain is a valid measure of instruction effectiveness in promoting conceptual change (Hake, 1998). For the experimental group the average N-gain value was 58 (medium category). In contrast, the students' conceptual understanding for control group was still far below entry threshold after instruction. In conclusion, the negative value (-1.28) of the average N-gain for control group indicated that the traditional approach was not effective in promoting conceptual change. Furthermore, the effectiveness of conceptual change approach over traditional one was also proved by statistical test of mean score differences between two groups. The finding about effectiveness of conceptual change learning in promoting students' conceptual understanding is supported by results of previous studies such as by Yürük (2007), Özmen (2007), Çetin, Kaya, & Geban (2009), Ozkan and Selcuk (2015), Yumuşak, Maraş, & Şahin (2015), and Yürük and Eroğlu (2016). Table 4 shows the dominant misconceptions that have been changed towards scientific concepts in this research.

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Table 4. Change of students' misconceptions towards scientific concepts.

	Conceptual Understanding	Exp* Pre (%)	Exp* Post (%)	Con** Pre (%)	Con** Post (%)
	Heavier objects always fall faster				
1.	Time taken by two metal balls that have the same size but one weighs twice as much as the other to reach the ground:				
	Scientific Concept two balls take about the same time.	11.36	100	3.45	10.34
	Misconception				
	about half as long for the heavier ball as for the lighter one.	47.73	0	44.83	31.04
	considerably less for the heavier ball, but not necessarily half as long.	36.36	0	44.83	48.28
	other: considerably less for the lighter ball	4.54	0	6.90	10.43
2.	If two balls above (point 1) roll off off horizontal table with the same speed, they will hit the floor at a distance:				
	Scientific concept approximately the same horizontal distance from the base of the table.	13.64	95.46	6.90	6.90
	Misconception				
	the heavier ball hits the floor at about half distance than does the lighter ball.	22.73	0	17.24	13.79
	the heavier ball hits the floor considerably closer than the lighter ball, but not necessarily at half distance.	50.00	4.55	55.17	62.07
	other: the lighter ball hits the floor considerably closer	13.64	0	20.69	17.24
	Mass makes object stop moving				
3.	A large object moving at a constant speed because being pushed by a person with a constant horizontal force. If the person stop applying the force, the object will:				
	Scientific Concept immediately start slowing to a stop.	25.00	29.55	13.79	17.24
	Misconception				
	immediately come to stop.	38.64	09.09	55.17	62.07
	continue moving at a constant speed for a while and then slow to stop.	34.09	54.55	24.14	20.69
	others: continue at a constant speed; increase then start slowing	2.27	6.82	6.90	0
	Motion of object implies active force				
	Impetus in circular motion				
4.	A ball is shot at high speed into a frictionless channel in the shape of a segment of a circle. Forces exerted by the air are negligible. Force(s) acting on a ball when it is within the channel is (are):				
	Scientific Concept a downward force of gravity and a force exerted by the channel pointing from the ball to the center.	6.82	86.36	13.79	6.90
	Misconception				
	a force in the direction of motion and a downward force of gravity.	43.18	0	37.93	44.83
	a force in the direction of motion, a downward force of gravity, and a force exerted by the channel pointing from the ball to the center.	31.82	4.55	17.24	34.48
	a force in the direction of motion, a downward force of gravity, and a force pointing from the center to the ball.	11.36	0	17.24	10.34
	other misconception: only a downward force of gravity.	6.82	9.09	13.79	3.45

	Motion of object implies active force				
5.	A a large object moving at a constant speed being pushed by a person with a constant horizontal force. If the person stop applying the force, the object will immediately come to stop.	38.64	09.09	55.17	62.07
	Impetus comes from hit				
6.	A tennis player hits a tennis ball with his racquet in a very strong wind. Force(s) acting on the tennis ball after it has left contact with the racquet and before it touches ground is (are):				
	Scientific Concept a downward force of gravity and force exerted by the air.	6.82	18.18	17.24	0
	Misconception				
	force by the hit and downward force of gravity.	9.09	9.09	6.90	13.79
	force by the hit and a force exerted by the air.	18.18	0	24.14	34.48
	force by the hit, downward force of gravity and a force exerted by the air.	65.91	6.82	51.72	51.72
	other: only a downward force of gravity.	0	65.91	0	0
	Impetus in circular motion				
7.	the path of ball above (point 5) after it exits the channel and move in frictionless horizontal table:				
	Scientific Concept				
	moving in the direction of its motion before exiting the channel.	54.55	93.18	34.48	20,69
	Misconception				
	still constructs a circular path.	40.91	6.82	37.93	48.28

** Experimental Group **Control Group*

Based on Table 4, all students in experimental group have changed their understanding towards scientific concept that "time taken by two balls" (point 1) is about the same. For the problem "two balls roll off the table" (point 2), there were 95.46% of them who have changed their conception to scientific concept that the ball will hit the floor at the same distance from the table. Only 4.55% of them still thought that the heavier ball hit the floor closer than the lighter one. However, this conception is better than conception before instruction where students thought that the time taken as half to the heavier ball. At least, they do not think that the time is directly inversely proportional to the weight. In learning activity they were challenged about the meaning of equation of falling object $t = \sqrt{2h/g}$ in which t (time) is not depend on weight of object. Thus, misconception *heavier object always fall faster* have been changed dramatically to the correct-scientific concept. All students have developed their Aristotelian belief that speed of falling object is proportional to its weight toward Newtonian thinking. In contrast, most students in control group still thought that the heavier ball takes time less than the lighter one either half as for the heavier ball or not necessarily half as for the heavier ball. In other words, they still strongly hold Aristotelian belief.

For point 3 about "a person stop applying the force on object moving", there were more students who have had the correct concept in experimental group after instruction. Most of them have moved from understanding the object "immediately come to stop" (09.09%) to "continue moving at a constant speed for a while and then slow to stop" (54.55%). The first understanding is closer to misconception, whereas the second one is closer to scientific concept that "the object immediately start slowing to stop". So, there was also change of students conception about mass makes object stop moving. On the other hand, for control group most students (82.76%) still had this misconception. Furthermore, for misconception "motion of object implies active force" and "impetus in circular motion", there were also incredible increase of students who hold scientific concept after instruction for experimental group. As many as 79.54% of them have changed their understanding to correct belief that there is no force in the direction of motion. Although there were 4.55% of them who chose option with phrase *a force in the direction of motion*, but their choice did not strongly describe this misconception because there are two others forces in this choice. In other words, students who still held misconception have developed better understanding. Misconception *impetus in circular motion* have been also overcome dramatically as described in point 7 where 93.18% of the students chose the ball will move in the direction of its motion before exiting the channel. In learning they were also challenged to demonstrate where a ball goes if its string suddenly breaks when it is in a horizontal circular path. Concept "impetus comes from hit" was also successful overcome. Only 15.91% of the students still held this misconception after instruction in the experimental group. Although there were 65.91% of them who chose option "only a downward force of gravity, however they have dispelled their impetus misconception.

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Finally, this research found that there is an increase of students' conceptual understandings in the Newtonian mechanics for a group taught by strategies based on conceptual change approach. The increase might be caused by the implementation of conceptual change oriented instruction that fulfilled Posner's et al. (1982) conditions. Based on general flow of POEA, the first target of this strategy was to create cognitive conflict and diagnose students' thinking. Answering and giving reason to the 'predict' cases within discussions helped students to review their prior knowledge and to re-examine their ideas. This does not only probe students' understandings but also induce them to discuss their insight (White & Gunstone, 1992). Then, students who had alternative conceptions became dissatisfied as important condition to initiate conceptual change. In the explaining phase, students gradually start getting the right concept. Fruitfulness of this new concept began being felt by the students at the last discussion. Additional of *Apply* phase in POE strengthened the fruitfulness of the new concepts. The effect of POEA was consistent with research by Sreerekha and Sankar (2016) that found POE was effective in enhancing students' achievement and Coştu et al. (2012) that found modification of POE helps students to achieve better conceptual understanding.

There are some reasons why CCT was also successful in increase conceptual understandings. Firstly, it was credible sources of information for the students. It informed various alternative conceptions that some may be the same as the students' ideas. These alternative conceptions remind students that their ideas are wrong. Then the scientific explanations given that guarantee why the replacing conceptions are correct and explain the consequences that occur if it is not as described make students aware that these are indeed the new correct conceptions. Secondly, CCT was a powerful tool for large class sizes such as in Indonesia. Informing all possible misconceptions and giving detailed explanations on CCT that can be read by the students repeatedly caused it become a potential resource to change readers' conceptions. Thirdly, the flexible properties of CCT made it became friendly learning resources that can be 'asked' by students anytime and anywhere.

Moreover, the differences in improvement of conceptual understanding between two groups might also be caused by differences learning atmosphere. Based on the observations during learning, students in experimental group seemed more active and interactive. Sreerekha and Sankar (2016) stated that POE can motivate students. Then, collaborative use of the POE gives students opportunity to articulate, justify, debate, and reflect on their own and peers' science views and negotiate new and shared meanings (Kearney, 2004). Mercer (2008) stated that a dialogue among students is a motor for conceptual change. He suggested that to achieve the next equilibrium, discussing beliefs with classmates ought to be productive. In addition, explanations and arguments of peers will be more easily understood by students as they discuss in "the same language". Bilgin and Geban (2006) reported that cooperative learning based on conceptual change conditions was significantly better at mastering scientific concepts compared to the traditional teaching.

On the other hand, unsuccessful of traditional learning in improving the students' conceptual understandings because the instructor had not turned her attention to the importance of this approach, so that she did not think about it further and did not attempt to implement it such as to probe students pre-conceptions. Treagust et al. (2014) asserted that an instruction strategy will be effective only by considering students' pre-conceptions. Learning activity done by the lecturer who taught in the control group was, first the lecturer wrote on the board or showed some derivation of equations on the projector; then explained them and gave an opportunity to the students to take note. After the students finished taking notes, the lecturer gave example of problem and explained how to solve the problem by using equations. Such kind of learning approach does never change students' conceptual understanding to the correct concept. This study provides a strong beneficial result that the traditional class did not obtain N-gain after instruction. It reinforces that to change learners' conceptions can only be done by applying conceptual change learning.

Conclusions

Conceptual change learning approach based on conceptual change model has been implemented in this research. Conceptual change learning strategies, POEA and using of CCT, adjusted to the characteristics of the subject-matter and the local conditions that have been implemented succeeded in helping students to change their conceptual understanding and overcome misconceptions in Newtonian mechanics and its six dimensional. The traditional learning being used apparently had no impact on the students' conceptual understanding.

This research contributes to the development of research in field of learning to increase conceptual understanding in Newtonian mechanics. However, the sample of this research was limited on the physics education students. It needs to take a broader sample to obtain more general conclusions. Research to investigate whether the change of students' conceptions is permanent or not and to see implementation of POEA and CCT as general guideline strategies in improving development of students' scientific thinking also needs to complete this findings.

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