Preliminary development of Conceptual Change Texts regarding misconceptions on Basic Laws of Dynamics

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Preliminary development of Conceptual Change Texts regarding misconceptions on Basic Laws of Dynamics

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Abstract. It has been done a study to develop a set of valid and practical Conceptual Change Texts (CCT) for Basic Laws of Dynamics materials. The research method used was educational research and development, comprising of three stages: preliminary study, design development, and evaluation. This preliminary development follows Tessmer’s formative evaluation for self evaluation, expert review, one to one, and small group steps. The design of the CCT is based on the Posner et al’s theory of conceptual change. The data is collected using expert validation sheets, student feedback questionnaires, and interview. The result is it has been developed a set of valid and practical CCT for Basic Law of Dynamics materials consisting of eight units of CCT. These teaching materials could be used by teachers in the Basic Physics courses in university level and in high school to overcome misconception experienced by students and to increase their conceptual understandings.

1. Introduction

Dynamics as a part of Newtonian mechanics is an important topic in physics. It covers fundamental laws of motion. This part of physics explains why an object starts moving, why it is accelerated and decelerated, why an object goes in circular path, what influences of environment to motion of an object are, etc. Therefore, almost all of the physics topics, such as energy and momentum, oscillation and wave, atomic and nuclear physics, thermodynamics, and electromagnetism depend on mastery of this materials. However, many students experience misconceptions on the dynamics concepts. Even though students know and can use equations related to the dynamics material to solve mathematical problems well but they still hold strong misconceptions. For example, students still think that an massive object exerts more interaction force to the less massive object than the less massive object does to the massive one, as described in Figure 1, although they can apply the equation of law of universal gravitational well.

![Figure 1](image-url) Students’ conception that \( F_{Mm} > F_{mM} \)
Many studies have also revealed abundant misconceptions on the dynamics. Most students have misconceptions on restoring force and they have difficulties connecting mathematical solutions to real motions [1]. The dominant misconception held by students revealed by Force Concept Inventory [2] was heavier objects always fall faster [3]. This back to classic Aristotelian law of falling object that velocity of falling object (v) is proportional to the weight of the object (w) and inversely proportional to resistance of medium (R), so \( v = \frac{w}{R} \), and in the case the objects fall in the same medium the result is \( v \propto w \) [4]. Syuhendri [5] also found that students had problems to resume effect of weight/mass towards acceleration of falling object and to discriminate between acceleration and velocity. Similarly, students think acceleration and instantaneous velocity have the same parameters [6]. Students’ perception about impetus concept also causes many misconceptions in dynamics materials such as impetus comes from hit and impetus also exists in circular motion [3].

To develop an effective physics instruction, detail informations about students’ misconceptions are essential to know. Moreover, misconceptions are difficult to change with traditional instruction [3, 7], so that the special approach is needed. Posner et al [8] proposed conceptual change theory to overcome misconceptions. They argue that students’ conceptions might be changed if an instructor can make the learning experiences promote dissatisfaction, plausible, intelligible, and fruitful conditions in students’ mind. Many methods, strategies, and teaching materials have developed based on this theory and seemly effective to dispel students’ misconceptions and to increase their conceptual understandings. Conceptual Change Texts (CCT) as a model of teaching material following this theory is reported successful deal with misconception problems [9-10]. Nevertheless, there is limited research about using CCT in physics classes. Moreover, there is no CCT developed in Indonesia language for physics subject especially for the dynamics materials. Therefore, the objective of the research was to develop a valid and practical dynamics CCT teaching materials that creates dissatisfaction, and be plausible, intelligible, and fruitful for students.

2. Methods

The research is part of the general research in developing teaching materials for physics course especially in Newtonian mechanics area to fulfill the lack of teaching materials that can be used to overcome misconceptions and to increase students’ conceptual understandings. The method used in this research was educational research and development. As general, the research consisted of three stages, namely preliminary study, design development, and evaluation. The preliminary study focus on the identification of misconceptions experienced by students. The design development was to develop prototype of conceptual change texts regarding misconceptions identified in the first stage. The evaluation stage was to evaluate and revise the prototype so that the developed conceptual change texts become valid and practice.

The conceptual change texts of Basic Laws of Dynamics was developed based on Posner et al’s theory of conceptual change [8]. There are four conditions that must be fulfilled in order to conceptual understanding can be changed, namely dissatisfaction to the old concepts and plausibility, intelligibility and fruitfulness of the replacing concepts. Based on these four requirements of conceptual change, Syuhendri [11] developed format of CCT as shown in Figure 2. This format was used to develop the prototype of the conceptual change texts of the Basic Laws of Dynamics.

The evaluation process used Tessmers’ formative evaluation model [12]. Since this study was preliminary development of CCT, the Tessmers’ evaluation formative was only applied for self evaluation, expert review, one to one, and small group staps. The evaluation is a process to obtain various reactions from various respondents towards the prototype of CCT materials. This reaction is an input to improve the teaching material and make it better. Self evaluation was needed to ensure that CCT made was truly based on available theory and can achieve the desired goals. The expert review emphasized scientific validity and accuracy of the CCT. In one-to-one step, several participants individually studied the CCT materials and then she/he was asked about readability, language, illustrations, lay out, and the level of difficulty of the texts developed. In small group trials, a small
group examines the CCT materials and then they were also asked to give comments about readability, language, illustrations, lay out and level of difficulty of the texts.

![Figure 2. Format of conceptual change texts](image)

3. Results and Discussion
The development of Basic Laws of Dynamics CCT refers to form of misconceptions experienced commonly by students in the dynamics topic. Based on the preliminary study, there were eight domains of misconceptions held by students in dynamics topic distributed in all materials. So, based on these domains, it was developed relevant CCT.

In the beginning of development process, the basic structure of the CCT was developed. Based on Posner et al’s theory, the first part of the CCT was developed in order to create dissatisfaction in students about their conceptions. To reach this goal, in the beginning of the CCT is put case and some questions. Then, a space is provided to answer the questions. Then, some kind of misconceptions are listed in the Texts. The list were composed based on previous research and the author experiences as an instructor. Based on this list, students know that their answer is wrong and categorized as misconceptions. The next parts of the CTT are to explain the correct concepts. The explanation is made in such a way that the new concepts become intelligible, plausible, and fruitful for students. Finally, a prototype of CCT can be composed. Based on the input from experts and the feedback from
students, this prototype was revised. The revision produces a set of valid and practice CCT for Basic Laws of Dynamics as shown in Table 1.

### Table 1. The CCT for Basic Laws of Dynamics topic

| Unit of CCT          | Kinds of misconceptions                                                                 | Explanations to support the correct concepts                                                                 |
|----------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| 1 Free Fall Motion   | Heavier object will arrive at the ground sooner, due to its weight.                     | Equations of free fall motion.                                                                          |
|                      |                                                                                       | Dropping two different weight objects.                                                                  |
| 2 Interaction between Two Different Mass Objects | Objects with greater mass does more force on smaller mass object. The Earth does greater force on the moon so that the moon revolves around the Earth. The Earth attracts coconuts by a force much larger than the coconut attracts the Earth. | Universal Gravitational Law. Effect of the same forces working on different mass objects. The equation of an object accelerated towards the Earth and the equation of “accelerated earth” towards an object. |
| 3 Force Exerted by Two Different Velocity and Mass Objects | Bigger objects attract greater contact force on small objects (small mass objects). More active objects do bigger force. Truck pushes the sedans while the sedan does not. Truck works bigger force on sedan than the sedan does on the truck. There is no force at all in the event a truck hits a sedan. | Hukum III Newton: Newton's Third Law. Action-reaction forces. Giving another example, a hammer does a force on a nail exactly the same as nail does on the hammer. |
| 4 An Object Pushes other Object that has Different Mass | The same as point 3                                                                     | The same as point 3                                                                                     |
| 5 Force on Stationary Object | There is no force acting on a stationary object. Only the gravitational force acting on the book. The force done by air pressure increases the force of gravity (the gravitational force consists of the earth's attraction and force of the air pressure). There are three forces acting on a stationary object on the table (gravitational force, air pressure force, and normal force). In the inclined plane, normal force still works in the vertical direction. The gravitational and normal forces are action-reaction pairs. | The force acting on a stationary object. Explanation of deformation of table atomic (Hooke force, known as normal force). Newton's First Law: Three forces acting on the book: gravitational force, normal force, and friction force. Normal force is perpendicular to the contact surface between two objects. Illustration of holding book with students' hand. |
| 6 Force on Moving Object | Force pushing a box is always larger than the force that opposes the movement of the box. The force given is equal to the weight of the box. The force given is greater than the weight of the box. If force applied to the object is doubled, the speed of the object become twice larger, at least faster than before. No force, no motion. | Four forces acting on objects: gravity, normal force, force given by the child (pushing), and force that resists the movement of the object (friction). Newton's first law. Newton's second law. |
| 7 Force on Moving Lift | There is no force acting on a lift going upward. The upward force of the cable in the lift is greater than the gravity. The upward force acting on the cable is greater than the sum of the gravitational force and force by the air pressure (downward). | There are two forces acting on the lift: the downward gravitational force and the force done by the rope upward. Newton's First Law. Action-reaction forces. Newton's Second Law. |
| 8 Force on a Stationary Box on the Floor | There is no force acting on a stationary box on the floor. Only downward gravitational force acting on the box. The force exerted by air increases the gravitational force. There are three forces acting (gravitational force, force by air pressure, and force done by the floor/norma force). | There are two forces acting on a box on the floor: the gravitational and the normal forces. Interaction force between an object and the earth, The principle of the appearance of the normal force; Hooke law. Action-reaction pairs. Newton's Third Law. |
The first unit of the CCT in Table 1 describes the misconception about free fall motion. Students think that the heavier objects always fall faster. To make this conception unsatisfactory for them, teacher drops two different heavier objects, for example one is a ball made from paper and another is a marble, from the same height. Students see that the two objects arrive on the floor at the same time. This means that the true concept is two different weight objects will arrive on the floor at the same time. Explanation on the CCT is made in such a way that the new concept is intelligible, plausible and fruitful for students. The explanation made is that the equation of free falling objects will result in the conclusion that the time \((t)\) taken by objects to fall if the resistance can be ignored only depend on the gravity and the height.

In the second unit of the CCT, it is described the interaction between two different mass objects. The misconception is a greater mass object does bigger force on small one. Students believe that large mass objects will attract small mass objects with a force greater than small mass objects attract the large mass objects, \(F_{\text{eqM}} > F_{\text{eqm}}\). In the case of the Earth-Moon system, the Earth is considered to provide greater force on the moon so that the moon revolves around the Earth. Likewise for the case of the Earth and coconuts, where the Earth is considered attract the coconuts with a force much larger than the coconut does on the Earth, which causes the coconut falls to the Earth. The correct concept based on the universal gravitational law is that the interaction forces between two objects are equal. The explanation given to support the correct concept is the emphasis on the conceptual understanding of the universal gravitational law. Thus for the Figure 1, the correct correlation is \(F_{\text{eqM}} = -F_{\text{eqm}}\). In the case of the Earth-Moon system, the moon will attract the earth with the same force as the Earth attracts the moon. Likewise the coconut will attract the Earth with the same force as the Earth attracts the coconut. However, because the mass of the Earth is much larger, than the effect of the attraction of coconuts on the Earth can be neglected. For objects close to the Earth, the gravitational force of an object is called the weight of an object, \(w = mg\), and the gravitational acceleration is obtained towards the Earth \(g = GM/r^2\). The same analogy, the acceleration of the Earth towards an object near the Earth, say the acceleration of “gravity of that object”, is \(g' = Gm/r^2\). Since \(m << M\), then \(g' << g\).

Misconception about force exerted by two different velocity and mass objects occurs in several forms. First, students think that larger object will do a greater contact force on small object (small mass object). It’s the same as the misconception that objects that are more active will do bigger force. This misconception may occur because of students’ experiences in everyday life that the big or the strong man will always win. Various forms of misconceptions often happen in a collision case between a truck and a sedan, such as: the truck does a force on the sedan while the sedan does not work a force on the truck, because the sedan looks destroyed while the truck can still move; the truck work more force on the sedan than the sedan does on the truck; or there is no force at all in the event, the sedan is destroyed just because it is run over by the truck. Even for a sedan that moves faster than a truck, the misconception arises from the assumption that the truck gives a larger force to the sedan so that the sedan stops moving. Improvement of Newton’s Third Law conceptual understanding is a solution to this misconception. This is the same for the fourth unit of the CCT in Table 1, an object pushes other object that has different mass.

The fifth and the sixth units of the CCT are regarding misconception about force on stationary and moving objects. Explanation of the correct concept for force on the stationary object is by showing the free diagram analysis of the forces acting on the object. The most difficult for students to accept is about the existence of normal force. Therefore, the explanation of the normal force is connected to the deformations of table atoms which give rise to the Hooke force (spring force) of the table atoms to the book. In the same way, the free diagram analysis of an object is also needed for forces on moving objects. In a moving object, the forces acting are connected with the Newton's First Law for an object moving with constant speed and with the Newton’s Second Law, \(F = ma\), for the constantly accelerated motion. Whereas in the stationary object, it is only connected with the Newton's First Law \(F = 0\).

The explanation of the correct concept for the seventh unit of the CCT is by emphasizing the existence of two forces acting on the lift, namely the downward gravitational force and the force by
the rope upward. Because the lift moves at a constant speed, this two forces are equal. Again, the understanding of the First and Second Laws are strengthened. Through explanation, students are not only expected to understand these laws mathematically but also conceptually. The last unit of the CCT in Table 2 is concerning the force on a stationary box on the floor. There are many forces working on a box rest on the floor. The impression of stationary objects makes students think that the resultant of forces acting on the object is zero. The explanation of the correct concept is that there are two forces acting on the object rest on the floor, namely the gravitational force and the normal force. Furthermore, the explanation is continued by explaining the normal force that counters the weight of the object. The normal force and force done by the weight of the box pressing down the table atom are the action-reaction pairs according to Newton’s Third Law. However, the normal force and gravity are not the action-reaction pairs.

The explanation of the correct concepts is made so that students are convinced that the replacing concepts are understandable and reasonable. Furthermore, the new concepts must also have the ability to solve new relevant problems. The replacing concepts are understandable and reasonable mean the new concepts should be intelligible and plausible, while the ability of the new concepts to solve new problems means it is fruitful. However, to show students that their old conceptions are not so powerful to solve problems is also the only way to deal with students’ misconception in order to convince them to construct a more plausible concept [10]. Such characteristics of the explanatory of the correct concepts is to guarantee that the replacing concepts are undoubted. This condition is important to replace the old concept that has been held in the students’ mind. The relationship between the old concepts, the new concepts and the warranty is shown in Figure 3.

![Diagram](image)

**Figure 3.** The relationship between misconceptions, warranties, and the correct concepts in CCT

The development of conceptual change texts based on Posner et al’s theory were reported in many studies successful in overcoming students’ misconceptions and increasing their conceptual understandings. The CCT used in the instruction is effective to remediate students’ misconception, and it is more effective if it is supported by other materials or experience [13]. Students’ conceptual understandings taught using strategies related to conceptual change approach, among them by using CCT, is significantly better than those taught by traditional approach [3]. The combination of computer simulations enhanced with conceptual change texts (CS-CCT) is useful for students to enhance their conceptual understandings [14]. A group of students reading conceptual change text enriched with metaconceptual processes is significantly better to promote their conceptual understanding [15]. In addition, Yumusak et al. [16] found that CCT and CCT with Computer-Assisted Instruction (CAI) are more successful in overcoming misconceptions than traditional teaching methods. It is clear that learning methods or strategies combined with the CCT or only use the CCT in the learning process can overcome misconceptions better. Therefore, conceptual change texts is learning materials prepared for eliminating students’ misconceptions [17].

4. Conclusion

It has been developed eight units of CCT for Basic Laws of Dynamics materials regarding misconceptions in this topic. The development followed requirements to change learners’ conceptions.
The texts firstly intended to emerge dissatisfaction in learners’ mind and followed by explaining of the correct concept plausible, intelligible, and fruitfulness. The CCT can be used by teachers in Basic Physics courses in universities and in secondary schools as a supplement reading materials which aims to improve conceptual understandings and to overcome misconceptions. Moreover, this research can be used as a model for developing of CCT for other materials. It is also recommended to find out the effectiveness of the Basic Laws of Dynamics CCT in promoting conceptual understandings and in overcoming misconceptions.

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