Student teachers’ misconceptions about gravity

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Abstract. The aims of this research were to explore misconceptions held by student teachers of physics concerning gravity and to reveal the level of the misconceptions. The subject of the research consisted of 73 Physics Education Department students attending Introductory Physics course in a state university in Indonesia. The instrument used was a set of diagnostic test comprised of selected items from the Indonesian version of the FCI. The data was analyzed by using descriptive statistics. The result of the study showed that the student teachers of physics experienced five kinds of misconceptions concerning gravity with the most common misconception (79.45%) was the heavier objects always fall faster. Four other misconceptions were gravity increases as objects fall (47.95%), gravity acts after impetus wears down (21.92%), air pressure-assisted gravity (16.44%), and gravity intrinsic to mass (4.79%). It can be concluded that the student teachers hold firm misconceptions about gravity. The findings of the research are similar to other research findings from other countries. The implication of the research is teachers should concern with students’ conceptual understanding in their classrooms. It is suggested to conduct further research to apply conceptual change learning to overcome the misconceptions.

1. Introduction

Students develop their own ideas about physics. They develop these belief systems mostly based on everyday-life experiences. Unfortunately, many ideas are inconsistent with what physicist belief. Disagreement between students’ ideas and the formal scientific explanations are often called as misconceptions. Based on previous studies, there are many misconceptions held by students in gravity topic. Students have naïf views about gravity such as “gravity is a pressing force”, “gravity is possesses exclusively by heavy body”, and “suspended substances are weightless” [1]. Students have idea that air is needed by gravity to exist [2]. Students have perception that gravity only act on object moving vertically downwards and not on object moving vertically upwards [3]. Students’ teacher had serious misconceptions about gravity, gravitational acceleration, gravitational force and weight, as well as inertia [4]. Whereas, gravity is one of the important material in physics. As a part of Newtonian mechanics, it is an essential basic for advanced physics course [5].

In teaching and learning process, some certain key concepts are needed to understand well to develop better conceptual understanding [6]. These key concepts are called as threshold concepts [7]. One of the threshold concepts is gravity. Gravity concept is closely related to other general physics concepts [8]. Therefore, students’ understanding of the gravity concept can be as an indicator for their understanding of other concepts in physics such as for kinematics and momentum [6]. Several concepts such as force, weight, free fall motion, projectile motion, circular motion, conservation of energy, and momentum are also influenced by understanding of the gravity concept.
The problem is some of the threshold concepts are difficult to understand by learners. Lack of understanding of the threshold concepts are believed to have long-term effect on students’ learning and their ability to use their knowledge in new contexts [6]. Students might think correctly about one case, but they go to wrong idea in another case, even the cases are constructed by the same concept. In terms of gravity concept, this inconsistency was reported for example by Ferreira & Lemmer [9] where students tended to use Newtonian thinking that gravitational acceleration is the same for vertical downward free fall motion, but they think that heavier object fall faster for vertical upward motion. Wilson et.al. [10] also reported that students could apply the mathematical expression of Newton’s second law for solving problems, but unfortunately they still hold strongly Aristotelian view about relationship between force and motion. This is also consistent with Syuhendri’s [11] research finding that students easily use mathematical equation to find time needed by an object to fall from a certain high but they give response that heavier object always fall faster.

Misconception is still one of the serious educational problems in Indonesia. Among the factors that caused lack of quality of educational outcome is misconceptions experienced by learners. Misconceptions interfere negatively the learning process. It is important that students have to develop sufficient conceptual understanding of threshold concepts to enable them to connect to the new material. Moreover, based on research findings, it is concluded that misconceptions are highly resistant to change by traditional teaching strategies [11,12]. Therefore, it is needed a particular learning approach under specific theory to overcome students’ misconceptions. This theory is called as Theory of Conceptual Change [13]. However, research addressed to overcome students’ misconceptions such as how to conduct the conceptual change learning is limited in Indonesia. Even though, it has been introduced by Author to Indonesian researchers since almost one decade ago.

To start the conceptual change learning, the identification of students’ misconceptions is the first step that have to do. The identification of students’ misconceptions can help teachers to design appropriate learning activities in order to foster cognitive conflict in students’ mind to lead them ready to overcome their misconceptions. This initial process can be a guaranty to facilitate a meaningful learning of a scientific topic. However, so far, there is a little research done on student teacher conceptual understandings about gravity, especially for Indonesian respondents. Since there is a lack of research to explore students’ conceptions about gravity, this research is worthy to be carried out. Therefore, this research aims to identify student teachers’ misconceptions about gravity. The study also reveal the level of the experienced misconceptions.

2. Method
This descriptive research was part of the continuing extensive exploration of misconceptions in Newtonian mechanics area. This research focus on physics student teachers’ misconceptions concerning gravity topic. Misconceptions held by respondents were explored by means of Force Concept Inventory (FCI) developed by Hestenes, Wells and Swackhamer [14]. The inventory instrument was translated by Author to Indonesian [15]. The Indonesian version of the FCI can be downloaded in website http://modeling.asu.edu/R&E/Research.html. The revision version of the FCI launched in 1995 by Halloun, Hake, Mosca, and Hestenes [16] is a 30-multiple-choice-items instrument consisting of five options in which one option is Newtonian thinking and four others are misconceptions commonly experienced in the Newtonian mechanics area. There are six domains covered by the FCI in probing misconceptions, i.e. Kinematics, Impetus, Active Forces, Action/Reaction Pairs, Concatenation of Influences, and Other Influences on Motion [14, 16]. Gravity topics is part of the Other Influences on Motion domain.

The instrument used in this descriptive research was the Indonesian translation version of the FCI related to gravity topics. There are nine items of The FCI related to five kinds of misconceptions in gravity. The relationship between gravity misconceptions and the FCI items is shown in Table 1.
Table 1. Taxonomy of Misconceptions Probe by the FCI for Gravity

| Gravity                                      | Items and Options |
|----------------------------------------------|-------------------|
| G1. Air pressure-assisted gravity            | 3E; 11A; 17D; 29C |
| G2. Gravity intrinsic to mass                | 3D; 11E; 13E      |
| G3. Heavier objects fall faster              | 1A; 2B,D         |
| G4. Gravity increases as objects fall        | 3B; 13B          |
| G5. Gravity acts after imputed wears down    | 12D; 13B; 14E    |

Based on Table of Taxonomy of Misconceptions Probed by FCI [16].

The subject of the research consisted of 73 Physics Education Study Program students of Sriwijaya University who enrolled Introductory Physics 1 course. About half semester of the Introductory Physics course discuss Newtonian mechanics topics. The Indonesian version of the FCI was administered to them in the beginning of the First Semester.

The data was collected both qualitative and quantitative. The quantitative data was gathered based on respondent choice to the instrument. The qualitative data collected based on analysis of students’ responses to the instruments, semi-structured interviews, and their work during the lesson. Descriptive data analysis was done by using frequency, means, and percentages of students’ correct and wrong answers for each aspect of gravity. The misconceptions were revealed based on student teachers’ wrong answers and consulted to Table 1 above.

3. Results and Discussion

Based on the data analysis, it was obtained misconceptions experienced by student teachers of Physics Education Study Program and their levels concerning gravity as shown in Table 2.

Table 2. Kinds and Levels of Misconceptions Experienced by Physics Education Study Program students Concerning Gravity

| No  | Misconceptions                              | Items and Options | % Mean |
|-----|---------------------------------------------|-------------------|--------|
| 1   | Air pressure-assisted gravity                | 3E; 11A; 17D; 29C | 16.44  |
| 2   | Gravity intrinsic to mass                    | 3D; 11E; 13E      | 4.79   |
| 3   | Heavier objects fall faster                  | 1A; 2B,D         | 79.45  |
| 4   | Gravity increases as objects fall            | 3B; 13B          | 47.95  |
| 5   | Gravity acts after imputed wears down        | 12D; 13B; 14E    | 21.92  |

Table 2 showed five kinds of misconceptions experienced by the students concerning gravity. The highest level misconception was “heavier objects fall faster”, while the least one was “gravity intrinsic to mass”. Next, it is described in detail for each of the misconceptions.

3.1. Air pressure-assisted gravity

The are 16.44% of student teachers who hold misconception that “air pressure-assisted gravity”. This conception is wrong in terms of the law of Archimedes (buoyancy forces by fluid) and the concept of air friction which inhibits the motion of objects. Example of naif ideas is in case “A stone dropped from the roof of a single story building to the surface of the earth (Question 13)”. Students who hold this misconception think that “the stone falls because of the combined effects of the force of gravity pushing it downward and the force of the air pushing it downward”. The air is considered pushing the rock down, instead of slowing down or floating it upwards (buoyant force here is not significant,
although conceptually there is the force exerted by the air “fluid”). This is relevant with Galili and Bar’s [1] research finding that children view gravity as a pressing force. Another example of naïf idea in Question 17: “An elevator is being lifted up an elevator shaft at a constant speed by a steel cable as shown in the figure below (all frictional effects are negligible)”. In this situation students think that “forces on the elevator are the upward force by the cable is greater than the sum of the downward force of gravity and a downward force due to the air”.

3.2. Gravity intrinsic to mass
This misconception was also revealed by four FCI items, i.e. number 3, 11, 13, and 29. For the case “A stone dropped from the roof of a single story building...” above, students think that “the stone falls because of the natural tendency of all objects to rest on the surface of the earth”. This is the same with students answer for Question 13: “A boy throws a steel ball straight up. Consider the motion of the ball only after it has left the boy's hand but before it touches the ground, and assume that forces exerted by the air are negligible”. For these conditions, students think “there is no force acting on the ball and the ball falls back to ground because of its natural tendency to rest. The natural tendency of an object to rest on the surface of the earth is similar to Aristotle’s view.

The interesting thing is found in Question 29 where the developers give a case “an empty office chair is at rest on a floor”, and give possibility the forces is (are) acting on the chair, i.e. a downward force of gravity, an upward force exerted by the floor, and a net downward force exerted by the air. However, students are consistent with their idea that there is no force action on the chair; since the chair is at rest there are no forces acting upon it. This case also revealed another massif misconception that students belief there is no force action at rest object. The students picture no force action on a book on a table (Figure 1.a). Even, when the book is pushed, if the book does not move, children think no force action on it (Figure 1.b).

![Figure 1. Students’ misconception no force action on the book even when the book is pushed.](image)

3.3. Heavier objects fall faster
This is a most common misconception held by respondents. Item number 1 of the FCI directly explored student teachers’ conceptual about effect of object weight toward its speed to fall. The question is “Two metal balls are the same size but one weighs twice as much as the other. The balls are dropped from the roof of building at the same instant of time. The time the balls take to reach the ground below will be....” it was only 6 of 73 respondents or 8.22% that answered correctly, i.e. the two objects will reach the ground almost at the same time, while 86.3% of them chose that the heavier ball will reach the ground first (options A and D). There are 54% of 86.3% respondents believed that the heavier ball takes time about half as long for the lighter one, while the remaining 46% respondents chose that the heavier ball takes time less than the lighter one, but not necessarily half as long.

This misconception has long being experienced by people. Aristotle was also caught up in this thought. He explained that the speed (v) of a falling object is proportional to the weight (w) of the object and inversely proportional to the resistance (R) of medium where the object move, so \( v = \frac{w}{R} \). In the case where the medium resistance can be neglected, like case above, the ratio of the speed of falling object between one object to another is \( v_1/v_2 = w_1/w_2 \), which means that if the objects fall from the same height then the heavier objects will reach the ground first. In other words, the heavier object falls faster in proportional to its weight. However, Newtonian thinking is difference, where the time needed for an object to fall if the medium resistance is ignored depends only on gravitational acceleration (g) and the distance (h) to fall, \( t = \sqrt{\frac{2h}{g}} \), which means that if the objects fall from the
same height then the time required to arrive to the ground is the same. Although this misconception has long been happening, unfortunately it still exists today.

3.4. Gravity increases as objects fall

It was 47.95% of respondents believed that gravity increases as objects fall. This kind of misconception is revealed by question number 3 option B where they think ”A stone dropped from the roof of a building to the surface of the earth speeds up as it falls because the gravitational attraction gets considerably stronger as the stone gets closer to the Earth”. The same proposition is also concluded when respondents chose option B for question number 13: ”A boy throws a steel ball straight up. Consider the motion of the ball only after it has left the boy's hand but before it touches the ground, and assume that forces exerted by the air are negligible. The force acting on the ball on the way down from its highest point is a steadily increasing downward force of gravity as the object gets closer to the Earth”. Respondents picture the gravitational force acting on an object as:

![Figure 2. Students’ misconception about gravitational attraction on an object](image)

Undistinguishing among velocity, acceleration, and force is also shown here. In reality, students look the object move faster and faster, but they think if the object moves faster, then the acceleration of the object must be increase and force acting on it must be also increase. Many studies reported this similar misconception, such as acceleration and instantaneous velocity have the same parameters [17].

3.5. Gravity acts after impetus wears down

There are three questions that revealed this misconception, i.e. question number 12 for option D, number 13 for option B, and number 14 for option E. An example of students conception that showed this misconception was: “The forces acting on the ball thrown vertically upward is the upward force decreases regularly from the ball loose from hand till it reaches the highest point; when the ball moves downward, the downward gravitational force that increases uniformly ....” (Question 13 option B). Students think that there is a force acting on the ball that comes from the hand of the thrower that make the ball moves upward. This kind of force is known as impetus, an intrinsic force that keep an object moving [14]. Moreover students think that this force decreases regularly as the ball moves upward till it reaches the highest point. As soon as the impetus wears down, the gravitational force that increases uniformly take over acting on the object and attracts the ball moves downward. It is clear that students not only hold misconception about increasing of gravitation force acting on an object on its way dawn as it gets closer to the earth but also hold misconception about availability of impetus.

The thought that it is needed a force to keep objects move is also in line with Aristotle's thought that the nature of objects are rest on the earth and a force is needed to keep the objects moving. However, this thought contradicts Galileo's view that objects will keep moving at a constant speed if there is no force acting to change the motion. Galileo's thinking was finally formulated by Newton as laws of motion. The problem is that even though students can remember these Newton laws well and can use the formulas to solve physical problems mathematically, they still experience misconceptions with the basic concepts.

The findings of the research are similar to other research findings from other countries such as in Saudi Arabia [12], Cambodian [17], and Japan [18]. The implication of the research is lecturer should
concern with student teachers’ conceptual understanding in their classrooms. Understanding concepts correctly is important for them as teachers in the future. It is suggested to apply conceptual change learning to overcome these misconceptions. Traditional instruction is reported not effective to change the misconception [11, 12]. Posner et al [13] have proposed conceptual change theory that describes how students’ conceptions can be changed to the correct concepts. They suggested four important conditions which must be fulfilled in order to conceptual change occur, i.e. dissatisfaction to the old concepts, and intelligibility, plausibility, and fruitfulness of the replacing concepts. Based on this theory, it was developed various conceptual change strategies to change misconceptions to correct concepts for example by using hands-on activities, concept mapping, analogies, and conceptual change texts [19].

4. Conclusion
This study has explored misconceptions experienced by student-teachers of physics concerning gravity by means of selected items of Indonesian version of the FCI. The result of the study showed that the student-teachers experienced firm misconceptions about gravity. The highest level of detected misconception was students think that the heavier objects always fall faster (79.45%). Four others misconceptions from the higher level were: gravity increases as objects fall (47.95%), gravity acts after impetus wears down (21.92%), air pressure-assisted gravity (16.44%), and gravity intrinsic to mass (4.79%). The finding of this research was similar to other research findings in the area of Newtonian mechanics. Based on the findings of this study and other relevant studies, teachers or educators should concerning with students’ conceptual understanding in their classrooms. The next research is needed to apply appropriate teaching approach, methods, or strategies to overcome misconceptions since the traditional way reported are not really effective in overcoming the misconceptions. Application of conceptual change theory is a solution for this problem.

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