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PHYSICS EDUCATION STUDENTS' CONCEPTIONS ON ACTIVE FORCES AND ACTION-REACTION PAIRS

Syuhendri[1]
[1]Physics Education Study Program, Faculty of Teacher Training and Education, Sriwijaya University, Indonesia
hendrisyukur@yahoo.com

ABSTRACT

The purpose of this research was to investigate student-teachers' conceptions on active forces and action-reaction pairs. The instrument used was made up of 13 multiple choice questions with 5 options selected from the FCI (ver. 1995). It was administered to physics education department students of faculty of teacher training and education of a state university in Indonesia. The qualitative data were also collected through interviews and observations performed during the learning process. The research findings revealed percentages of seven common misconceptions on active forces based on taxonomy of misconceptions probe by FCI, i.e. 1) only active objects exert forces (17,81%), 2) the motion of an object representatives of active forces acting on the object (63,01%), 3) no motion means no force (50,68%), 4) velocity is proportional to applied force (40,41%), 5) acceleration of an object implies increasing force acting on the object (35,62%), 6) force causes acceleration to reach terminal velocity (15,53%), and 7) active force wears out (28,77%); and two misconceptions on action-reaction pairs, i.e. 1) greater mass exerts greater force (33,22%), and 2) most active object produces greater force (47,49%). The results of the research showed that the Indonesian physics education students held strong misconceptions on active forces and action-reaction pairs. The results of this research are similar with the findings of related studies in other countries.

Index Terms— Misconceptions, Active Forces, Action-Reaction Pairs

1. INTRODUCTION

The purposes of science education in Indonesia among them are to develop students' understanding of natural phenomena, concepts, and principles of science that are useful and can be applied in everyday life; and to increase their knowledge of concepts, and science skills as a basis for continuing education to the next level. This great goal has not been accompanied by satisfactory results yet. Indonesia has been struggling to face a variety of education issues, including the issue of the quality of science education.

Based on research reports of the Organisation for Economic Co-operation and Development (OECD) through its PISA program (Programme for International Student Assessment) for years 2000, 2003, 2006, 2009, and 2012 the science literacy of Indonesian senior high school students were at ranking 38 out of 41, 38 of the 40, the last of the 57, 57 of the 65, and 64 of the 65 countries respectively. Similarly, according to a report of TIMSS (Trends in International Mathematics and Science Studies) for year 2011, Indonesia was at ranking 40 out of 42 countries. This finding was not better than the previous TIMSS findings, for example in 2003, Indonesia was at ranking 36 out of 45 countries both for science and mathematics. Survey by the IEA (International Educational Achievement) on the ability of science and mathematics of senior high students, Indonesia was at ranking 38 out of 39 countries. Generally, based on the record of the UNDP, the quality of Indonesia human resources a.k.a. the Human Development Index (HDI) for year 2000 was ranked 105 out of 108 countries, and Indonesia was far below ranking of regional countries such as Singapore, South Korea, Brunei Darussalam, Malaysia, Thailand, and the Philippines [1].

Among the causes of the lack quality of science education in Indonesia are the tendency of science education to tests/exams-oriented, and teachers conveyed science as a product to be memorized by students [1]. Sciences or physics questions at various examination dominated by quantitative computational questions have been encouraging teachers to drill students to solve the questions by using formulas instead of increasing students' conceptual understanding. Kim and [2] found a little impact of doing computational problem toward increasing of conceptual understanding. Lack of conceptual understandings continues until they are in the university even after returning to schools as physics/science teachers. Misconceptions occur generation to generation and are taught by teachers in the classroom. Syuhendri, Jaafar, and Yahya [3] who studied about physics education student-teachers' conceptions of a public university in Indonesia reported that average students' conceptual understanding in mechanics was 18.18%. This finding was worrying. Hestenes and Halloun [4] stated that only by mastering mechanics concepts of 85% a

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learner can apply them well and only by mastering 65% of the concepts he/she is ready to learn mechanics.

Mechanics is important material in physics. Almost all parts of physics depends on mastery of mechanics concepts. Zukoski [5] argued that students enrolling in a college physics course do have misconceptions concerning force. Therefore, the basic conditions of students in mastery of concepts in mechanics need to be known. Two of the key concepts in mechanics are active forces and action-reaction pairs. The purposes of this study are to see 1) how the conditions of students' conceptions on active forces and action-reaction pairs, and 2) what kinds and what levels of the misconception experienced by the students at that field.

2. METHOD

The instrument used in this descriptive research was the Indonesian translation version of the FCI. The FCI is a set of diagnostic test in mechanics domain developed by Hestenes, Wells and Swackhamer [6]. The revision version of the FCI consists of 30 multiple choice items [7]. Each item has five options, one is a correct concept and the four others are misconceptions often experienced by students in the mechanics field. The Indonesian translation version of the FCI and other language versions can be downloaded in http://modeling.asu.edu/R&E/Research.html. As many as 13 items of the FCI corresponding to active forces and action-reaction pairs were selected for this study.

The subject of the study was all first semester Physics Education Department students of a pubic univeristy in South Sumatera comprised of 73 students who enrolled in Basic Physic 1 course. The FCI test was administrated to them in the beginning of the Semester 1.

Descriptive statistical data analysis by using frequency, means, and percentages of students' answer for each of five options for one or several items was calculated to probe students' misconception. The misconceptions were revealed based on all students' wrong answers consulted to the table of Taxonomy of Misconception probed by the FCI [6]. The qualitative data were also collected through semi-structure interviews and observations during the learning process. The sample for the interviews based on opportunistic sampling [8] was consisted of 9 students who were indicated hold dominant, middle, and low misconceptions.

3. RESULTS

Based on the data analysing, it was obtained the student-teachers' misconception and their levels in active forces and action-reaction pairs as displayed in the following table.

Table 1. Misconceptions Experienced by Respondents and Their Percentages on Active Forces and Action-Reaction Pairs

No	Misconceptions	Items and Options	N	%
	Active Force			
1	Only active agents exert forces	15D;16D; 17E; 18A; 28B; 30A	78	17,81
2	Motion implies active force	5C,D,E; 27A	92	63,01
3	No motion implies no force	29E	37	50,68
4	Velocity proportional to applied force	22A; 26A	59	40,41
5	Acceleration implies increasing force	3B	26	35,62
6	Force causes acceleration to terminal velocity	3A; 22D; 26D	34	15,53
7	Active force wears out	22C,E	21	28,77
	Action/Reaction Pairs			
8	Greater mass implies greater force	4A,D; 5B; 16B; 28D	97	33,22
9	Most active agent produces greatest force	15C; 16C; 28D	104	47,49

Based on Table of Taxonomy of Misconceptions Probed by FCI [7].

Table above showed 7 and 2 types of misconceptions held by respondents on active forces and action-reaction pairs respectively. The most common misconception was *"motion implies active force"*, while the lest common one was *"force causes acceleration to terminal velocity"*. Next, it is described in detail each of these misconceptions.

3.1. Only active agents exert forces

There were 17.81% of respondents held the misconception that *only active agents exert forces*. Question number 15 showed *a car is pushing a broken truck*. Respondents who had this conception would think that *only the car exerts a force on the truck, and the truck cannot push the car because the truck's engine is not on*. The same thing was also revealed by the option **D** of question 16. In question 28, it was illustrated *there are two children sitting in a wheelchair; child A heavier than the child B. Then child **A** suddenly pushes child **B** outward with his feet so that they move away each other*. Students thought that *only child **A** exerts a force on **B**, while **B** does not.* It can be concluded that students held perception that only active objects can exert forces.

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3.2. Motion implies active force

As many as 63,01% of respondents held the conception that motion represents active force. This misconception is contrary to the first Newton's law that an object either remains at rest or continues moving at a constant velocity if the resultant of forces acting on it is zero. There were two questions revealed this misconception, i.e. number 5 and number 27. In question 5, about *a ball moves in a circular channel*, the students chose option **C**, **D**, and **E**, that described there is a force in the direction of the ball motion. Meanwhile on the question 27, option **A**, it was described *a box will immediately stop moving if the push is stopped*. So the students thought that the box moves because of being pushed constantly and it will stop moving if it is not pushed anymore, instead of it stop moving due to the frictional force that works in the opposite direction of its motion.

3.3. No motion implies no force

There were 50.60% of respondents experienced misconception that *there is no force acting on a rest object*. Similar to the previous statement, it is argued that if the object does not move then it means that there is no force acting on it. Question 29 depicted a stationary chair on the floor. Respondents who held this kind of conception chose the option that *there is no any force working on the chair*. Because the chair is in a rest condition, it means that there is no force acting on it. Lack understanding of the action-reaction force, the third Newton's law, was also revealed besides lack of understanding of the first Newton's law.

3.4. Velocity proportional to applied force

This kind of misconception means that *the greater the force applied on an object the greater the velocity of the object is*. It was again disclosure that a force needs to keep an object moving. It is clearly contrary to the first Newton's law. There were 40.41% of respondents held this misconception. This was revealed by their answer for question 22 option **A**, *the rocket are going to move in space without the influence of external forces with a constant speed when the rockets' machine is turned on to get the thrust*. While on the question 26, students chose the answer that *the box will move with a constant speed that is double the original speed if a person doubles the constant horizontal force that he or she exerts to push the box*.

3.5. Acceleration implies increasing force

There were 32.65% of respondents held misconception that acceleration implies increasing force. It was described by option **B** of question number 3. If an object's speed is increase it means that the forces acting on the object are also increase. The implications of understanding that velocity is directly proportional to the force is *the greater the velocity (accelerated), the stronger the force acting on the object*.

3.6. Force causes acceleration to terminal velocity

In question number 3 it is stated that *a stone was dropped from the top of a building to the earth's surface*. Students who held misconception that force causes acceleration to terminal velocity thought that *the stone will reach its maximum speed shortly after it is released and then moves with constant speed*. In this case, the existency of a constant gravitational force acting on an object was not understood as something that is steadily accelerating the stone. So the respondents assumed that the stone will be accelerated from the rest to move and then will continue moving at the same velocity. The number of respondents who experienced such misconception was 35.62%.

3.7. Active force wears out

As many as 28.77% of respondents believed that the forces acting on an object were used up by the objects to move. Question 22 option **C** and **E** revealed this misconception. Respondents chose option to *a rocket moving in outer space freely from external force* that *the rocket will move with a constantly decreasing speed or maintain constantly its original speed for a moment and then decreased, despite rockets' engines was continuously providing thrust on the rocket*. This kind of misconception arise because students assume that the rocket fuel continues to be reduced so that its force continues to decrease as well.

3.8. Greater mass implies greater force

It has been stated in several sections above, the understanding of action-reaction pairs was becoming a serious problem. Many students hold this misconceptions. Although students know that forces on the action-reaction pairs are equal and work in opposite directions, but on implementation they can not apply that understanding well to analyze given cases.

There are four questions in the FCI proved that students are difficult to apply the concept of action-reaction pairs. In question 4 it was given a case, "*a large truck collides head-on with a small car. At the time of collision ...*". Students' misconception was disclosed by their answer for option **A, "***the truck exerts a greater amount of force on the car than the car exerts force on the truck"*, and option **D** *"the truck exerts a force on the car but the car does not exert a force on the truck"*. Both options **A** and **D**

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confirmed that respondents thought that the larger object exerts the greater force. Furthermore, in question 15 *"a small car pushes a large truck"*, the same conditions are shown by the answer for option **B**, *"the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car"*. Although the idea of action-reaction pairs on this option has appeared, but the action-reaction is just determined by the ratio of the mass of interacting objects. The same choice also happened for question 16. Finally, such kind of understanding was again revealed by the question 28 for option **D**, that is *the bigger child or the greater-mass child will give the greater force*.

3.9. The most active agent produces the greatest force

This misconception is similar to the previous one, *"only active agents exert forces"*. Questions that revealed this conception were questions (along with their options) 5**C**, 16**C**, and 28**D**. There were 47.49% of respondents classified into this misconception. The main cause of this misconception was lack in understanding of the action-reaction concept.

4. DISCUSSION

The serious problem of Indonesia student-teachers' misconceptions found in this research is similar to findings of other studies. For example, Kim and Pak [2] reported that students had many of well-known conceptual difficulties in basic mechanics area. Rahman, et.al [9] in a study of student teachers' conceptions on force and motion found that respondents strongly adheres to Aristotelian understanding that was not accepted in scientific belief. In addition, Bayraktar [10] also got an average score of pre-service physics teachers from an education faculties in Turkey about force and motion was below the threshold, i.e. 40.89%.

This condition of misconceptions requires specific learning strategies. It refers to the theory of conceptual change learning [11]. Techers need special learning strategies to overcome misconception because it is resistant and difficult to change. Hasan, Bagayoko, & Kelley [12] suggested that misconceptions need a modified instruction that is intended just to eliminate the misconceptions. Only by conceptual change learning that misconceptions which have long been in students' mind can be changed to the true one. Similarly, Bayraktar [10] suggested that to overcome misconceptions requires effective teaching and learning strategies. Traditional teaching and learning process was reported in many studies failed to do that. So, it is recommended that for Basic Physics 1 course, lectures should apply conceptual change learning strategies in order to improve students' conceptual understandings.

5. CONCLUSION

Based on description above, it can be concluded 9 types of common misconception held by respondents on active forces and action-reaction pairs. The order of the misconceptions from the dominant one are: 1) an object moves due to an active force works on the object, 2) one of the possible condition of an object if no force acting on the object is at rest, 3) the most active agent influencing an object gives the greatest force on the object, 4) the bigger the force acting on an object the faster the velocity of the object is, 5) if a speed of an object is increase from time to time it means that the force working on the object is increase as well, 6) object has greater mass will exert the greater force, 7) active force acting on an object will wear out, 8) only active agents exert forces on an object, and 9) force will accelerate an object till it gets its terminal velocity.

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