Identify 11th Grade of Senior High School Jogoroto students’ misconceptions on Dynamic Rotation and Rigid Body Equilibrium concepts using Four-Tier Diagnostic Test

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Abstract. Understanding physics concepts is the main goal of learning process in school. However, it was frequently found that students faced difficulties to understand the concepts on physics taught in class. These difficulties mainly due to the difference between students’ initial knowledge and the concepts taught by the teacher. For example, students assumed that a top can spin for a long time due to big speed of rotation, so it can maintain the spinning balance. However according to physics concept, the longer spinning balance is caused by the moment inertia is big. When the angular momentum of the top is conserved, the moment inertia can maintain the spinning of the top. This assumption frequently called as preconceptions. The incompatibility of preconceptions with the physics concepts above may lead misconceptions. This study aims to identify conception of students one science class in Senior High School of Jogoroto, Jombang on Dynamic Rotation and Rigid Body Equilibrium and their causes using four-tier diagnostic test. A total of 30 students participated in this study. The instrumen contains 16 numbers of physics-concepts questions. The highest conception is dominated by misconceptions that occur in rotational motion, equilibrium and center of gravity concepts was due to humanistic thinking and preconception.

1. Introduction
Events or phenomena physics are often found in daily activities, such as when someone is opening the door of a room. This phenomena is the application physics concept about force moment. Based on the results of the previous work held by the authors in senior high school Jogoroto, Jombang, it was found when students are asked to opened the door of room, so what they do is hold the door handle (Figure 1-2). Students assumed that holding the door handle near to the rotary axis (Figure 1) is the easiest way to open the door compared to holding the door handle be far from the rotary axis (Figure 2). According to student experience, opening the door with way A is usually done in everyday life and will be initial understanding of student it called preconception.

In physics [1], the moment of force is a cross product between force and force arm $\vec{\tau} = \vec{F} \times \vec{r} = Fr \sin \alpha$, $\alpha$ is the angle that lies between force and force arm(1). For the same force, when the force of the arm is minimized, the produced moment of force is also smaller than force arm is maximized. The length of the arm will be large if the distance between the force and the point of the rotary axis is enlarged, vice versa.
Figure 1. Open the door in a way the hand is placed near to the rotary axis, the position of the hand like this is called way A.

Figure 2. Open the door in a way the hand is placed far to the rotary axis, the position of the hand like this is called way B.

Figure 1 illustrates a person opening the door with way A, the hand positioned near the rotary axis, so the result of force arm length is small and based on the equation 1 force moment produced is small. Meanwhile, for Figure 2, when open the door with way B, the hand is positioned far from the rotary axis, so the result of force arm length is big and force moment produced is also big. Based on the physics concept, opening the door with way B is easier to do than opening the door with Way A.

From these events, the initial understanding of students (preconception) with the concept of physics has a difference, so it can be said that students are misconceptions. Misconception is an initial concept that is not in accordance with the correct concept. Misconceptions should be detected as early as possible because if left unresolved, it can affect to the student’s understanding in next concept.

According to Rusilowati [2] the detection of student misconception can be used four tier diagnostic test. Diagnostic tests are used to know student’s learning difficulties, one of which is a misunderstanding of the concept. A four tier diagnostic tests consist of (1) the first level (1st tier) is given a question along with the choice of answer reason, (2) the second level (2nd tier) there is an answer option along with reasons for choosing, (3) the third level (3rd tier) is added to the choice answer reason and the confidence level for answer, (4) fourth level (4th tier) added confidence level separately for answers option and reasons. From the four test, the most complete is four-level multiple choice test because it can got student answer with reasons and bealiefs in choosing.

From the results of the answers with four-tier multiple choice, it can be determined the categories of student understanding [3][4]: (1) understand the concept (Scientific Conception) when the answer option and the reason for the answer are correct and sure about the answer (2) partial understanding (Lack of Knowledge – guessing) occurs when there is a correct answer on one of the option or reason and sure with the answer or reason chosen (3) False Positive is define when the answer correct, the reason for the answer is wrong but sure of both (4) False Negative is opposite from false positives, (5) Misconception occur when the option and reason for the answer are wrong but are sure of both (6) do not understad the concept (Lack of Knowledge – deficiency) is condition when the answer or reason chosen by the student is wrong, but not sure about the answer and reason. Besides the conception category, from the result of the answer of students with four-tier multiple choice also can be determined the cause of misconception which derive from the students themselves are preconception, associative thinking, humanistic thinking, incomplete reasoning and wrong intuition. This paper is intended to identify the profile of student’s misconceptions and their causes of 11th grade students in senior high school Jogoroto, Jombang in the chapter of Dynamic Rotation and Rigid Body Equilibrium using four-tier diagnostic tests.
2. Method

2.1. Sample

The subjects in this study were 11th grade students of science one at senior high school Jogoroto, Jombang who had been taught the chapter of Rotational Dynamics and Rigid Body Equilibrium. A total of 30 students was selected using purposive sampling or based on certain considerations.

2.2. Instrument

Four-tier diagnostic test for chapter Dynamics of Rotation and Rigid Body Equilibrium had been developed using the Research and Development (R & D) method before this paper was published [5]. The step is first, detect potential misconceptions experienced by students for the chapter of Rotational Dynamics and Rigid Body Equilibrium in senior high school Jogoroto, Jombang. Second, based on the results of the detection, then prepares predictions of misconceptions and question grids. Third, from the prediction after that make a multiple choice diagnostic test instrument with open reasons. The question was tested to the new students in Physics Department, Universitas Negeri Surabaya to collect their reasons. The collected reason data was analyzed and the selected and used to arrange questions of four-tier diagnostic test. Fourth, the four tier diagnostic test questions are given to students to test the validity and reliability aspects of the instrument.

Finally, there are 16 items about four-tier diagnostic tests instrument and the validity and reliability was available in [6]. The developed instrument consist of rotational motion (ROM), force moment (FOM), inertia moment (INM), law of conservation of angular momentum (LCAM), rotational kinetic energy (RKE), equilibrium (EQB), Type of equilibrium (TOE), center of gravity (COG). Table 1 provide one example of four-tier diagnostic test for the chapter of Rotational Dynamics and Rigid Body Equilibrium that has been developed in previous study [6]. The reasons options b, c, d, e, f is representing preconception, wrong intuition, humanistic thinking, incomplete or wrong reasoning, associative thinking and the option b is the correct reason.

Table 1. Question of four-tier diagnostic test on Rotational Dynamics and Rigid Body Equilibrium.

| Tiers       | A Sample Question Number 1                                                                 |
|-------------|-------------------------------------------------------------------------------------------|
| First Tier  | To move the tires of bicycle so that can go on, the tire is supported by the front gear (A) and rear (B). If the front gear (r_A) twice as big as the rear gear (r_B), so that r_A = 2r_B and for the two gear to move together, so the correct statement is |

Figure 3. Two gears are relaxed

A. Linear velocity of gear B (v_B) > Linear speed of gear A (v_A)
B. Linear speed of gear B (v_B) < Linear speed of gear A (v_A)
C. Linear speed of gear B (v_B) = Linear speed of gear A (v_A)
D. Angular speed of gear B (w_B) > Angular speed of gear A (w_A)
E. Linear speed (v) and angular speed (w) of gear B = gear A

Second Tier

Are you sure of your answer?
A. Sure
B. Not sure
Third Tier

The reason of answer
A. The edges of the two gears are connected to each other, so that the linear velocity of the two gear is the same.
B. The angular velocity and linear velocity of the two chain gear are the same. (Preconception)
C. The angular velocity and linear velocity for the chain gear are different because the size of gear is also different. (Wrong intuition)
D. Small gears tend to move quickly, so the linear velocity of rear gear is bigger. (Humanistic thinking)
E. The linear velocity of the gear is affected by the size of the gear. (Incomplete or wrong reasoning)
F. Large fingers will produce a large angular velocity. (Associative thinking)

Four tier

Are you sure of reason of your answer?
A. Sure
B. Not sure

2.3. Data analysis

Student answer combination determined from six categories levels of concept is divided into scientific conception (SC), lack of knowledge – guessing (LK-g), false positive (FP), false negative (FN), misconception (MSC) and lack of knowledge – deficiency (LK-d) were analyzed using Equation (1).

\[ P_J = \frac{n_x}{n_s} \times 100\% \]  \hspace{1cm} (1)

where PJ is the percentage of students answers to each concept, \( n_x \) is the number of students that categorized as SC, LK-g, FP, FN, MSC, LK-d and \( n_s \) is the total number of students.

Hereafter, the causes of student misconceptions consist of preconception (PRE), associative thinking (AST), humanistic thinking (HMT), incomplete or wrong reasoning (IWR) and wrong intuition (WRI) (see the answer reasons in Table 1) were calculated using equations (2).

\[ PPM = \frac{n_x}{n_M} \times 100\% \]  \hspace{1cm} (2)

Where PPM is the percentage of causes of misconception, \( n_x \) is the number of students due to the reasons PRE, AST, HMT, IWR, WRI and \( n_M \) is the number of students.

3. Results and Discussion

3.1 The Profile of Student’s Misconceptions in Dynamics of Rotation and Rigid Body Equilibrium Concepts

Figure 4 shows conception distribution of 30 number of students consist of sub concepts rotational motion (ROM), force moment (FOM), inertia moment (INM), law of conservation of angular momentum (LCAM), rotational kinetic energy (RKE), equilibrium (EQB), Type of equilibrium (TOE), center of gravity (COG).
As seen, more than 40% of students suffered misconceptions in sub concept ROM, TOE and COG, less than 40% students were detected to have understood well the concept, less than 31% suffered false positive, less than 33% showed false negative, less than 13% showed partial understanding and less than 21% interfered didn’t understood the concept. The following paragraph provides a more detailed picture of the results of the conception distribution mentioned.

From the results of the Figure, it can be seen that the highest percentage of student conceptions is misconception. As many as 50% of students were detected to have misconception in the sub concept ROM. In this sub concept students must good understanding concept, mostly due to memorizing the formula without understand the concept as a result the highest misconception occurs in this sub-concept. For example, Question Number 1 about the concept of rotational motion: "Given conditions where the front gear (A) and the rear gear (B) on tel bicycle are connected by a chain. If the gear on the front of the fingers (r_A) is twice as large as the rear gear (r_B), so that r_A=2r_B. students are asked to determine the linear speed that occurs in the system". During this time students assumed that the linear velocity in the system will be different, namely the front gear has a linear speed greater than the rear gear because the front gear radius is larger than the rear gear. Meanwhile, based on the physics concept the linear speed (v) of the two chain gear is the same (v_A = v_B).

Furthermore, the other sub-material with a high percentage of misconception is equilibrium. For example, Question Number 10: "Given a picture of a ball given two force with opposite directions. One force moves up and the other is down. The magnitude and distance from the center are the same namely F and l. Students are asked to choose a statement are correct based the picture". Students reasons that objects will be balanced if the opposite forces destroy each other, so the resultant force is zero. While based on physical concepts, equilibrium occurs when the resultant force and the resultant moment of force are zero. From this assumption it is clear that students suffered misconceptions in the sub chapter equilibrium.

The last, with a percentage that is still relatively high, 40% occurs in sub concept center of gravity. This sub concept students are faced with conceptual understanding, so it is very likely that students
who didn’t well understand the concept will interfered misconception. For example, Question Number 14: “Given a picture of three trucks located on the inclined plane. The first truck is in the lowest position followed by the second and third trucks which are higher above it. If the three trucks have a adjusted center of gravity, the students are asked to determine which truck is most easily overturned”. The student answered that objects experience equilibrium if the center of gravity is right on the axis of rotation of an object, so that when rotated it will maintain its position. Meanwhile, based on the physics concept, if the center of gravity is drawn in the axis of rotation and does not exceed the axis of rotation, the object tends to maintain it’s position when rotating or equilibrium.

3.2 The Profile of Student’s Misconceptions in Dynamic Rotation and Rigid Body Equilibrium Concepts Based on The Causes

Figure 5 shows an overview of the causes of student misconceptions in the the chapter of Dynamic Rotation and Rigid Body Equilibrium consist of preconception (PRE), associative thinking (AST), humanistic thinking (HMT), incomplete or wrong reasoning (IWR) and wrong intuition (WRI).

As seen, as many as 35% of students suffered misconceptions caused by humanistic thinking, 13-22% are caused by preconceptions, less than 6% are caused by incomplete reasoning, 3-11% are associative thinking and less than 6% are caused by intuition wrong. In this study, humanistic thinking and preconception are the causes of the highest misconception. Humanistic thinking is the assumption of students that the nature of things is the same as human nature, whereas preconception is the initial understanding that students have as a result of experience with the environment before following formal learning. One way to reduce the misconception caused by humanistic thinking is to invite students to do it directly so that they realize that objects are like humans. Meanwhile, misconceptions caused by preconceptions can be minimized by providing new experiences to students, in this case asking students to see and perform experiences that are not in accordance with their preconceptions directly, so that students realize and can change these incorrect thoughts.
4. Conclusion

Based on this study can be identified that in 11th grade students of science one at senior high school Jogoroto, Jombang for the concept of Dynamic Rotation and Rigid Body Equilibrium the highest conception occurs because of misconceptions and scientific concepts. Meanwhile, the misconception occur in rotational motion, equilibrium and center of gravity was due to humanistic thinking and preconception.

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