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DAFTAR ISI

Science Education

CONDITION OF STUDENT TEACHER CONCEPTIONS ON MECHANICS: AN INVESTIGATION USING FCI EMPOWERED BY CRI

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Abstract

It has been done a research to investigate condition of student's conceptions in the domain of mechanics. Identification was carried out by using the FCI empowered by CRI. FCI version 1995 is a diagostic-test consists of 30 multiple choice items with 5 options. Beside only a correct choice, four other choices are form of misconceptions that are dominant in mechanics. The subjects consisted of 73 student teachers of Physics Education Department of Faculty of Teacher Training and Education from two different campuses. The results of the research provided that the conditions of respondents' conception are in serious problem, i.e. 18.01 %. The lowest score was obtained in an item related to the concept of impetus. Respondents have a strong impetus concept, a view back to the days of pre-Galilian that "force" is necessary to keep an object moving. Analysis by CRI revealed that students had a strong misconception associated with 29 questions and lack of knowledge about 1 question. Classically 61.51 %, 25.25 %, and 13.24 % respondents classified respectively as misconceptions, lack of knowledge, and have correct concepts. Although the most respondents have mistakes to aswer question related to concept of impetus, but the highest misconceptions, 87.67 %, is shown when answering question number 1, i.e. the heavier objects fall faster, the same conception as of the understanding of Aristotelian mechanics. It is suggested further research to explore student conceptions for each topic in mechanics domain to formulate appropriate conceptual change learning strategies for based-class remediation.

Key words: Conceptual understanding, FCI , CRI .

Introduction

Knowledge about student understanding of a concept is important in teaching and learning process. Understanding the concept is like a foundation of a building. If students do not have a strong concept about a topic then the higher knowledge is built will be the more fragile the knowledge is. Students' conception of nature have been built far earlier than they came to school. Conceptions are built as soon as one understand his environment. Unfortunately, these conceptions are not always benefecial. Many studies reported that students experienced misconceptions in almost topic in the field of science, including physics. A number of alternative conceptions appear across a wide variety of culture, countries, and ages (Grayson, 2004). Also, the same misconceptions are held by students from different countries and cultures. Bayraktar (2009) on his study comparing different cultures from different countries suggest that misconceptions in various topics of physics are universal. Misconception also happen to all levels of students from elementary school to university, it is known that students of all ages (elementary, secondary, and undergraduate) can have alternative conceptions in all areas of science (Pinarbaºi, Canpolat, Bayrakceken, & Geban, 2006).

Mechanics is an importance topic in physics. It is the main concept that students need to have an adequate understanding in order to move to the next steps of physics study. In Curriculum of Physics Education Department of the Faculty of Teacher Training and Education of Sriwijaya University, mechanics topic for the first time is in Fisika Dasar 1 (Basic Physics 1) course, given in the first semester to freshmen students. In this course, students learn again and more deeply than what they have learned in senior high school. The course than is basic for the physics course in the next semester. However, based on observation during the class it is found that many students have serious problems with their mechanics conception in this area. Students, for example, can calculate time needed by a stone to reach the ground in free fall motion, but unfortunately they give wrong answer when they are asked how two different weigh stones released from the same height reach the ground. It is a paradox. Based on preliminary research using the FCI to Educational Physics Department students who enrolled in 2010, it is found that students' mean scores are 20.17 % and 15.33 % for regular class and for the extension class respectively. Zukoski (1996) suggested that it is apparent students enrolling in a college physics course do have misconceptions concerning force. Therefore, the basic conditions of student in mastery of concepts in mechanics topic need to be known. The purposes of this study are to see 1) how the conditions of conceptions of the student teacher of Physical Education Department in mechanics area, and 2) Is there any misconceptions and how high the levels of the misconception experienced by the students of the Physical Education in mechanics.

Method

Condition of students' conceptions in the mechanics domain is determined by using a FCI test developed by Hestenes, Wells and Swackhamer (1992). Indonesian version of FCI translated by the author is used in this research. After completing administrative process and scientific validation, Indonesian version of FCI finally can be accessed on the website of Modeling Instruction Program, Dept. of Physics, Arizona State University at http://modeling.asu.edu. The validation process is reported in another paper.

FCI that consists of 30 multiple choice items with five options that can explore all the concepts in the domain of mechanics are elaborated in 6 dimensions; kinematics, the first law, the second law, the third law, principle of superposition, and kinds of forces. In each dimension it will reveal the various forms of misconceptions in mechanics area. The uniqueness of the FCI is all item are interconnected

in terms of identifying the concept mastery: one question can report some of the misconceptions and a misconception can be revealed by some questions. FCI can reveal at least 31 types of misconceptions in mechanics. Comprehensive information about students' conceptions can be explored by analyzing the whole answers of all the questions.

By analyzing conventionally the answers of FCI can be determined the concept mastery level of respondents. However, to analyze the further conditions of this conceptions, the analysis is continued by applying the concept of CRI (Certainty of Response Index) by Hasan, Bagayoko, & Kelley (1999). CRI is to see the level of confidence of respondents to their answers. Then the conceptions of respondents are mapped into three categories, namely 1) have a correct concept, 2) lack of knowledge, and 3) have misconceptions, by connecting 5 confidence levels of respondents' answers to right or wrong the answers. Five levels of confidence to the answers are.

The CRI	Criterion
0	Guessing totally
1	Almost guessing
2	Not sure
3	Sure
4	Almost certain
5	Certain

The decision of category of the respondents' conception about the subject-mater is consulted to the following Table 1.

Table 1. Decision matrix for a given question to categorize responden's conceptions.

	Low CRI (< 2.5)	High CRI (> 2.5)
Correct answer	Correct answer and low *average* CRI (CL) Lack of knowledge (lucky guess)	Correct answer and high *average* CRI (CH) Knowledge of correct concepts
Wrong answer	Wrong answer and low *average* CRI (WL) Lack of knowledge	Wrong answer and high *average* CRI (WH) Misconceptions

(Hasan, Bagayoko, & Kelley, 1999)

To use the Table 1 for both individual and a group respondents are conducted in the same way, however for a group of respondents CRI value used is the average value of the CRI for each item. For that it is determined the average CRI for the correct answer (CRI_b), the average CRI for the wrong answer (CRI_s) and the fraction of correct answers (<C>).

$$CRI_b = \frac{\sum CRI_b}{N_b}; CRI_s = \frac{\sum CRI_s}{N_s}; \langle C \rangle = \frac{N_b}{N}$$

"CRI_b = the total of CRI scores for the respondents who answered correctly.

"CRI_s = the total of CRI scores for the respondents who answered incorrectly.

Nb = the number of respondents who answered correctly.

Ns = the number of respondents who answered incorrectly.

N = total number of respondents.

The FCI-concept-test was given to respondents at the beginning of Semester 1 in Academic Year 2012, on September 2012. Respondents who take the test are all the Physics Education Department Students who take courses Basic Physics 1 in Academic Year 2012 as many as 73 people, consisting of

44 students from Inderalaya Campus and 29 students from Palembang Campus. Every student taking the test on its campus, where students from Palembang did it on room 9 Campus Palembang and students from Inderalaya did it in room 3012 Campus Inderalaya. The tests were conducted in different days in the same week. In order to keep the quality of the test, participants were prohibited to use communication devices and taking photographs of the instrument, prohibited to write anything in the instrument, and asked to submeet the instrument along whit the answer sheet. Both classes were also not given any information about kinds of the test they will take. Furthermore, between the two campuses are no communications that they will take the test. They all are new students in the campus.

Discussion

Based on analysing of the data, it is obtained the student concept conditions. The mean score of all the students for the whole item of FCI is 18.08 (on a scale of 0 -100). This means that the level of student mastery of concepts for subject-matter of mechanics is 18.08%. This condition is far below the threshold of good mechanics concept mastery 85% or limit entry to understand the mechanics of 60% (Hestenes and Halloun, 1995). From the above data it can be concluded that the students where the research was conducted for both campuses experienced a fatal misconceptions in the domain of mechanics.

The results of the data analysing related to the total correct answers for all respondents for each item of FCI are represented as a graph of percentage of correct answers and a graph of average of right and wrong answers as well as the fraction of correct answers.

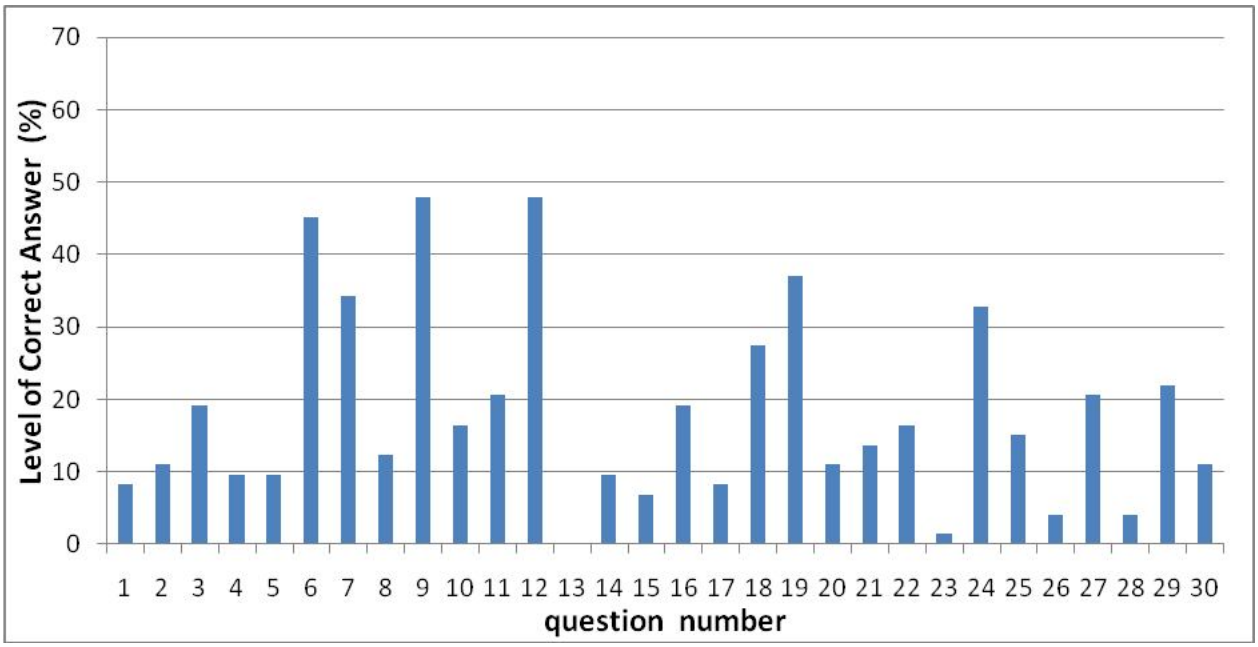

Figure 1. Percentage of respondents who have correct answers for each item of FCI.

It is known from Figure 1 that there is no item answered correctly by more than 50% of the participants. The most correct answers are for problem number 12, 9, 6, 19, 7, 24, and 18 respectively with a percentage of 35%, 35%, 33%, 27%, 25%, 24%, and 20%. While the lowest correct answer are for problem numbers 13, 23, 26, 28, 15, 1, and 17 respectively in a percentage of 0%, 1%, 3%, 3%, 5%, 6%, and 6%.

Question 13 is about concept of impetus. Impetus is known as “intrinsic force”, a force that is in

an object that keeps the object moving. Impetus is conceived to be inanimate "motive power" or "intrinsic force" that keeps moving things (Hestenes, Wells and Swackhamer, 1992). The question is about a case of a ball thrown vertically upward. The question is what are the forces acting on the ball after the ball leave the hand. More than half of the respondents, i.e. 60.27 %, choose option **B**, which is "the force is an upward force that decreases uniformly starting from the ball leaves the hand until it reaches the highest point, when the ball moves down ...." The rest of the respondents, 35.62 %, choose option **C**. One respondent choses option E, which is "no right answer" and 2 respondents (2.74%) choose option **A**. Choice **C** is "force acting on the ball is gravity force that is nearly constant downward along with the an upward force decreases uniformly until the ball reaches the highest point". Both groups of respondents (choose **B** and **C**) have the same concept, that is the force is needed to keep an object moves, and this force is more and more reduced and finnaly lost described by more and more slow the object meves. It is like a vehical that must be always suplayed a power, the longer the power suplay run the more weak it energy and the slower the vehical moves.

The difference between these two groups is the respondents who chose **B** also assume there is no gravitational force downward acting on the object. Their concepts that the force is need in the direction of the object moves to maintain the object move are strong enough. No movement means no force. Because the object moves up, so the gravitational force that they know leads to the ground, also necleted. Based on both pattern of answers selected by respondents, it is clear that a very strong impetus concept embedded in the minds of students.

Problem number 23 is about a case of a rocket moves in a space free from influence of external forces. There are four questions relating to this case, i.e. problems number 21, 22, 23, and 24. In question number 23 asked what is rocket trajectory after the rocket that moves freely in the space gets force perpendicular to the original path until it reaches a certain position (point C) and then the rocket engine is shut down. Most of the respondents, 53.42 %, choose answer **A**. The rest, 23.29 % and 20.55 % respectively choose options **C** and **D**. Only one person (1.37 %) chose **E**. According to the taxonomy table of misconception by Hestenes and Jane Jackson (2007) options **A** and **D** are also associated with the concept of impetus. In options **A** and **D**, respondents have a concept that the impetus can be lost and or recovered. While the choice **C** revealed that the respondents had misconceptions that the last force acting on an object determines the motion of the objects, rather than the resultant of forces. Based on the fact of the answer to question number 23, it reinforces the existence of misconceptions on the mechanics about "innate force" or "impetus". The impetus concept is contrary to the Newton's law. This means that the first law is not well understood by the respondents.

Furthermore, Figure 2 shows a graph of the average correct answers for each question, the average CRI for wrong answers as well as the fraction of correct answers for all respondents.

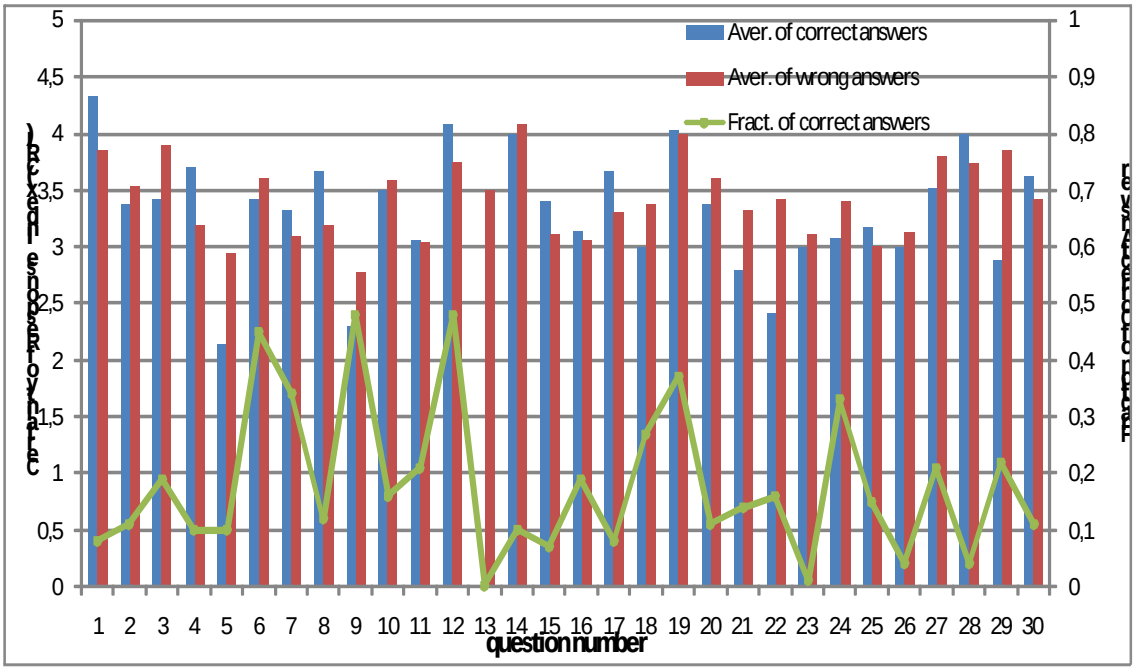

Figure 2. Average scor of CRI of correct answer and wrong answer and fraction of correct answers for each question and for all respondents.

By looking at whether the respondents answer are correct (C) or wrong (W) and it CRI scores are high (H) or low (L) and based on Table 1 it is obtained the condition of conceptions of the respondents. There are 28 questions that are categorized as the wrong-high (WH), i.e. numbers 1 , 2 , 3 , 4 , 6 , 7 , 8 , 10 , 11 , 12 , 13 , 14 , 15 , 16 , 17 , 18 , 19 , 20 , 21 , 22 , 23 , 24 , 25 , 26 , 27 , 28 , 29 , and 30. In accordance with the definitions in Table 1 on these questions all respondents classically experienced misconceptions. In other words, the respondents had misconceptions about the time that it takes by objects of different weight to fall from the same height, the action-reaction force, centrifugal force, innate force "impetus" and so on. Furthermore, no question is classified as wrong-low (WL). This means that no student is classified as lack of knowledge.

Average CRI for wrong answer for questions number 5 and 9 are close to 2.5. To determine whether these are high or low is decided by considering the fraction of correct answers (Hasan, Bagayoko, & Kelley, 1999). For Question 5, the average CRI for wrong answers can be ranked high (WH) due to most of the respondents chose the wrong answer. It is only 9.59 % of respondents who answered correctly for this question. The large number of respondents who answered incorrectly and the average of CRI is around 2.5 open the possibility that some respondents gave high CRI values for their wrong answers. Thus Question 5 can be classified wrong-high (WH) which means the learners have misconceptions related to the case on the question. While the average CRI for wrong answer for question number 9 can be classified as low (WL) because the number of respondents who answered the question correctly are relatively high, 47.95 %. Thus question 9 indicates there are students categoried as lack of knowledge. This is also reinforced by the average CRI for correct answer below 2.5 which means that many of the respondents guess the answer to that question.

From the above analysis clear that classically students of Physical Education Department where this study conducted experience misconceptions associated with 29 questions and conditions lack of knowledge with 1 question of the FCI. It can be concluded that classically the status of the respondents' conceptions on the subject-matter of mechanics is misconceptions.

Misconceptions	Lack of knowledge
29 questions	1 question

Although it is found that one respondent is categorized as lack of knowledge, but when talking about FCI, there is no an item stand-alone to identify misconceptions. Problem number 9 is only one of several other questions that reveal misconceptions on the one of the dimensions of mechanics area. For example, for the dimension of the kinematics there are six other questions beside question number 9 that responsible, namely number 12, 14, 19, 20, 21, and 22. Therefore it can be concluded that the Physics Education Department students where this research take place experience misconceptions on the subject-matter of mechanics, and consequently the learning strategy of conceptual change is needed in for all topics in the mechanics.

Limitation of the analysis of the CRI based on the fraction of correct answers is obtained conclusions are only grouped the respondents into two categories i.e. misconceptions and lack of knowledge. We can not categorise further where the respondents have the correct concpet and guesses the answer correctly (lucky guess). For example, for the question number 8 of Figure 2 showed that the average of correct answer is high (CH). Based on Table 1, it means that the respondents have a right concept. It means that there are two conclusions, the former conclusions (the respondents had misconceptions) and this last conclusion, the respondents understand the concept correctly. There's just a small fraction of correct answers (0.12) that helped us to make decision that there are large number of the respondents who chose the wrong answer but they are sure with their answer (misconceptions) and a limited number of respondents who answered correctly and confident with their answer (corect concept). We can not know what are the status of respondent conception clearly based on four categories listed in Table 1.

Hassan, Bagayoko, and Kelly (1999) only analyzed answer for wrong-high (WH) and wrong-low (WL) on their paper. Average CRI value for correct answer is used only as additional information in the analysis, "... the average CRI values for correct answers provides additional evidence that the CRI is a useful indicator of the certainty with roomates the students answer questions" (Hassan, Bagayoko, & Kelly, 1999). This kind of analysis they meant to be easily carried out by teachers and lecturers to distinguish between students who have misconceptions and lack knowledge.

To find out conditions of conceptions of Physics Education Department students completly is carried out further analysis, i.e. to map the students who have the right concepts, misconceptions and lack of knowledge. From the four possible combinations of conditions of students' conception based on correct and wrong answers as well as high and low CRI in Table 1, there are only three real conditions that arise, namely 1) students experience misconceptions, 2) students know the concept correctly, and 3) students are lack of knowledge. Category of students who lack of knowledge is a combination of a group of lucky guess (correct guesses) (CL) and lack of knowledge (WL). For both conditions the respondents only guess the answer (not based on a strong knowledge), the difference is the first group guess the answer and gets the correct one while the second group guess the wrong answer. Both groups do not have knowledge to answer the questions. Therefore, in Figure 3 below there are only three histograms depicting conditions of students' conceptions for each question. The results of the data analysis are presented in Figure 3 below.

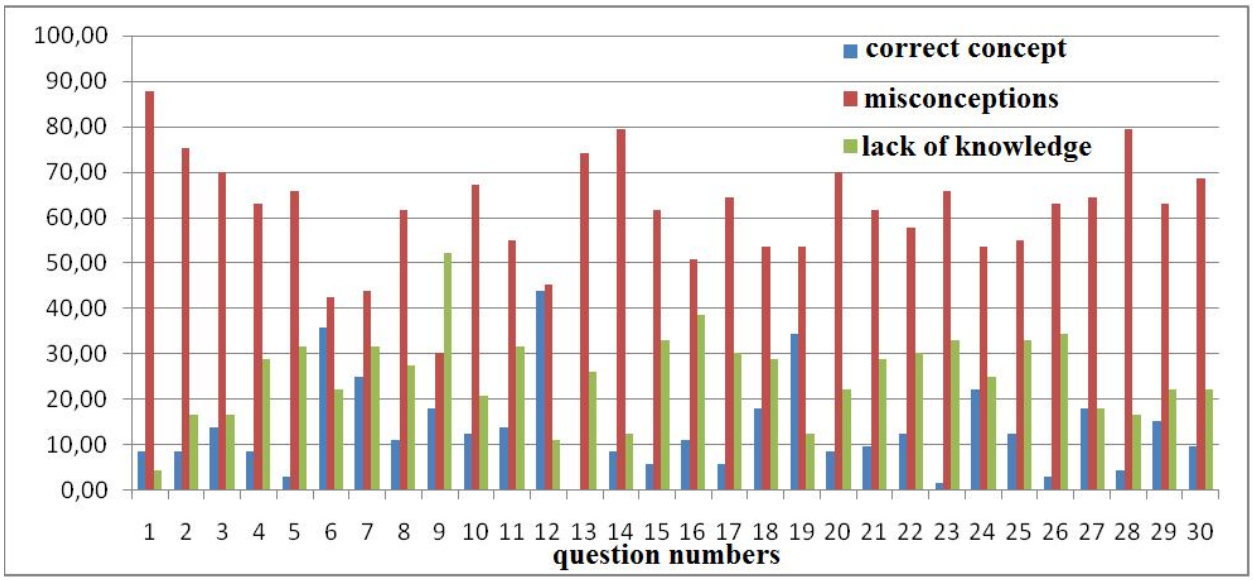

Figure 3. Percentage of students conceptions for each FCI question given.

Based on Figure 3 it is obtained the highest percentage of misconceptions occurred at question number 1, which is 87.67 %, for a question related to the concept of free fall object. The question asks the time required by the different weight objects falling freely from the same height. The correct answer to this question is both objects arrive about the same time in the ground. It only 8.22% respondents answered according to this correct answer. The remaining 4.11% did guess the answer. The conception that the heavier objects fall faster exists from time to time in any group of students either on physics or non-physics students as well as on physics teachers and other people generally, and it was first proposed by Aristotle's law of falling objects which came to the conclusion $v_1 : v_2 = w_1 : w_2$, or heavier object fall faster directly proportional to its weight (Halloun, Hestenes, 1985). The next biggest misconception is in questions number 14 and 28, i.e. 79.45 %. The question 14 deals with the concept of objects thrown from a certain height. As for the number 28 relates to the concept of action-reaction force. The next highest misconceptions were detected in questions number 2 and 13. Problem number 2 is about a falling object after sliding on a horizontal trajectory, while question 13 relates to the force acting on the object thrown vertically upward. From Figure 3 it is known that, except for number 9, all of questions are answered by the respondents with choice that belong to misconceptions. Question number 9 relating to the final velocity of an object after receiving some influence from the environment. For this question a number of the respondents also answered incorrectly because of lack of knowledge. From the picture above it is clear that redspondents have high levels of misconceptions in answering all of the questions. Students use the wrong concept in answering the questions.

For all students, the condition of the conception of the teacher students of Physical Education Department in the domain of mechanics can be seen in Figure 4 below.

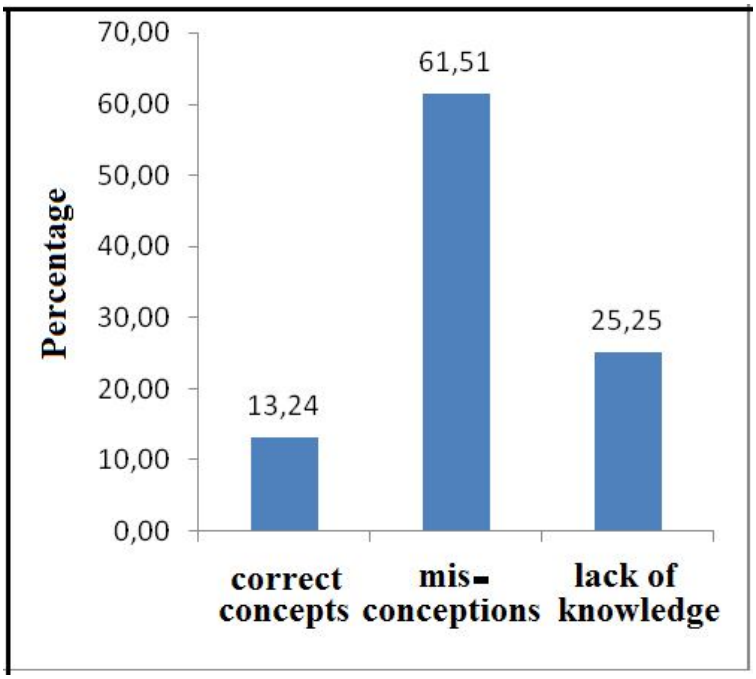

Figure 4. Status of Conception of respondent in mechanics domain

It reveals that the conditions of the conception of the respondents are: 61.51 % of the respondents have misconceptions, 25.25% are lack of knowledge, and 13.24% have correct concept. So it can be concluded that on the mechanics domain most of respondents have misconceptions and misconceptions occur in all the subject-matter of the mechanics. Therefore, it is necessary to use conceptual change learning in teaching the subject-matter of mechanics in Physics Education Department of Sriwijaya University.

Lack understanding of the concept of student teachers in mechanics are also found in other studies. Rahman, et.al (2007) in a study of conceptions on force and motion in Malaysian reported that student teachers are strongly adheres to Aristotelian understanding of force and motion that is not in line with today accepted scientific belief. Bayraktar (2009) by the FCI ver. 1992 (29 items) also gets an average score of student teachers of physics in the largest education faculties in Turkey is below the threshold, i.e. 40.89%. Kim dan Pak (2002) from Seoul National University found that students still had many of the well-known conceptual difûculties with basic mechanics even though after solving 1000 traditional problem, and there was little correlation between the number of problems solved and conceptual understanding.

The condition of misconceptions and lack of knowledge require different learning strategies. To remediate misconceptions it is required learning strategies refers to the theory of conceptual change. It is only by learning which refers to the theory of conceptual change that can remediate someone misconception which has long been in his or her mind to be correct concepts, and survive as a new conception. In traditional teaching and learning process, students sometime can come to believe that they have wrong concepts, but only occure for a moment, then it will be back to the old conception. However for the lack of knowledge, teacher or lecturer can use a variety of other strategies that are not specifically based on the theory of conceptual change. The existence of specialized learning strategies to overcome this misconception because it is difficult to change. Hasan et al. (1999) suggested that misconceptions need a modified instruction that is intended just to eliminate the misconceptions. Furthermore, Bayraktar (2009) suggested to overcome misconceptions requires effective teaching and learning strategies.

Posner et al (1982 in Syuhendri, 2010) suggests four requirements in order to conceptual change occure in a person, i.e. 1) dissatisfaction, 2) intelligible, 3) plausible, and 4) fruitful (see also Hakkarainer & Ahtee, 2006; Pinarbasi et al., 2006, and Greiffenhagen & Sheram, 2008). Dissatisfaction means that the learner first is made not satisfied with his conception. Their conception was not able to explain the phenomenon. Here teachers or lecturers spark cognitive-conflict on student minds, that what they think is different with what they see. Second, the conception they have doubted must be replaced by the concept that can be received by a reasonable mind. Students are shown that this new conception can explain phenomenon faced. Third, the new conception can solve the other problems. Finally, the new concept should open opportunities for the exploration of knowledge.

There are a variety of learning strategies based on the conceptual change theory. Syuhendri (2010) proposed some strategies such as analogy, bridging analogy, conceptual change text (CCT), concept substitution, modification of learning cycle by Continuous Computer Assisted Activation (Contac 2), constrastive teaching, Predict-Observe-Explain (POE), and concept maps. Conceptual change text (CCT) for example, is a form of teaching materials (texts) made in such a way, for example in the form of worksheets, which can reveal student preconceptions, reminding them of the possibility of the misconceptions and comparing it with the true-conceptions that accepted by scientists. Ozmen (2007) concluded that the CCT can help learners change alternative conceptions into scientific concepts. Treagust et al. (1998, in Rahman, 2004) defines analogy as the process of identifying similirities between two concepts. The two concepts are analogous concept and target concept. Analogous concept is a concept that has been known by students. For example concept of gravitational field as an analog and the concept of electric field as a target. Students however have known before the concept of gravitational field. While the substitution concept has been tested by Grayson (2004) and concluded that participants experienced some conceptual changes as evidenced by the post-test results

Conclusion

Based on respondents' answers to the FCI it is obtained that the level of respondents' conception on mechanics domain is far below the threshold of sufficient mastery of concepts for application in problem-solving and others use. The most respondents answered incorrectly for numbers 13 and 23 that are related to the concept of impetus, the model of pre-Galilio understanding which considers moving objects require an intrinsic force to keep them moving; or a force needs to make an object start moving. Analysis of FCI empowered by CRI indicated that the respondents have misconceptioan dominatly on 29 question and experienced lack of knowledge on 1 question. Although the dominant incorrectly are for number 13 and 23, the highest misconceptions are for item number 1 and number 14. Problem number 1 relates to the speed of falling objects of different weight, which the respondents considered a heavier object would fall faster. It is about 61.51% of the respondents have misconceptions, 25.25 % are lack of knowledge, and 13.24 % have correct concept in mechanics area.

Because of the massive misconception in this subject-matter, and beacuse of large number of Indonesian students and limited infrastructure and the number of teachers in some school it would be difficult to remediate the misconceptions per item for ndividual students. It is needed the remedial based on class and for a certain meeting. So, it is recommended for further analysis to see the condition of understanding of concepts per sub-topic of mechanics so that it can be done a remediation in the class for each meeting based on conceptual change. It is also recommended to apply the conceptual change strategy when teaching the mechanics subject-matter in Basic Physics 1 course.

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