Analysis of students’ misconceptions on mechanics using three-tier diagnostic test and clinical interview

A Fadllan¹,²*, W Y Prawira¹, Arsini¹ and Hartono²

¹ Physics Education Department, Universitas Islam Negeri Walisongo Semarang, Indonesia
² Science Education Department, Universitas Negeri Semarang, Semarang, Indonesia

*Corresponding author: andi_fdl@walisongo.ac.id

Abstract. Students’ misconceptions analysis on mechanics had been done with qualitative approach. Data were obtained through a Three-tier Diagnostic Test adopted from the Force Concept Inventory Test and combined with the Certainly of Response Index of Saleem Hasan, and a clinical interview. Data is validated in three ways, namely the triangulation technique, using reference material, and member check. Then the data is analyzed through data reduction, data presentation, and conclusion. The results showed that misconceptions occurred in almost all the concepts. Misconceptions occur most often in the concepts of the object velocity in the Accelerated Linear Motion and the object motion in a parabolic trajectory. Factors that cause misconceptions mostly come from associative thinking, incomplete or wrong reasoning, and wrong intuition. Through clinical interviews, results were obtained that misconceptions were also influenced by the learning of teachers, instructional textbooks, internet, films, and the daily experiences of the students.

1. Introduction

A misconception is the most common obstacle faced by teachers in physics learning at all levels of education. Many misconceptions research has been done with various solutions offered. However, these problems always arise and recur. Not only in primary and secondary education, but also in higher education. In fact, many teacher candidates have misconception [1-4,8,11]. As teacher candidates, this is certainly very worrying because they will pass this misconception to their students.

Misconceptions occur to almost all concepts of science, including in physics, such as mechanics [4,5], sounds [4], optical geometry [3], electrical circuits [6,13], waves [2], heat, temperature, and inner energy [5,7,8,14], and photoelectric effects [9,15]. Even from 700 studies of misconceptions in physics, 300 of them examine misconceptions in mechanics; 159 in electricity; 70 in heat, optics and material properties; 35 in the earth and space, and 10 studies of modern physics [10,16]. These data show that mechanics is the most misconceptions field of physics.

Correspondingly, at least three times Cornell University held international seminars in 1981, 1987, and 1993 featuring more than 600 titles of papers, based on field and theoretical research on how to help overcome student misconceptions. A variety of ways can be used to identify misconceptions among students and students such as using an intelligent concept mapping tool [9,11], interviews, drawings, multiple choice tasks, diagnostic tests, and others [10,12]. One of the instruments that can be used to uncover misconceptions is a three-tier diagnostic test.
2. Materials and Methods
The three-tier diagnostic test of this study is the development of the Two-tier Diagnostic Test. It was prepared by adopting the Force Concept Inventory (FCI) test [7,13]. FCI is an established instrument designed to assess students' understanding of the concept of force and motion. This test is suitable for measuring conceptions related to force and motion at high school to college [taufik A]. The FCI contains 29 items of multiple choice, consisting of kinematics, Newtonian law, the principle of force superposition, and the types of forces (the force of gravity and frictional force). But, the tests of this study are limited to kinematics. This is based on consideration of novelty and sustainability of previous research.

The test is also combined with Certainty of Response Index (CRI) at all three levels. CRI is a method used to measure the level of confidence or certainty of respondents in answering each question. Respondents were asked to provide a degree of certainty of their own ability by associating that level of belief to the truth of the response alternative [12,14]. However, the CRI method by Hasan has weaknesses. The weakness lies in categorizing the level of understanding of students that have low confidence level and the magnitude of factors guessing students in answering the problem because of the form of multiple choice. This is showed by the existence of students that are actually able to answer and understand the concept of the problem, but because it has a low level of confidence led to choose a low CRI scale, so grouped into categories do not understand the concept. Taking into account this condition, Hasan's level of the understanding category was modified by adding the Understanding the Concept but Not Sure (UCNS) and adding an open reason for the multiple-choice test forms [6,15].

In addition to the three-tier diagnostic test, the students' concept comprehension test is also conducted through a clinical interview to determine the factors causing the misconceptions and from which the conception is obtained. Thus it is expected that the problem of misconception can be found the solution.

2.1. Research model
This is qualitative research to describe and analyze the misconception of Physics Teacher Candidates (PTC). This study was conducted on students in the physics education department.

2.2. Sampling
Samples were determined using purposive sampling with the consideration that the sample has taken the subjects of Introduction Physics I, Mechanics, Physics Curriculum Studies of Junior High School, and Physics Curriculum Studies of Senior High School.

2.3. Data collection
Data were collected using a three-tier diagnostic test consisting of 15 questions and a clinical interview. Data were validated using three ways that are triangulation technique, using reference material, and member check.

2.4. Analysis of data
The data analysis is done by referring to the modification of level categories of understanding developed by Aliefman [1,16] as in Table 1.
Table 1. Grades of Aliefman's understanding

| Answer | Reason          | CRI   | Description                     | Code   |
|--------|-----------------|-------|---------------------------------|--------|
| True   | > 2.5           | Good Concept Understanding  | GCU    |
|        | < 2.5           | Understanding the Concept but Not Sure | UCNS   |
| False  | > 2.5           | Misconception          | M      |
|        | < 2.5           | Not Understanding the Concept | NUC    |
| True   | > 2.5           | Misconception          | M      |
|        | < 2.5           | Not Understanding the Concept | NUC    |
| False  | > 2.5           | Misconception          | M      |
|        | < 2.5           | Not Understanding the Concept | NUC    |

While the CRI scale refers to the scale compiled by Hasan as Table 2.

Table 2. Hasan's CRI scale

| Scale | Category         | Code |
|-------|------------------|------|
| 0     | Totally Guess Answer | TGA  |
| 1     | Almost Guess     | AG   |
| 2     | Not Sure         | NS   |
| 3     | Sure             | S    |
| 4     | Almost Sure      | AS   |
| 5     | Certain          | C    |

3. Result and Discussion

Based on the test of respondents, it was obtained the results of three-tier diagnostic tests as presented in Table 3.

Table 3. Three-Tier Diagnostic Test Results

| No   | PTC-1 | PTC-2 | PTC-3 | PTC-4 | PTC-5 | PTC-6 | PTC-7 | PTC-8 | PTC-9 | PTC-10 |
|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|
| 1    | GCU   | GCU   | GCU   | GCU   | M     | GCU   | GCU   | GCU   | GCU   | GCU    |
| 2    | M     | GCU   | GCU   | M     | GCU   | M     | GCU   | GCU   | GCU   | UCNS   |
| 3    | UCNS  | M     | NUC   | M     | NUC   | M     | M     | M     | GCU   | NUC    |
| 4    | M     | NUC   | NUC   | GCU   | NUC   | GCU   | M     | M     | GCU   | GCU    |
| 5    | M     | M     | NUC   | M     | NUC   | M     | M     | M     | NUC   | UCNS   |
| 6    | M     | GCU   | NUC   | M     | NUC   | M     | GCU   | M     | GCU   | UCNS   |
| 7    | NUC   | GCU   | UCNS  | GCU   | M     | M     | M     | GCU   | GCU   | GCU    |
| 8    | M     | UCNS  | NUC   | M     | NUC   | M     | M     | M     | UCNS   | UCN    |
| 9    | NUC   | GCU   | NUC   | M     | NUC   | GCU   | M     | GCU   | M     | UCNS   |
| 10   | NUC   | NUC   | NUC   | GCU   | NUC   | M     | GCU   | M     | M     | UCNS   |
| 11   | NUC   | NUC   | NUC   | M     | NUC   | M     | M     | M     | UCNS   | UCN    |
| 12   | NUC   | UCNS  | M     | GCU   | NUC   | M     | GCU   | M     | GCU   | UCN    |
| 13   | M     | GCU   | UCNS  | M     | NUC   | GCU   | GCU   | GCU   | GCU   | UCNS   |
| 14   | NUC   | UCNS  | NUC   | GCU   | NUC   | GCU   | M     | GCU   | GCU   | GCU    |
| 15   | M     | NUC   | NUC   | GCU   | M     | GCU   | M     | GCU   | GCU   | NUC    |
Based on the analysis of respondents' answers, the following are forms of PTC misconceptions:
1. A mass of twice as big will take less time to reach the ground than a small mass object when dropped from the same height.
2. The greater the mass of an object, the greater the gravitational force of the earth.
3. The object that moves to the right is then subjected to a perpendicular force, then the object moves in the direction of the force and then turns right like the original direction.
4. The direction of motion of an object depends only on the forces acting on it.
5. The object subject to an instantaneous force will move with a constant acceleration.
6. If there is one thing that does the Uniform Linear Motion and another thing does the Accelerated Linear Motion, and one object overtakes the other, then on both of these objects there will never be the same speed.
7. The trajectory of a horizontal object shooting from a certain height will be straight in the horizontal direction for a certain time because its speed is then slowed down as it speeds up to zero.
8. More speed will lead to more acceleration as well.
9. When the ball straps that move circularly broken, the ball will still maintain a circular motion and then move straight.

From the test data, it can be seen that the main cause of misconceptions is the confidence level of respondents exceeding 2.5 (CRI > 2.5). This shows that respondents have high confidence in the truth about the answers to the first tier and the second tier. The answers to the first tier and or the second tier are indicated wrong. Also, information is also obtained that the responder is not intact in understanding some concepts. Respondents understood the concept partially, without deepening it again, so that respondents were confused with choosing an answer or found it difficult to give a reason. This then triggers the number of respondents' answers labeled misconception (M). Thus it can be seen that the factors that cause misconception come from self PTC itself that is associative thinking, incomplete or wrong reasoning, and wrong intuition.

Meanwhile, based on the results of clinical interviews it is known that most of the concepts obtained by respondents come from schools, such as teaching from teachers, textbooks supporting learning. It also comes from everyday experiences, movies, and the internet. Thus, when entering the college level, the concepts already obtained by the respondents have been firmly entrenched in them. The new respondents acquired a broader and deeper concept when they started college. Nevertheless, there are still some concepts that have not been well understood by the respondents.

4. Conclusion
Based on the discussion that has been presented, it can be concluded some findings related misconception experienced by Physics Teacher Candidate (PTC) in understanding the concept of kinematics particle. Misconceptions occur to almost all of the concepts tested. The most common misconception of the respondent is the change in the velocity of the object of the accelerated linear motion and the motion of the object motion on the parabolic motion. Factors causing misconceptions in most of the questions come from PTC itself are associative thinking, incomplete or wrong reasoning, and wrong intuition. The other sources, derived from teaching teachers and some also from lecturers, textbooks supporting learning, internet, movies, and the daily experience of PTC.

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