Investigating the ability of multiple representations and scientific consistency of high school students on Newton's laws

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Abstract. The ability of multiple representations and scientific consistency are two things closely related to students' conceptual understanding. The research has been carried out aims to find out the ability of multiple representations and scientific consistency of high school students in Newton's laws. The multiple representations measured includes verbal, vector, motion map, graph, and bar chart representations. The scientific consistency measured is the consistency of students in correctly and consistently answering each of the three questions which presents different representations. The research method used is survey. The research instruments used were a multiple representations test consisting of 5 items to measure multiple representations ability and Representational Variant of Force Concept Inventory (R-FCI) test consisting of 27 items. The research samples consisted of 102 students from class X, XI, and XII at SMA Negeri 14 Bandung who were selected using stratified random sampling technique. The data obtained were analyzed using the Zipgrade Item Analysis Tool and R-FCI Consistency Analysis Tool. The results showed that the type of representation that is most mastered by students is vector representation and most students are categorized as inconsistent.

1. Introduction
Conceptual understanding is the most essential thing that always to be the main objective in every learning, including physics because concept understanding will underlie more complex abilities and higher-order thinking skills. Even today the understanding of concept is still the main focus of physics education research [1]. One indicator of conceptual understanding is being able to manipulate concepts with a variety of correct representations [2]. Various modes of representation will provide opportunity for students to communicate concepts that they have understood [3]. The ability of multiple representations does not only indicate students' understanding of concepts but also can build a deep and coherent concept understanding [4], improve the ability to understand the concepts of physics [5,6,7,8], and promote the ability to solve physics problems [9]. This is related to the functions of multiple representations, they are completing information, limiting interpretation and building deep conceptual understanding [10].

The format of representation influences students' ability to solve problems [3]. Students sometimes able to apply concepts to certain contexts and representations, but failed when the context and...
representation are changed [11]. It shows that students have not fully understood the concept well. Students who truly understand the concept will be able to recognize and manipulate concepts in various representational formats [2] or it can be said that the students’ understanding concepts has not been consistent. Therefore the concept understanding will be closely related to scientific consistency [12].

Although the ability of multiple representations and scientific consistency of students are two important things related to students’ concepts understanding, but there are still few researches done to find out the ability of multiple representations and scientific consistency, especially in Indonesia. This is important especially for teachers to find out whether students have really understood the concept being taught so that it can be an evaluation material in learning for both teachers and students. Therefore, author conducted a research to obtain description of multiple representations’ ability and scientific consistency of high school students. The researcher hopes that the description of the multiple representations’ ability and scientific consistency can be useful as information for teachers to know how far students understand the concept. By knowing the level of understanding concepts and knowing the types of representations that are considered difficult to understand by students, the teacher is expected to be able to plan and implement a better learning process so that students' conceptual understanding becomes more profound. By applying the appropriate learning model and providing teaching materials that use multiple representations, teachers are expected to help students in order understand the concepts of physics that are difficult to understand.

2. Methods

2.1. Design
The method used in this research is survey. The author conducted a survey of students at Senior High School Number 14 Bandung. The population of this research are all students in the school, amounting to 945 people. To determine the sample, the author used stratified random sampling technique based on grade level. There are three grade levels of classes at the school, namely grade X, XI, and XII.

2.2. Participant
From each grade level, the author took 1 class randomly so that the number of samples used was 3 classes consisting of 102 students or about 11%. This amount is considered quite representative.

2.3. Instrument
The instruments used in this research are tests as the main instruments and interview sheet as supporting instrument. The instrument used to determine the ability of multiple representations in this research is a multiple representation ability test. The types of representation mode used are verbal, vector, motion map, graph, and bar chart. The number of questions from each of these types is 1 so the number of multi-representation ability test questions is 5, which includes the material of Newton’s first law, Newton’s second law, and Newton’s third law.

The instrument used to measure scientific consistency in this research is the standard test Representational Variant of Force Concept Inventory (R-FCI). This test was previously developed by Nieminen [13]. R-FCI is an isomorphic test (having the same concepts and forms among items) in the form of multiple choices presented in various different representations, namely verbal, vector, motion map chart, and bar chart. The R-FCI consists of 27 items divided into 9 themes and includes 3 Newton's laws of motion, namely Newton’s first law, second law, and third law. Each theme consists of three items with different representations.

2.4. Data analysis
To find out the multiple representations ability of students, firstly the author calculated the number of correct answers for each type of representation mode. There are five modes of representation used, namely verbal, vector, motion map, graph, and bar chart. Each representation mode consists of one problem that is different in context. If students can answer each question correctly then they are given 1
score that means students can use representations correctly in physics. Conversely, students who cannot answer correctly are given 0 score, meaning students have not been able to use representation correctly in physics. Then the student's total score is calculated for each type of representation mode. Furthermore, this score is converted into a percentage that shows the percentage of students who correctly answer the multiple representation ability test items.

To determine the level of scientific consistency of students overall, the scores were first calculated for each theme with a score range of 0 to 2 with criteria referring to the rules used by Nieminen [13] as shown in table 1 below.

| Score | Criteria |
|-------|----------|
| 2     | Choosing scientifically correct representations on three of the three items with different representations on the same theme |
| 1     | Choosing scientifically correct representations on two of the three items with different representations on the same theme |
| 0     | Choosing scientifically correct representations on one of the three items with different representations on the same theme |

After that, the average score of the theme is calculated by adding up the total score of all themes divided by the number of all themes. Furthermore, the average score of this theme is used as a reference in categorizing the level of scientific consistency of students into 3 levels of scientific consistency according to Nieminen [13], namely consistent (level I), fairly consistent (level II), and inconsistent (level III) as shown in table 2 below.

| Level | Score Interval | Category |
|-------|----------------|----------|
| I     | 1,70 ≤ KI ≤ 2,00 | Consistent |
| II    | 1,20 < KI < 1,70 | Moderately Consistent |
| III   | 0,00 ≤ KI ≤ 1,20 | Inconsistent |

3. Result and Discussion

3.1. Ability of multiple representations
Description of students’ multiple representations ability are obtained from the results of the multiple representations test. From the results of the calculation and analysis of the data, the author obtained the number of students who use multiple representations correctly physically in each type of representation mode, they are 24 of 102 students for the mode of verbal representation, 44 of 102 students for vector representation mode, 19 of 102 students for motion map representation mode, 26 of 102 students for graph representation mode, and 31 of 102 students for bar diagram representation mode. The data of students' multiple representations ability in the form of percentages is presented in Figure 1 below.
Figure 1. Percentage of students using multiple representations correctly physically in each type of representation mode.

The research data in Figure 1 shows that the type of representation mode that mostly done by students correctly physically is vector, 44 of 102 students or 43.14%. Meanwhile the type of representation mode the least done by students correctly in physics is the motion map which is 19 of 102 students or 18.63%. But overall the percentage of students who use multiple representation correctly in all types of representation mode is below 50%.

Most students can only make 1 or 2 types of representation mode correctly physically for the same concept. Generally, representations that students can make correctly in physics are vectors and bar charts. At the time of the interview the students revealed that the vector representation mode was easier to create or use because the value and direction could be seen easily. The longer the arrow, the greater magnitude of force and the shorter the arrow, the smaller magnitude of force. Meanwhile the direction of the arrow can be seen from the end of the arrow without having to pay attention to the axis and positive or negative signs. In addition, the magnitude and direction of each force that works on objects is described directly on the object at the point where the object is located so that it is considered to be easier to understand for students.

Only a few students can make more than 2 types of representations correctly and physically, especially the motion map. There are students who actually understand the physics concept of the test problem but they have difficulty in representing it in the motion map. Students have difficulty describing the process of motion at the points that the object passes due to the resultant force and Newton's laws that apply to it. But most students do not understand the physical concepts so that they cannot represent them. This is in accordance with a research conducted by Sinaga [14] that an in-depth understanding of the concept of physics that is represented greatly determines the ability of students to use multiple representations. The low ability to understand these concepts is ultimately due to the fact that physics learning had not emphasized yet the concepts and multiple representations as expressed by students in the interview.

3.2. Scientific consistency

Students' scientific consistency data are obtained from the results of scientific consistency test using the Representational Variant of Force Concept Inventory (R-FCI) with the average score in the range of 0 to 2. The level of scientific consistency of students was determined based on the average consistency score obtained by each student. From the results of the calculation and analysis of the data, author obtained the number of students who are at each level of scientific consistency, 71 students are at level III (inconsistent), 29 students are at level II (quite consistent), and 2 students are at level I (consistent). Student scientific consistency data in the form of percentages is presented in Figure 2 below.
Figure 2. Percentage of students at each level of scientific consistency.

The research data in Figure 2 shows that most of the students are at inconsistent level, they are 71 of 102 students or 69.61%. Most students can only answer one of three items in the same theme, which uses a different representation. For example, item number 9, 18 and 27 are items with the same theme, the force that arise from the interaction of two objects with the same magnitude and opposite direction. In item 9 the answer choices are presented in bar chart representation, item number 18 answer choices are presented in vector representation, and item number 27 answer choices are presented in verbal representation. Most students can answer correctly item number 9 and 18 in the representation of bar chart and or vector diagram.

4. Conclusion
Based on the discussion above, it can be concluded that the students' multiple representations ability is still very low because of all the types of representation mode tested shows that the number of students who can use each representation mode correctly and physically is no more than 50%. Among these various representations, vector representations is the most mastered by students because it shows the magnitude and direction then it is more easily observed so that the students easily answer the item correctly. Then most students are still categorized as inconsistent because they cannot answer questions with several different modes of representation correctly and consistently, they are about 70%. This is caused by the understanding of students' concepts and multiple representations ability is also low.

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