Identifying SMM on momentum and impulse using two tier diagnostic test

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Abstract. Almost students have difficulties to understand the concept of momentum and impulse because the concept still considered abstract in physics. The aim of this research was to find students mental models of momentum and impulse. The participants of this research were eleven grade students of senior high school in Bandung. This sample have been selected from 30 students (17 boys and 13 girls, their age average 16 years old) in the one of senior high school at Bandung. The research method is a case study with descriptive quantitative analysis. The data analysis was carried in two stages, first identified student level of understanding and the second identified the student model of understanding. The diagnostic test utilized to find students mental models was two tier test in the form of open ended questions as many as 5 questions. The result shows that mental models of eleven grade students which have been identified in the three categories that are, Initial 62.6%, Synthetic 26.7%, and Scientific 10.7%. In conclusion, mental models of the scientific category is lower than other categories.

1. Introduction
Students representation of a phenomenon especially on physics concepts will not be the same for each individual because there is information obtained from the learning process and some are obtained from their experiences. According to Vosniadou [1] the kind of mental representation that individuals construct when they describe about the physical world can be explained by mental models. The assumption about SMM (Student’s mental models) are used to construct new and it is important to reach some understanding about a concept [1]. In appropriate to the statement of Arslan and Buckley [2,3], student’s mental models are cognitive representations used for reasoning, defining, explaining, guessing or sometime testing operations about a phenomenon. Based on the theory of mental models, there are three fundamental principles about mental models, they are [4] mental model represents what is communal to a discrete set of possibilities, mental models are iconic that is their structure as far as possible agrees to the construction of what they represent and mental models based on descriptions characterize what is true at the spending of what is false.

In other words, mental models is a form of individual representation and it used to describe or visualize an individual's concept and understanding of scientific phenomena. Based on their level of understanding, there are three kind of students’ mental model. Initial model consistent based on observation in daily life experiences, synthetic model representing attempts to adjust the culturally accepted and scientific model which agree with scientific view [1].
In education, mental models have an important role to find out students' understanding of a concept. Mental models can provide important information about the underlying knowledge structure from the origin of students' knowledge structures [1]. Educators need to know the students' mental models to help students building their scientific knowledge [5]. In science teaching, teachers use mental models in two distinct ways. First, they try to communicate the models of science to their students. Second, they use certain types of models particularly analogy, to explain scientific ideas to students [6].

Mental models can be used in helping of physics learning. There are lots of physics concepts learned in senior high school that involve abstract thinking level [7]. According to Ergul [8], the concept of momentum and impulse is still considered abstract so as to analyze require mental activity. This is conformable to Sekercioğlu [9] suggesting that the concept of momentum and impulses is considered simple when in fact it is a complex concept. Such as the concept of momentum and impulse, the magnitude of the momentum of an object is expressed by the equation (1):

\[ p = mv \]  

\[ p \] = momentum (kg m/s)  
\[ m \] = mass (kg)  
\[ v \] = velocity (m/s)

the general form of Newton’s second law states that the rate of change of momentum is equal to the net force acting on an object as shown by equation (2):

\[ F_{\text{net}} = \frac{\Delta p}{\Delta t} \]  

\[ F_{\text{net}} \] = net force (N)  
\[ \Delta p \] = rate of change of momentum of the object (kg m/s)  
\[ \Delta t \] = time interval (s)

the product of net force and interaction time is called impulse. So, Impulse is equivalent to the change in momentum that an object experiences during an interaction.

The concept momentum and impulses is difficult to observe directly even though many are applied in everyday life, because momentum and impulses occur in a very short time. In real life, many interactions occur during very short time intervals. For example, as seen in figure 1.

![Figure 1. When a baseball bat hits a ball](image)

During very short time intervals, it was difficult to measure the net force, because \( F_{\text{net}} \) increases from zero to a very large value in a short period of time.

In previous research it was found, when tests were given to students before any special treatment, the students cannot answer in a way correctly to provide the concept and the reasons are clear, focused and accurate, containing scientific definitions about the concept of momentum and impulse [10]. To explain a concept that requires mental activity and abstract thinking, it takes a form of diagnostic test to diagnose scientific knowledge of the student. In a previous study, two tier test is great to use for diagnosing students' understanding [11]. This test have certain restrictions in the discerning lack of
understanding as of misconceptions, error or scientific knowledge [12]. Therefore, the researchers will use two tier tests to identify the students’ mental models on the concepts of momentum and impulses.

2. Methods

2.1. Research purpose
The aim of this research was to find students mental models of momentum and impulse.

2.2. Research method
This research method is case study with descriptive quantitative analysis. From the result of quantitative data, students’ mental models were identified and analyzed descriptively.

2.3. Participant
The participants of this research consisted of 30 students (17 male and 13 female, their age average 16 years old) in the one of senior high school at Bandung. Eleven grade students were selected as the sample because these levels already studied the concept of momentum and impulse in physics lessons.

2.4. Instrument
To find mental models in this research, two tier test used in the form of open ended questions as many as 5 questions about the concept of momentum and impulse. Question of number 1 and 2 is about concept of momentum, question number 3, and 4 is about concept of impulse and question number 5 is about conservation of momentum. The example of question shown in Figure 2.

![Figure 2](image_url)

**Figure 2.** The example of two tier test.
2.5. Data Analysis
The data analysis was carried in two stages. The first, identified student level of understanding and the second identified the student model of understanding. The researcher analyzed the data from student level of understanding [13-14]. To determine the level of understanding by asking a descriptive question referring to the rubric used on the literature [14-15]. The rubric for understanding levels as shown in the following Table 1 below:

Table 1. Evaluation rubric for understanding levels

| Level of Understanding (LU)            | Score | Criteria                                                                 |
|----------------------------------------|-------|--------------------------------------------------------------------------|
| Sound Understanding (SU)               | 4     | Answer containing all components of the scientifically accepted response. |
| Partial Understanding (PU)             | 3     | Answer containing some components of the scientifically accepted response. |
| Partial Understanding with             | 2     | Answer showing that the concept is understood but also containing        |
| Alternative Conception (PU-AC)         |       | alternative conceptions and did not give a reason.                      |
| Alternative Conception (AC)            | 1     | Scientifically incorrect responses containing illogical or incorrect    |
|                                        |       | information                                                             |
| No Understanding (NU)                  | 0     | Blank, irrelevant, repeating questions or unclear responses              |

The second, understanding level matched to rubrics students’ mental models. Students’ mental models were classified as scientific, synthetic and initial [15]. So, we can identify the students’ mental models as shown in the following Table 2:

Table 2. Evaluation rubric for mental models

| Model of Understanding | Content                                      | Level of Understanding |
|------------------------|----------------------------------------------|------------------------|
| Scientific             | Perceptions coincide with scientific         | [3 3 3 3 3]            |
|                        | knowledge: the answer at the level of 3 (PU) | [4 4 4 4 4]            |
|                        | or level 4 (SU).                             |                        |
| Synthetic              | Perceptions which partially coincide or do   | [Al other possibilities]| |
|                        | not coincide with scientific knowledge.      |                        |
|                        | Perceptions everything do not coincide       |                        |
|                        | with scientific                              |                        |
| Initial                | knowledge: answers on level 0 (NU), 1 (AC)   | [0 0 0 0 0]            |
|                        | and 2 (PU-AC).                               |                        |

To understand the rubric in Table 2, they are given 5 question as indicated by columns the matrix in Table 2 while the rows in the matrix show answer according to the level achieved of understanding. For example the student cannot answer about momentum question incorrectly and not give the reason or just repeat a question so his answer can be grouped at AC level with score 1 and the reason can be grouped at NU with score 0. Using the last column on table, student 1 have been classified at initial model.
3. Results and Discussion

3.1. Students’ Level of Understanding
Table 1 shows data from the students’ answer after analysing each item about momentum and impulse. The results are presented below.

| Level of Understanding | Q1 | Q2 | Q3 | Q4 | Q5 | Average |
|------------------------|----|----|----|----|----|---------|
|                        | f  | %  | f  | %  | f  | %    |
| SU                     | 2  | 6,7| 0  | 0  | 1  | 3,3  |
| PU                     | 3  | 10 | 2  | 6,7| 1  | 3,3  |
| PU-AC                  | 10 | 33,3| 5  | 16,7| 13 | 43,3 |
| AC                     | 14 | 46,7| 11 | 36,6| 7  | 23,3 |
| NU                     | 1  | 3,3| 12 | 40 | 8  | 26,7 |

As seen in Table 1, just over 2% of student were classified at the SU understanding level by identifying the answer of all questions, about 8,6% of student were classified at the PU understanding level, 26,6% of student were classified at the PU-AC understanding level. It seen that students in all question are dominant classified in AC 32%, and NU 30,6%. Based on data analysis for all of questions, the average of student understanding is still dominant at the AC level. It indicated that the students providing an answer to the wrong conceptual, containing illogical or incorrect information.

In fact, the total number of students who are at the NU level of understanding was still dominant. This proves that the students cannot give a reason in the correct concept, leaving blank or just repeat the question. The similar results are shown from previous studies that no student can understand the phenomena of momentum and impulse scientifically (SU or PU) when pre test is given [10]. So, students were dominant at AC or NU level of understanding.

3.2. Students’ Mental Models
The percentage of students’ mental model based on their level of understanding for each item from all of question are shown in figure 3.

![Figure 3. Percentage of students' mental models for each question.](image)

The highest percentage, found 76,6% students still at initial model in question number two that asked about concept of momentum. It means that almost all of students could not answer and explain the reason for question number two. After calculating the average of the overall question items, the percentage of
the student's mental model on the concept of impulse momentum, can be expressed in the following figure 4:

![Figure 4](image)

Figure 4. The average percentage of the student's mental model.

Based on the figure 4, it was found that 62.6% students were classified at initial, 26.7% students were classified at synthetic and 10.7% students were classified at Scientific. Whereas, from the previous research in the synthetic model have larger numbers than scientific and initial that is caused some students are inconsistent in answering questions [10]. However, the students' condition in this research were not being given any treatments and only diagnoses the level of understanding of each individual on the concepts they have learned in the previous class. Actually, all of students are still dominant in the category of initial model and the comparison is very significant with students in the category of scientific models.

4. Conclusion
From the result of data, can be concluded that among the three mental models in the concept of momentum and impulse, the scientific model significantly lower than synthetic and initial models. The facts show that the majority of students have an initial mental model. This means that students cannot give explanations which coincide to scientific knowledge.

5. References
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