Students’ understanding level and scientific literacy competencies related to momentum and impulse

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Abstract. Momentum and impulse are one of the material that often experienced difficulties by students. This happens because students’ ability to understanding the concept is different. Conceptual understanding is very important for students, as the basis of scientific literacy. The aims of this research were to analyze students’ understanding level and scientific literacy competencies on momentum and impulse. This research used the descriptive survey method. The subjects of this research were 28 students of physics education program from Universitas PGRI Madiun. Subjects consist of 1st semester (9 students) and 3rd semester (19 students) who have received the Basic Physics course previously. Subjects determined by using random sampling techniques. Data collected using test and interview. The results showed that 40.18% students categorized in misunderstanding and 27.68% students have scientific literacy competencies. Some students do not understand the concept correctly, even though the material has been taught before. Misunderstanding can arise because the material that has been taught not associated with its application in daily life and not presented in various form of representation. The results of this research can be used as a reference for lecturers to determine the appropriate strategies that improve students’ understanding of momentum and impulse.

1. Introduction

Achieving scientific literacy for all students is one of the main goals in science education [1]. Scientific literacy is important for students. It relates to students’ ability in understanding the concept of science and using the concept in their daily life [2, 3, 4]. Students also can be said to have scientific literacy competencies if they are able to (1) explain the phenomenon scientifically, (2) evaluate and design scientific enquiry, (3) interpret data and evidence scientifically [5]. The development of scientific literacy in the learning process is very important because scientific literacy can provide benefits for social economic life, and improve citizens performance [6]. Therefore, literate people are expected to reduce various problems and will lead to sustainable development [7].

The main basis of scientific literacy is conceptual understanding [1]. Conceptual understanding is the ability of students to explain a concept, use a concept in different situations, and develop some consequences of the existence of such concept [8]. The conceptual understanding of students is said to evolve if they can integrate new knowledge into their existing understanding [9]. Consequently, students’ conceptual understanding that has been owned before or preconception is important to be known by the lecturers. Students who have the correct understanding, certainly they also have scientific literacy competencies.
Causes of students’ difficulties in understanding the concept can be classified into five aspects. The aspects are students’ preconception, wrong intuition, wrong conception, misunderstanding in verbal representation, and factual misunderstanding [10]. Students already have preconception before following the lectures [11]. This preconception is usually obtained from their parents, friends, previously learning, and experiences in the environment. Preconception sometimes makes students difficult to receive the new knowledge. Wrong intuition also causes misunderstanding. Students usually spontaneously express their assumption based on their intuition. Misunderstanding on concept arises when students are taught about scientific information that does not guide them to discover their knowledge through the scientific process.

Physics topics such as mechanics is an area in which students have various misunderstandings and difficulties [12]. Momentum and impulse are one of the subtopics on mechanics. Momentum is the tendency of moving objects to continue its movement at a constant speed. The momentum change influenced by outside force that works for a certain time is called an impulse. Momentum and impulse are basic concepts in physics, but still many students have difficulty interpreting the concept [13].

Other researches have shown that students’ ability to understand the concept of momentum conservation is still limited and they can not apply it to different situations [14, 15]. Momentum and impulse also become an important part of physics learning at various levels. This material began to be studied from high school to university.

The aims of this research were to analyze students’ understanding level and scientific literacy competencies in momentum and impulse materials. Every student has their understanding of a concept and learning styles for processing the new knowledge [16]. Therefore lecturers need to be aware of the students misunderstanding and their difficulties in learning that materials [17].

2. Method
This research used a descriptive survey method. The subjects of this research were 28 students of physics education program from Universitas PGRI Madiun. Subjects consist of 1st semester (9 students) and 3rd semester (19 students) who have received the Basic Physics course previously. The place of research was determined by purposive sampling, because the previous research showed Universitas PGRI Madiun students had difficulty in understanding the concept of physics [18].

Subjects determined by using random sampling techniques. Data were collected using test and interview. Interview used to clarify students answer after the test. The test consists of 8 items based on scientific literacy competencies. The categories of scientific competencies, as shown in Table 1. Content validity from 8 validators shown that all test items are valid, because they have a validity value above 0.75 [19]. This test also has reliability which is categorized as moderate with a Cronbach alpha value of 0.56. Reliability value that is not high enough indicated that students have not been able to build their knowledge and relate it to the experience they had before [20].

| Table 1. Categories of scientific competencies |
|------------------------------------------------|
| Scientific competencies | Question number |
|-------------------------|-----------------|
| 1 Explain phenomena scientifically | 1, 3, 4, 5 |
| 2 Evaluate and design scientific enquiry | 6, 7 |
| 3 Interpret data and evidence scientifically | 2, 8 |

In this research, students’ answers were analyzed and categorized to the appropriate understanding level. The understanding level based on Akbas [21], as shown in Table 2. Students have scientific competencies if they can understand the concept correctly.

| Table 2. Criteria for understanding level |
|------------------------------------------|
| Understanding level | Criteria |
| No Answer | No answer and no reason, answer and reason are irrelevant or unclear |
| Misunderstanding | The answer and reason are not in accordance with the correct concept |
3. Results and Discussion
The results of this research showed that only a few students have a conceptual understanding related to momentum and impulse. Most of the students, 40.18% categorized in misunderstanding level. If the students cannot understand the concept correctly, then they do not have scientific literacy competencies. Most of the students not understanding the correct concepts although they have learned momentum and impulse in Basic Physics courses. Students who categorized in understanding level and have scientific literacy competencies are 27.68%. Percentage of students’ understanding level shown in Table 3.

### Table 3. Percentage of students’ understanding level

| Students’ Understanding Level | Percentage |
|------------------------------|------------|
| The mat can change momentum in a longer time |           |
| No answer                    | 3.57%      |
| Misunderstanding             | 57.14%     |
| Limited understanding        | 14.29%     |
| Understanding                | 25%        |
| Graph of momentum change over time if there is a force acting on the particle |           |
| No answer                    | 10.71%     |
| Misunderstanding             | 50%        |
| Limited understanding        | 7.14%      |
| Understanding                | 32.14%     |
| Superelastic collision on a tennis game |           |
| No answer                    | 17.86%     |
| Misunderstanding             | 25%        |
| Limited understanding        | 10.71%     |
| Understanding                | 46.43%     |
| The law of conservation momentum |         |
| No answer                    | 14.29%     |
| Misunderstanding             | 39.29%     |
| Limited understanding        | 3.57%      |
| Understanding                | 42.86%     |
| The concept of impulse or momentum change |           |
| No answer                    | 39.29%     |
| Misunderstanding             | 46.43%     |
| Limited understanding        | 3.57%      |
| Understanding                | 10.71%     |
| Comparing the impulse on one-dimension and two-dimensions collision |           |
| No answer                    | 10.71%     |
| Misunderstanding             | 53.57%     |
| Limited understanding        | 17.86%     |
| Understanding                | 17.86%     |
| Comparing the impulse in different condition |           |
| No answer                    | 10.71%     |
| Misunderstanding             | 25%        |
Limited understanding 42.86%
Understanding 21.43%

Graph of momentum over time during the collision

| No answer | 35.71% |
| Misunderstanding | 25% |
| Limited understanding | 14.29% |
| Understanding | 25% |

Based on Table 3, the highest misunderstanding is a concept about impulse when falling on the mat. Students who categorized in misunderstanding level are 57.14%.

Question 1:
In acrobats always use thick mats as a safety when players fall, see figure (a). Falling on the mat will be safer than falling on the floor because ....

A. Mat gives a smaller impulse than the floor.
B. Mat changes momentum for a longer time.
C. Impulse when falling to the floor has a smaller value than falling to the mat.
D. Impulse when falling to the mat has a smaller value than falling to the floor.
E. Mat changes momentum in a shorter time.

Example of student’s answer to question number 1 can be seen in Figure 1.

(Figure 1. Student answer to question number 1)

Falling on a mat or on the floor, it takes the same impulse to decrease your momentum to zero. Impulse with the same value does not indicate the two conditions have the same force or time interval [22]. The same impulse means the same product of force and time, in accordance with equation (1).

\[ F \Delta t = \text{Impulse} \]

The use of a thick mat on an acrobatic game is an example of impulse concept application. Falling on the mat will be safer than falling on the floor. The mat can change the momentum in a longer time, so it can resulting smaller force. Whereas if it falls on the floor, the collision will occur in a short time and produce a greater force. This resulted in acrobats who fall on the floor can suffer serious injury.

Most students assume that fall on the mat produces the greater impulse than falling on the floor, see in figure 1. The reason for student’s answer in figure 1 was reinforced by interview. The interview results shown student’s reason write the answer because of the longer collision time interval. The
Interview results also shown that student answer the question based on their experience in daily life and intuition. Intuition sometimes can encourage students to the wrong concept. Question number 1 can be classified on the competence to explain phenomena scientifically. Table 3 shows 25% of students who understand the concept on question 1 as a whole. Scientific literacy is closely related to the understanding of concepts, so it can be concluded there are only 25% of students who have the competence of scientific literacy.

The 2nd highest misunderstanding level is related to the comparison of impulse between one-dimension and two-dimensions collision (question number 6). There are 53.57% students that categorized in misunderstanding level.

**Question 6:**

- The massive ball moves with speed \( v_i \). The ball then strikes the field by forming an angle \( \theta = 30^\circ \), see figure (a). Another ball with the same mass and velocity, moving horizontally to strike a vertical plane, see figure (b). If the collision in both cases occurs perfectly elastic, then the following corresponding statement is ...

- A. Impulse of the ball in figure (a) = figure (b).
- B. Impulse of the ball in figure (a) > figure (b).
- C. Impulse of the ball in figure (a) < figure (b).
- D. The final velocity of the ball in figure (a) < figure (b).
- E. The final velocity of the ball in figure (a) > figure (b).

**Example of student’s answer to question number 6 can be seen in Figure 2.**

“(A) Impulse of the ball in figure (a) = figure (b). Because when both objects experience a perfect collision \( v = v' \) there are no changes in velocity, so the impulse is equal to the mass of an object \( I = m \) and both objects have the same impulse”.

**Figure 2.** Student answer to question number 6

The massive ball moves with velocity \( v_i \). The ball then strikes the field by forming angle \( \theta = 30^\circ \), see the Figure 3 (a). The force direction components acting before and after the collisions can be described in Figure 3 (b).
Figure 3. The collision of a ball which strikes the field by forming an angle.

Based on Figure 3 (b) can be obtained equation (2) and (3).

\[ \Delta p_x = -2mv_x = -2mv_1 \sin \theta \]  
\[ \Delta p_y = mv_y - mv_x = 0 \]  

The larger angle formed between the ball and the vertical plane, the greater momentum change of a system. Collision in one-dimension has greater impulse than two-dimensions. The negative sign in equation (2) only shows the direction of impulse. Figure 2 shows student assumption that impulse on one-dimension and two-dimensions collision have the same value. Students have not understood the concept of momentum and impulse are vector quantities. Question number 6 can be classified on the competence to evaluate and design scientific enquiry. Table 3 shows 17.86% of students who understand the concept as a whole, so there are 17.86% students who have the competence of scientific literacy.

Learning physics especially the material about momentum and impulse, lecturers should convey the material by doing demonstration or experiment activities. This learning method expected to help students in forming their physics concept.

The 3rd highest misunderstanding level is related to the graph of momentum change over time (question number 2). There are 50% of students that categorized in misunderstanding level.

Question 2:

Two objects have the same shape and mass move on a frictionless plane, see figure (a). The mass and velocity of object 1 are \(m_1\) and \(v_1\), while for object 2 is \(m_2\) and \(v_2\). The two objects then move in the same direction and collide elastically. If there is a force acting on a particle, then the following graph illustrating the relationship of momentum change over time is ....

Example of student’s answer to question 1 can be seen in Figure 4.
The average force is a constant force that gives the same impulse to the object in time interval as in the actual force:

\[ I = F \Delta t \]

\[ F = ma \]

\[ F = m \left( \frac{v_2 - v_1}{\Delta t} \right) \]

\[ F \Delta t = \Delta p \]

\[ I = \Delta p \]

\[ F \Delta t = m(v_2 - v_1) \]

**Figure 4.** Student answer at number 2

Impulse is a change in the momentum of an object that is influenced by external force acting at a certain time interval. Based on equation (1), it can be obtained equation (4).

\[ \Delta p = m \Delta v \]  \hspace{1cm} (4)

If the collision occurs between the two objects are reviewed at each point of the movement, then the changes velocity of an object is very small and can be written as \( \Delta v \).

\[ m \Delta v = Ft \]

\[ p = Ft \]

\[ p = Ft \]  \hspace{1cm} (5)

If there is force acting on a particle, then the graph that illustrates the relationship of momentum change over time shows in Figure 5.

**Figure 5.** Graph of momentum change over time

Based on interview results and figure 4 have shown that students understand the mathematical representation related to impulse, but they cannot determine the appropriate graph. Question number 2 can be categorized on the competence to interpret data and evidence scientifically. Table 3 shows 32.14% of students who understand the concept as a whole and have the competence of scientific literacy. The cause of motion can be shown graphically using Newton’s law and the relationship between impulse-momentum concepts [23]. Sketch graphs of momentum change over time make Newton’s law seem clear.

4. Conclusion

Data of research which have been described can be concluded that students find it difficult to understand the correct concept of momentum and impulse. The results showed that the average of 17.86% students categorized in no answer level. Students of 40.18% categorized in misunderstanding, 14.29% are limited understanding, and only 27.68% from 28 students can understand the concepts as a whole. Students who have correct understanding certainly also have scientific literacy competencies. Students who have scientific literacy competencies are 27.68%. Almost all of the students experience misunderstanding related to the concepts of impulse when falling on the mat, a comparison of the impulse on one-dimension and two-dimensions collision, and the graph of momentum change over time.

Most students assume the momentum changes that experienced by acrobats if fall on a mat has a greater value than falling on the floor. Half of the total subject also categorized in misunderstanding level related to the relation between force acting on the particles to the momentum change over time. Students are mostly unable to draw the appropriate graph of momentum change over time if there is force acting on the particle, even though they already understand the mathematical equations. Such misunderstandings can occur because the material is presented only on the basis of theory and not given examples of applications in daily life. Learning physics should be doing demonstration or
experiment activities. Physics material also needs to be presented in various forms of representation, so it can help students in forming their concept.

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