The identification of high school students' knowledge of Newton's law of science literacy using a test based on nature of science (NOS)

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The identification of high school students’ knowledge of newton’s law of science literacy using a test based on nature of science (NOS)

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Abstract. Science literacy shows that students should be familiar with the most basic principles of science, one of which is Newton's Law. The purpose of this research is to determine the ability of high school students in Newton's Law of science literacy using a test based on Nature Of Science (NOS). The NOS-based instrument consists of 25 multiple-choice test items with 4 alternative options modified by Nature of Science Literacy Test (NOSLiT) and is specifically developed on Newton's Law. The subjects of this study are 110 high school students of the IPA program. Data collection techniques were performed using tests based on NOS-based instruments and interviews using questionnaires. The method of his research used descriptive qualitative. The results show that the average percentage of students who answered correctly was 38.73% of 110 students. The highest average percentage was shown in the scientific disposition framework is 53.33% of students answered correctly, and the lowest in the major misconception about science framework is 23.93%. Based on the results of the study can be concluded that students who can’t answer correctly about the NOS are the students who are less able to understand the language of the questions presented in the instrument NOS. Other factors that influence student performance in answering questions on the NOS are knowledge of science that is still less widespread, low student understanding and still many misconceptions on Newton's law. It can be said that the student has a low literacy ability in science.

1. Introduction
The importance of understanding science, so it must be the characteristic of every student’s education for the progress of science [1]. In the last few decades, students in schools have learned to use knowledge to develop their skills. Thus, science educators can not underestimate the importance of the application of knowledge and information. Expertise such as knowledge of science content and reasoning skills, contribute to action to solve multidimensional social problems whose solutions depend on scientific knowledge [2]. Understanding and application of science in solving problems is the definition of science literacy [3].

Defining operational science literacy, the general populations must first be familiar with the "most basic principles of science". The principles possessed by all sciences on the central laws of physics include Newton's Law, Law of Thermodynamics, Electricity, and Magnetism, as well as the Atomic Structure of matter [4]. One of the central laws of physical law that can represent verbal, mathematical, physical, and visual languages is Newton's Law. The understanding of Newton's law has been intensively discussed by physicists and physics educators. Understanding the language of physics, mathematics, visual, and intuition is the key to understanding the concepts of physics [5]. An
understanding of conception and misconception is important in physics learning, as it affects the overall understanding of physics [6]. The main sources of student misconceptions include students' personal experiences, textbooks, the language used, and teachers [7]. Literacy of science is a multi-dimensional capability that includes knowledge (vocabulary, facts, and concepts), process skills (skillful and intellectual), disposition (attitude and behavior), good relationships between science-technology-society, and the history and the nature of science owned students [4]. Literacy of science is also defined as the ability to engage with issues and with ideas about science [1]. From a review of the historical development of the definition of science literacy, one of the most important themes is an understanding of the nature of science (NOS). NOS is one of the steps to assess science literacy more comprehensively. In addition to functioning as operational definitions and organizing principles for science instruction and science literacy assessment, NOS has a significant impact on curriculum design and practice of learning [4]. This study aims to determine the ability of high school students in Newton's Law against science literacy using a test based on Nature Of Science (NOS). NOS-based instruments are used to determine students' literacy skills in Newton's Law. The NOS instrument consists of multiple choice questions. Multiple-choice tests are the kind of tests that make it easier to identify student misconceptions because multiple-choice tests have custom-designed items within a limited and clear content area [8]. The NOS instrument was developed by researchers by modifying the Nature Of Science Literacy Test (NOSLiT) which originally contained general science knowledge into NOS-charged instruments especially in Newton's Law.

2. Experimental Methods
This research is a descriptive qualitative study. Subjects in this study amounted to 110 high school students IPA program. The technique of collecting data is done by test and interview. The tests used validated and reliable NOS-based instruments, while interviews used questionnaires containing student responses related to NOS tests. The NOS-based instrument consists of 25 multiple-choice test items with 4 modified alternative options of the Nature of Science Literacy Test (NOSLiT) instrument and is specifically developed on Newton's Law. The NOS instrument is composed of 6 frameworks adopted from NOSLiT as presented in Table 1.

| No | Frameworks                              | Many of Questions |
|----|----------------------------------------|-------------------|
| 1  | knowledge of associated scientific    | 4                 |
|    | nomenclature                          |                   |
| 2  | intellectual process skills            | 7                 |
| 3  | rules of scientific evidence           | 5                 |
| 4  | postulates of science                  | 3                 |
| 5  | scientific dispositions                | 3                 |
| 6  | major misconceptions about NOS        | 3                 |

3. Results and Discussion
The results of the test are divided based on the NOS instrument framework, as shown in Figure1. The results showed that the average percentage of students who answered correctly was 38.73% of 110 students. NOS instruments were tested on high school students who had previously studied Newton's Law. The result of the NOS test on Newton's Law is the right and wrong answer. Figure 1 presents the average percentage of students who can answer correctly from each NOS instrument framework.
Figure 1. The average percentage of students correctly answered from each NOS framework

Based on the description of Figure 1, the 5th framework (scientific dispositions) obtained the highest percentage of 53.33%. In science literacy, students should understand some common characterizations of scientists, such as curious and skeptical, objective and not dogmatic, creative and logical, and honest and trustworthy [9]. In the framework of scientific dispositions consists of 3 questions presented about events related to Newton's Law. It can be concluded that 53.33% of students have sufficiently understood the concept of the Newton Law event, so that it can answer correctly related characteristics of scientists in response to the events presented. Not all students who answered correctly can be said to understand the concept, because the question is in the form of multiple choice is likely that students who do not understand the concept only answer with feelings (intuition) [10] or also just guessing.

The second sequence is the 3rd framework (rules of scientific evidence) 44.35% of students are able to answer correctly. Rules of scientific evidence supporting scientific literacy include, scientific conclusions must be based on public evidence and do not accept accidental relationships that are not supported by evidence [9]. This framework consists of 5 questions presented in relation to the Newton Law concept.

The questions presented in Figure 2 can only be answered correctly by 19 students. The correct answer is option A but more students who answer option B. Newton's third law states that the force acting on the first object is as large as the force acting on the second object, but in the opposite direction [11]. From the statement that in Newton's third Law works on two objects, there are still many students who are misconceptions and think Newton's third law works on one object. Mathematically can be written F action = -F reaction, negative sign (-) indicates the direction of F reaction opposite to direction F action. Some students do not understand what they are doing so they are fooled into choosing the C option.

13. Two students are talking. The first students says, "the stronger we kick the stone, the more pain our feet are because the force we give to the rock is as big as the force that the stone gives to our feet". The second student replied, "our feet hurt while kicking rocks due to hard rock, and silent stone. If the stone is silent, then where does the force that causes the foot hurt? If you think that rock has a force try to prove! "Which answer is most appropriate to prove it?

   a. The action force is as the reaction and counter clockwise, acting on two different object that are interacting.
   b. The action is as large as the reaction force and counter clockwise, acting on one object.
   c. The action force is as large as the reaction force and direction, acting on two different object that are interacting.
   d. The action force is as large as the reaction force and direction, acting on one object.

Figure 2. The problem on Framework rules of scientific evidence
and D options. Because some students do not understand the concept of monster so misconception and they can’t find the correct evidence to answer the question.

The next sequence is the 2nd framework (intellectual process skills) 39.73% of students are able to answer correctly. The question in Figure 3 correct answer is option D but more students answer option B. The relationship between the mass of objects with the acceleration of this object is the relationship presented in the equation of Newton’s second law. Newton’s second law states that the acceleration acting on an object is directly proportional to its force and inversely proportional to its mass \((F = m.a)\) [12]. In answering the question in Figure 3, the students already understand if the acceleration of the object is influenced by force and mass because there are only 6 students who choose option A. In fact, most students answer option B because they are fooled by the images presented in the question text. Can be said students think if the size of the object (volume) affects the mass of the object, and the mass affect the acceleration of the object. Judging from Newton’s second law that influences the acceleration of objects is force and mass, so the most appropriate answer is option D.

6. A physicist wants to determine how the mass of an object affect the acceleration of an object. He puts a beam shaped object on the floor and driven in a certain force. Next, he puts a second cube-shaped object and driven it in the same force as the beam. By ignoring the frictional force on both object. The proper experiment design should be?

| a. | The shape of the object affect the acceleration of the object. |
| b. | The size of the object affect the acceleration of the object. |
| c. | The acceleration of the object does not depend on the force given to the object. |
| d. | The acceleration of an object depends on the mass of the object. |

**Figure 3.** The problem on Framework intellectual process skills

A person who has science literacy should be able to distinguish between observations and conclusions and be aware of the relationship between law and theory [13]. The important skills students possess in science literacy include one of them identifying the variables [9]. From the analysis of student answers from the question in Figure 3, it is concluded that the students are still weak in identifying the variables.

A total of 36.05% of students were able to correctly answer questions on the 4th framework (postulates of science). Postulates of science is a view of science that run from the past until [9]. There are three questions in this framework, number 23 is a question with a correct answerer for at least 9 students.

23. Aristoteles declared a conclusion if the moving object would stop if it not pushed continuously. About 2000 years later Galileo found a very different concluding obtained from the result of his experiments. Galileo concludes that if an object that moves on a perfectly slipper path is perfectly smooth and does not create frictional force, it will continue to move at an unchanging rate. Which statement is more appropriate and why?

| a. | Aristoteles’s statement, because good scientific conclusion will remain unchanged as time pases. |
| b. | Aristoteles’s statement, because scientific conclusion made by scientists will never change in the future because the law of the universe are always and everywhere the same. |
| c. | Galileo’s statement, because scientific conclusions may change over time as new evidence in found. |
| d. | Galileo’s statement, because the scientific conclusion drawn from the old theory have a high probability of errors. |

**Figure 4.** questions on the postulates of science framework
Figure 4 presents a question about the effect of the evidence on the change in conclusions. The correct answer is option C, but more students answer B. The concept presented in Figure 4 is Newton's first law concept which states that "a thing that is silent will remain silent, and things that move perpendicularly straight will remain in perpendicular motion if no external force influences it (ΣF = 0)". The friction force is an outer force that affects the motion of an object because it can slow the motion of a moving object. Science acknowledges repeated observation and enduring scientific knowledge but is tentative [9]. The error in answering the question can be because the student does not understand Newton’s first law concept, lacks knowledge of science, or does not understand both.

The fifth order is the knowledge of associated scientific nomenclature of 34.99% of students who are able to answer the questions correctly. Consists of 4 questions that discuss the terms often used in science presented in Newton’s law theory. Instrument NOS uses only a few such as hypothesis, principle, assumption, theory, law, and explanation. A total of 65.01% of students are said to have low science literacy, because students have not been able to distinguish between hypothesis and assumptions, theoretical and legal terms, and students have not been able to determine the Newtonian Law related statements which are an explanation. Science literacy at the school level should consider several levels, such as nominal and functional (can use scientific vocabulary) [3].

The last order is major misconceptions about NOS only 23.93% of students are able to answer questions correctly. Major misconceptions about NOS is a fake story about science on the scientific method [9]. The questions presented in this framework are more about the history of Newton’s law. Most students do not know that Newton’s law is a motion theory of Galileo which is further refined by Isaac Newton to be named Newton’s law. Teaching an understanding of the history and philosophy of science to students will make progress toward teaching science as an expected inquiry [14]. Literacy of science is a multidimensional ability, a good relationship between science-technology-society, and history and the nature of science that must be owned by students [9].

Interviews in this study are intended to determine the factors that affect the occurrence of misconceptions experienced by students in doing the test. Results of interviews interviewed using a questionnaire showed as many as 73.3% of students said the language presented in the NOS instrument difficult to understand. This is because NOS modified NOS instruments developed by Carl. J. Wenning for students in the United States, so the writing of sentences is still very similar to NOSLiT. Students are still familiar with the scientific terms presented in NOS instruments and almost all types of questions presented in NOS Instruments are the domain of analysis. The use of language is a source of misconception because it can make representations [6]. Misconceptions and false conceptions can occur if one language is not understood, or only one language dominates over another when it comes to conclusions [5]. Misconceptions occur in students due to lack of knowledge in the affective domain or knowledge in the cognitive domain [7]. Students understand the concept well if they solve the problem will be solved with low anxiety level (belief) and the answer is correct [6]. The more complex and more concepts understood by students will increase students’ understanding of a scientific problem, so that students can find solutions in complexity. The process of finding solutions is one of the processes that can provide science literacy skills to students [15].

4. Conclusion

The results showed that the average percentage of students who answered correctly was 38.73% of 110 students. The highest average percentage was shown in the scientific disposition framework of 53.33% of students answered correctly, then scientific proof test of 44.35%, experimental ability and basic observation 39.73%, science postulation 36.05%, scientific naming 34.99%, and the lowest in the main misconception framework on science is 23.93%. Based on the results of the study can be concluded that students who can’t answer correctly about the NOS are the students who are less able to understand the language of the questions presented in the instrument NOS. Other factors that influence student performance in answering questions on the NOS are knowledge of science that is still less widespread, low student understanding and still many misconceptions on Newton’s law. It can be said that the student has a low literacy ability in science.
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