Assessing scientific literacy on optics among high school students in Kudus

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Abstract. The purpose of this research is to assess scientific literacy profile of grade 11th and 12th high school students on optical geometry and optical instrument. Students’ scientific literacy was determined based on four components, there are (1) role of science, (2) scientific thinking and doing, (3) mathematics in science, and (4) science and society. The subjects of this research are high school students of class XII IPA from five different schools. This study used descriptive method. Scientific literacy data were collected by O-SLA test developed by researcher. The results showed that the highest mean score of scientific literacy component was science and society component and the lowest meanscore was scientific thinking and doing component. Overall, the average of high school students’ scientific literacy are in low category.

1. Introduction
Science as one of the subjects in high school is very important to learn because science lives in every human activity. According to NRC (National Reasearch Council) [1], everyone needs literacy skill to make decisions in their daily life. Scientific literacy encompasses various components ranging from knowing and understanding the concept of science, using the concept of science to be applied in everyday life or decision making, explaining scientific phenomena, and criticize scientific information [1-4]. Quoted from the OECD [5], PISA defines scientific literacy as the ability to engage science-related issues and the notion of science, as a reflective citizen.

Levels of students’ scientific literacy can be known from an international instrument in the form of PISA (Program for International Student Assessment) tests conducted every three years. The achievement of student scientific literacy in Indonesia based on the latest PISA 2015 survey showed an increase of 6 rankings compared to the position of scientific literacy achievement in 2012 which currently occupies the bottom two position [5]. The scientific literacy rankings of Indonesian students who are always ranked in the bottom ten in each of their participation encourage various studies on scientific literacy so that it is necessary to evaluate the development of scientific literacy in Indonesia by measuring the literacy of science regularly.

Assessing scientific literacy are important to know the extent how far a student have been literate in science. Indeed, some studies have discussed the achievements of scientific literacy of its citizen, including Japan [6] and China [7]. Several studies have been conducted to measure the level of scientific literacy in physics [8,9], chemistry [10], and biology. Much of the scientific literacy research is still rarely found the measurement of scientific literacy in the field of physics or physics literacy. Many findings reveal the scientific literacy profile of children aged 13-15 years i.e. students who are
in 9th grade middle school or 10th grade high school. In addition, there are several studies on the profile of students’ scientific literacy capabilities but still rarely encountered the scientific literacy profile of high school students over 15 years old. Whereas, assessing scientific literacy is important for all levels of education, not just middle school students.

Physics as a whole part of science can explain the natural phenomena expressed in matter and energy residing in the universe. Physics contains an understanding of the concept to understand the phenomena. Moreover, physics also contains mathematical formula to be applied to solve problems in every day life. Considering that arguments, the four scientific literacy components developed by Fives, et al [11] are suitable for use to assess high school students’ scientific literacy. These four components namely (1) the role of science, (2) mathematics in science, (3) scientific thinking and doing, and (4) science and society.

2. Methods
This study was conducted on 239 grades 11th high schools’ students who have received lessons about optics before, especially optical geometry and optical instrument. The samples in this study were randomly selected from four schools in Kudus with different school grades. There are high, medium, and low school rankings. The ranking of schools was based on the results of national examinations on physics subjects in the last three years. All schools are state-owned and there was a total of seven state high schools in Kudus.

This study used descriptive quantitative method. The instrument used to collect scientific literacy data was O-SLA (Scientific Literacy Assessment on Optics) developed by researcher. Prior to use for measuring the scientific literacy in optics, O-SLA was validated by 6 lecturers as experts (evaluation, materials, and language) and 3 teachers from different schools as practitioners. After that, the O-SLA was modified using PISA construction and was repaired according to expert advices. The instrument has been valid and reliable after being tested to more than 200 of high school students on grades 12th.

3. Results and Discussions
Analysis of students' scientific literacy profile can be viewed from four components of scientific literacy adopted from Fives, et al [11], namely (1) role of science, (2) scientific thinking and doing, (3) mathematics in science, and (4) science and society. The average of scientific literacy measurements on 11th grade high school students can be seen in Figure 1.

![Figure 1. High school students’ scientific literacy profile](image-url)
Figure 1 shows that the highest scientific literacy mean score of students is the component of science and society. This result was supported by research on scientific literacy which shows similarities in the high achievement of the society component [12]. However, this result was different from the results of previous studies conducted in junior high school which showed the lowest percentage of science components related to society and technology [13]. High percentage in this study because the contexts used in the matter are close to their environment. Another thing that is the reason is that textbooks used by senior high school students in the latest curriculum have many examples of science applications in society or everyday life.

The scientific thinking and doing component is the component with the lowest percentage among the other components. This result is in line with the results of the study concluding that the lowest achievement of scientific literacy was achieved in the science as the way of thinking and investigating aspect with a low percentage of 20% [14]. The study using the SLA instrument [15] also showed low results on this aspect. In the research, scientific thinking and doing aspect only reach 31.31%. The main factor causing this lowest percentage is the lack of students' understanding of the research variables. In fact, many students still can not distinguish between dependent, independent, and control variables. The government demand for preparing the questions in accordance with the national examination also makes the teacher reduce the activity in the laboratory. To improve scientific literacy in this component, teaching and learning with laboratory experience is required [16]. Laboratory activities provide students with a lot of science learning and develop their scientific process skills.

The second lowest percentage is mathematics in science. This aspect contains questions about the application of mathematics in science. This aspects also be the lowest percentage of the research conducted by Rachmatullah et al [15]. Many students can not answer the questions on this aspect because they lack the mastery of geometry. Students are still confused with the concept of congruence and angular relationships. Based on the results of the interview, students claimed to be familiar with the matter of optics by memorizing the equations of mirrors or lenses that exist in their physics textbook. They are unfamiliar with optical problems that are directly related to the concept of geometry. The concept of this geometry should have been mastered because it is taught in middle school and often used to study mathematics in high school.

Meanwhile, preliminary study conducted on several high school students in Kudus related to understanding the optical concept of high school students [17]. The results showed that many high school students did not understand the concept of geometric optics. This can be one of the reason for component role of science to be one component with a low percentage after component scientific thinking and doing and component mathematics in science.

Students’ scientific literacy in this study was also presented based on the ranking of schools in every component of scientific literacy to see in more detail the achievement of students’ scientific literacy. The results of scientific literacy measurements on 11th grade high school students are distinguished based on school rank and can be seen in Figure 2.

Figure 2 shows that the achievement of students’ scientific literacy in each school is different. When viewed from a schools ranking, high-ranking schools have a higher average of scientific literacy achievement than other schools. Although the scientific thinking and doing component of scientific literacy is achieved with highest score by students from low-ranking school. However, the percentage difference in this component is not too significant. Based on interview results, teachers in schools with this low category teach students to actively conduct experimental activities. In this case, Vieira et al [18] stated the need for students to be involved in scientific investigations. Student participation directly helps them learn the science process. The achievement of scientific literacy for low and medium category schools is also different.

Compared with medium-ranking schools, low-ranking schools have achieved scientific literacy in the mathematics in science component with significant score differences. Students in high-ranking and low-ranking school admitted that they are often trained to do the calculation problems so that the ability of scientific literacy on this component is good. Students’ mathematical (geometry) abilities affect the acquisition of results in this component.
Figure 2. Students’ scientific literacy based on school ranking

In general, the achievement of students' scientific literacy using O-SLA is still at a low level, i.e. below 50%. Many new studies in other areas also measure scientific literacy with achievement of scientific literacy students under 50% i.e. students scientific literacy measurement in physics using four-tier test [19]. It indicates that there is still need to improve the scientific literacy of students in high school level. With frequent measurement of scientific literacy, it is expected to encourage students to continuously improve their scientific literacy skills. That way, the students will be able to compete in the 21st century. So, students with good scientific literacy becomes a foundation for a person to contribute in society with rapid technological advancement.

4. Conclusion
The scientific literacy and conceptual understanding among high schools students in Kudus on optics content are in low levels. The average percentage of scientific literacy on the content of optics based on O-SLA achieved by students was 41.34%. Component of scientific literacy that is not mastered by students is the scientific thinking and doing component while the most controlled component is the science and society. There is still a need to improve the scientific literacy of students in high school level. With frequent measurement of scientific literacy, it is expected to encourage students to continuously improve their scientific literacy skills.

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