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Analysis of Students' Science Literacy Concerning Chemical Equilibrium

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Abstract. In today’s era of modernization, people are unequivocally required to have abilities in contributing to certain, often multiple fields and developing themselves in this regard, including having particular skills in chemical science literacy. Such literacy skills are essential, especially for students, as they concern issues related to science and its relation with everyday human life. Hence, this study was conducted to describe the science literacy skills of students in terms of their achievements regarding the topic of chemical equilibrium. This study used a descriptive quantitative approach. The sample comprised 60 students in grade XI. The instrument comprised an essay testing three aspects of the science literacy domain: context, competence, and knowledge. The data constituted scores analyzed using descriptive statistics (analysis of percentages). The qualification of science literacy was classified into five criteria. Based on the data analysis, it is shown that students’ literacy in science skills is categorized as low.

Keywords: chemical equilibrium, chemistry education, literacy science.

INTRODUCTION

One of the challenges in global science education, as stated in the UNESCO Science Report of 2008¹, is the implementation of science education in school. There are associated impacts on science content as taught in the curriculum, learning strategies, and evaluation systems, as well as access and equity in science education. Therefore, science education should be more progressive and relevant to real life for the betterment of the nation's competitiveness through the development of human resources. In addition, in the real practice of science education in schools, it is found that science learning is more at theoretical level, whereas the applications and processes of science are rarely learned, so that learners do not comprehend the important relations between science and life. Hence, developing varied and authentic learning strategies, and assessments effective in evaluating and improving cognitive skills in science literacy is truly necessary.

Science literacy concerns the ability to use scientific knowledge in solving various daily problems, based on evidence and facts. Science literacy requires not only knowledge of science concepts and theories, but also knowledge of general procedures and practices related to scientific inquiry, and how it occurs and is viewed from the perspective of the progress of science. To achieve literacy skills in science, learners must have knowledge of the concepts and ideas that shape the basic underpinnings of science and technology, how knowledge is explained, and at what level knowledge is justified by scientific evidence or explanation. Science literacy is therefore considered a key outcome of science learning, and it is important that learners master it.² In addition, increasing science literacy in schools has been the goal of curricula and science teachers for more than a century.³ Science literacy is important for students in terms of how they understand the environment, health, economics, and other issues faced by modern society, which relies heavily on technology, and the advancement and development of science.

Science literacy represents the intersection between what people know and what people can do.⁴ Furthermore, according to the Organization for Economic Co-operation and Development (OECD), science literacy concerns the ability to associate issues related to science with the idea of science.⁵ Moreover, science literacy in the view of PISA is characterized by four domains. First, the context domain includes personal, local/national, and global contexts. Second, the domain of competence includes aspects of the ability to explain scientific phenomena, to evaluate and design scientific research, and to interpret data and scientific evidence.
Third, the knowledge domain encompasses aspects of content knowledge, general knowledge, and empirical knowledge. The fourth domain concerns attitudes toward science, technology, and issues affecting individuals in real situations. Being literate in science also means one can search for and determine the answers to questions that derive from curiosity about everyday experiences and phenomena. This means that one has the ability to describe, explain, and predict natural phenomena. Above all, the focus of this study is on the students' science literacy skills in the domains of context, knowledge, and scientific competence related to learning the topic of chemical equilibrium.

METHOD

Research Design

This study was descriptive in nature and adopted a quantitative approach. This quantitative research aimed to describe the characteristics of the population based on data collection among a particular sample. The analysis of the science literacy skills of students was based on an essay concerning the topic of chemical equilibrium.

Research Sample

In this study, the population comprised science students in grade XI in semester one of the 2017/2018 academic year in one of the senior high schools in Yogyakarta, Indonesia. The participants were 60 science students who had previously studied the topic of chemical equilibrium. The sampling technique used was purposive, based on certain characteristics and criteria as follows: the students had studied chemical equilibrium and were assessed as having moderate cognitive skills namely choosing samples with moderate cognitive skills from among the population.

Data Collection Techniques

The study was carried out with 60 students, and was conducted in two different 11th-grade classes in a senior high school. The purposive sampling technique was used: considering the learning hours for chemistry in each class, the average test scores were almost the same. The instrument for data collection (an essay) was developed by the researcher. The empirical validity testing of the research instrument was conducted with 60 students in the XII science grade, and reviewed by two expert judges. The scope of the subject was chemical equilibrium. The science literacy skills measured included the contextual domain, competences, and knowledge. Domain attitudes were not measured in this study because the study focused on domains directly related to cognitive knowledge. An instrument can be used if it has been tested for its validity and reliability. Based on the validity test, 15 questions were found to be valid, while the reliability test showed that the instrument was reliable (0.755). The distribution of questions is presented in Table 1.

<table>
<thead>
<tr>
<th>Literacy Science Domain</th>
<th>Situation</th>
<th>Question Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context</td>
<td>Personal</td>
<td>15*, 17</td>
</tr>
<tr>
<td></td>
<td>National</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Global</td>
<td></td>
</tr>
<tr>
<td>Science Competence</td>
<td>Explaining the phenomenon scientifically</td>
<td>12, 13, 14c</td>
</tr>
<tr>
<td></td>
<td>Evaluating and designing scientific experiment</td>
<td>14a, 14e*</td>
</tr>
<tr>
<td></td>
<td>Interpreting scientific evidences and data</td>
<td>14d</td>
</tr>
<tr>
<td>Knowledge</td>
<td>Content</td>
<td>1*, 2, 4, 5, 6*, 7, 8, 9, 10, 11, 16</td>
</tr>
<tr>
<td></td>
<td>Procedural</td>
<td>14b</td>
</tr>
<tr>
<td></td>
<td>Epistemic</td>
<td>3</td>
</tr>
</tbody>
</table>

*not valid

Data Analysis

The data obtained were in the form of scores from 0 to 2. The score per se was categorized based on the marking scheme determined. Moreover, the score gained was analyzed using analysis of percentages. Thus, the equation used to count the percentage scores for the data was as follows:
The phases of data analysis determined the scores for students’ answers based on the marking scheme, counting the scores of students’ answers for each item, and determining the qualification criteria for science literacy skills (Table 2).

### Table 2. Qualification of literacy science criteria

<table>
<thead>
<tr>
<th>No.</th>
<th>Interval (%)</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>81 – 100</td>
<td>Very high</td>
</tr>
<tr>
<td>2</td>
<td>61 – 80</td>
<td>High</td>
</tr>
<tr>
<td>3</td>
<td>41 – 60</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>21 – 40</td>
<td>Low</td>
</tr>
<tr>
<td>5</td>
<td>≤20</td>
<td>Very low</td>
</tr>
</tbody>
</table>

### RESULTS

A prerequisite for statistical analysis is establishing the normality and homogeneity of data. Based on the results of the analysis, the data are normally distributed and homogeneous. Thus, the results of the students’ literacy science skills in terms of percentages are presented in Table 3.

### Table 3. Frequency distribution of the literacy science test score

<table>
<thead>
<tr>
<th>Literacy Science Domain</th>
<th>Situation</th>
<th>Percentage (%)</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context</td>
<td>Personal</td>
<td>40.42</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>National</td>
<td>33.33</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Global</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science Competence</td>
<td>Explaining the phenomenon scientifically</td>
<td>33.61</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Evaluating and designing scientific experiment</td>
<td>15.42</td>
<td>Very Low</td>
</tr>
<tr>
<td></td>
<td>Interpreting scientific evidences and data</td>
<td>5.00</td>
<td>Very Low</td>
</tr>
<tr>
<td>Scientific Knowledge</td>
<td>Content</td>
<td>26.29</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Procedural</td>
<td>20</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>Epistemic</td>
<td>33.33</td>
<td>Low</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>25.925</td>
<td>Low</td>
</tr>
</tbody>
</table>

Based on Table 3, it can be seen that the mean score for students’ science literacy skills related to the chemical equilibrium topic is 25.925%. This indicates that the skill of students in terms of science literacy is low.

### DISCUSSION

The aim of this study was to describe science literacy skills in relation to the topic of chemical equilibrium. The focus of the analysis was therefore on the ability of students to demonstrate understanding of chemical equilibrium with regard to three respective science literacy domains: context, competence, and knowledge. First, in terms of the aspect of the scientific context, an important aspect of the PISA science literacy assessment is the involvement of students in various situations presented in the form of scientific issues. This aspect involves important issues related to science in everyday life. Moreover, the assessment of science literacy is designed for contexts not only limited to school life but also to general student life. PISA also refers to situations related to individual, family, social, global conditions, and several topics aimed at understanding the progress of science in the field. Second, the aspect of science competence refers to the mental processes involved when answering a question or solving a problem. The priority of the PISA 2012 assessment of science literacy is focused on several aspects of science competence: identifying scientific issues, explaining scientific phenomena based on scientific knowledge, and using scientific evidence to draw conclusions. Third, in terms of science knowledge, students need to grasp a number of key/essential concepts in science aimed at understanding certain natural phenomena and the changes that occur due to human activities. The purpose of the PISA literacy test is to illustrate the extent to which students can apply their knowledge in a context relevant to their lives.

Literacy skills in science are identified by calculating the mean percentage of students who correctly answer each item. The results are presented in Fig. 1. Furthermore, the results of each domain are obtained by
calculating the correct percentage of answers for each indicator in the domain. This percentage is derived by comparing the scores obtained by each student in relation to the maximum score. Thus, the average achievement scores for science literacy skills are determined for each indicator in each domain.

![FIGURE 1. Student' Literacy Science Skills for Each Domain.](image)

Fig. 1 shows that students have low science literacy skills. Moreover, for each domain, it is suggested that students answer the questions based on the texts in the instrument. To enhance our understanding of the results of students’ answers in this study in detail, we examine the following aspects:

- **Domain: Context—National**
  Text: Tooth decay (caries) in Indonesia
  Task: Explain how human teeth can rot and give your idea of what people should know about dental caries.
  Student 1: “The cause of caries is the acid of bacteria that dissolves hard tooth tissue (enamel, dexamine, and cementum). This acid is produced from food scraps or sugar on tooth surfaces. Simple sugar in food is the primary source of bacterial energy. People may require extensive dietary changes (reduced frequency use of sugar), improving oral hygiene (brushing twice daily with regular fluoride toothpaste); moreover, a person needs to have understanding and motivation as well as consistent dental maintenance, otherwise, the rot will continue.”
  Student 2: “The cause of caries is from sugar in food and drink. People may need to brush their teeth consistently.”

- **Domain: Scientific Competencies—Evaluating and designing scientific inquiry**
  Text: Hemoglobin in the human body
  Task: When Sasa rides a motorcycle in conditions of congestion, she feels dizzy. According to doctors, this happens because Sasa inhales too much CO2 from motor vehicle fumes. How can CO2 affect the human circulatory system? What happens to oxygen when CO2 enters the blood?
  Student 1: “Carbon monoxide has a higher diffusion coefficient compared to oxygen. The traditional belief is that carbon monoxide toxicity arises from the formation of carboxyhemoglobin, which lowers the oxygen-carrying capacity of the blood so that it inhibits the transport, delivery, and utilization of oxygen by the body. The affinity between hemoglobin and carbon monoxide is approximately 230 times stronger than the affinity between hemoglobin and oxygen, so that hemoglobin binds to carbon monoxide.”
  Student 2: “Sasa feels dizzy due to lack of drinking water while driving, so that oxygen in the body is reduced.”

- **Domain: Scientific Competencies—Evaluating and designing scientific inquiry**
  Text: Effects of hemoglobin on the human body
  Task: Write a simple experiment that proves the doctor's diagnosis. Write a) a research questions, b) procedures, and c) hypotheses.
  Student 1: a) What is the effect of CO2 on the human body? b) Put a white mouse in an aquarium, close the aquarium using styrofoam, insert the hose connected to the exhaust, turn on the motor, and watch what happens to the mouse, c) the mouse moves very aggressively then faints, due to inhaling CO2 from the vehicle fumes.
Student 2: a) What happens if you are driving but you are not drinking? b) Turn on the motor vehicle, put your nose close to the vehicle fumes, and see what happens, c) after inhaling the exhaust fumes, one will feel dizzy.

- Domain: Content Knowledge
Text: Kabayan (A Story from West Java, Indonesia)
Task: Based on the Kabayan story, identify evidence that proves Kabayan’s reaction is considered an equilibrium reaction.
Student 1: If water is left in an open container and left for a long time, then the water in the container will decrease, as the vapor droplets evaporate and come out from the container. In a closed container, the vapor in the evaporation process does not come out of the container; consequently, when it becomes saturated in the form of steam, there will be lot of air vapor that condenses and sticks to the lid of the container, then turning back into water that flows back into the pan.
Student 2: Because the system is closed, the direction of the reaction is back and forth, and is dynamic.

Analytical questions are given by relating the cognitive aspects to the science phenomena encountered in everyday life. It is found that students’ science literacy skills concerning the personal context are quite good. This is demonstrated in terms of the ability of students to explain the scientific phenomenon by interpreting scientific evidence and drawing conclusions to solve question in the related texts. In addition, students exhibit the ability to use scientific evidence, that is, being able to identify assumptions, evidence, and reasons as reflected in their conclusions in solving problems concerning the concept of chemical equilibrium (illustrated using the problem of a person who feels dizzy due to being stuck in traffic). Moreover, the ability to identify scientific problems is demonstrated by students who are able to recognize the problems and characteristics of scientific phenomena. These abilities reflect students’ understanding of the aspects of the science knowledge, in this case related to the concept of chemical equilibrium.

Based on cognitive learning theory, students use their initial knowledge to process new information. This new information is then connected to their initial knowledge. This means that the cognitive aspects of students influence their ability to identify scientific problems. This is demonstrated by the results of this study, namely that not all students were able to apply their science knowledge in solving the science literacy problem on the concept of chemical equilibrium. In this regard, students are perceived to need competencies in evaluating and applying scientific knowledge. The concept of knowledge of the students affects their ability to describe or interpret scientific phenomena. The results obtained for this indicator reveal that students lack the ability to evaluate scientific investigations. This lack of ability is due to several factors, one of which is the approach or method of science learning used by teachers in building the concept of learning. The learning method is an essential factor in enabling teachers to attract students' interest in learning topics and foster their motivation to solve problems, leading to the building of students' literacy skills. Therefore, the teaching and learning process must be focused on the process of the scientific method, aiding students in building correct conceptual understanding independently, and providing an avenue for students continuously to develop their ability to discover the concept of science and foster their science literacy.

Science literacy also includes cognitive understanding, which aligns with the concept of science skills, such as designing, collecting, and analyzing data, and drawing conclusions based on scientific evidence. It requires multidimensional activities that can help students understand the real practice of science learned in school. This can be done through integrated science learning that allows students to plan their lessons, apply learning, and evaluate learning independently. The main factors resulting in low literacy skills in science concern aspects of attitudes to science, related to the reading interests of students and student involvement in science learning.

CONCLUSION

The purpose of this study is to describe the students’ literacy skills in science drawing on the topic of chemical equilibrium. Based on the results, it can be concluded that on average students’ science literacy is still in the low category. Therefore, it is suggested that the learning of chemistry should be designed to optimize and integrate literacy aspects in chemical learning topics in a way that is relevant to the students’ lives.

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REFERENCES