A Comprehensive Scientific Literacy Analysis of Biology Textbooks Used by Indonesian Senior High Schools

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Abstract. As the primary teaching material for the learning process carried out in school, textbooks contribute to the development of students' scientific literacy. This study examines the literacy element of scientific literacy in Biology textbooks commonly used in Indonesian high schools. This analysis process involved four aspects of scientific literacy. A scientific literacy analysis was carried out on seven highly used Biology textbooks in senior high schools. The results suggest that the textbooks have properly involved the scientific literacy aspects, primarily in the aspect of science as a body of knowledge (85.89%), science as a way of thinking (68.1%), and science as a means of investigation (65.54%). Meanwhile, the textbooks only moderately discuss the aspect of the interaction of science, technology, and society (57.32%). Consequently, improvements in the content of biology textbooks on the aspect of scientific literacy are required to grow scientific literacy skills through teaching and learning in schools.

Keywords: Books · Indonesian Biology · Scientific Literacy

1 Introduction

With the rapid advancement of science and technology, scientific literacy becomes very essential. Reformation in education around the world currently promotes science for all, aiming to achieve excellent scientific literacy [1]. Scientific literacy has become a better standard in measuring students' ability, while also carrying long-term good effects [2]. Scientific literacy is defined as the capacity to use scientific knowledge, identify questions and then draw conclusions based on facts and data in formulating decisions based on changes that occur due to human activity [3, 4]. The scientific understanding, theory, law, and phenomena from various sources become a reference of scientific literacy [5]–[7]. Science learning should promote the use of science in everyday life to develop students' scientific literacy skills. Contextual science learning increases students' scientific literacy by facilitating them to understand science, its development, and its correlation in everyday life [8, 9]. Therefore, the learning process should enhance students' scientific literacy to help them resolve the current and future global challenges.

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One of the most essential and widely utilized teaching materials in science learning is textbooks [8]. A science text or science textbooks contain aspects of scientific literacy, including the scientific content, context, and processes that improve the quality of science learning following the curriculum [10–12]. As the main learning source, the presence of science textbooks is highly essential. Science textbooks are often used to convey a lot of real science information to students [13, 14]. This shows that the importance of scientific literacy for students, as it illustrates scientific literacy directly to students [15].

Scientific literacy discussed in textbooks is expected to be a representative forum in developing students' potential. The content of science textbooks is expected to incorporate discussion on the nature of science, activities to engage students in gathering information and carrying out laboratory investigations, as well as illustrations on the relationship between science, technology, and society. These learning resources reflect many goals of science education, such as the understanding of the nature of science, proficiency in inquiry, competence in using technology, appreciation of science, attitudes towards science, and great scientific decision making [16]. Furthermore, the purpose of science learning is to nurture curiosity; grow the focus on science, social, economic, and religious environment learning; while also developing thinking, communication, investigation, and creative skills. A reformation and teacher empowerment is required to replace the current science teaching procedures in schools [17, 18]. Besides, science textbooks should support the development of students' scientific literacy by providing a balanced representation of science [19].

Students' scientific and technological understanding, skills, attitudes, and are very important [20]. Thus, they should use science textbook that contains aspects of good scientific literacy. A good textbook connects the material with scientific research as well as the current development of science, technology, and society, highlighting the use of science in human life [21]. Good science textbook has scientific literacy aspect ratio of 2:1:1:1, with 40% for the category of knowledge as the body of science, 20% for the investigation of the nature of science, 20% for the category of science as a way of thinking, and 20% for the interaction of science, technology, and society [22].

Textbooks should properly contain balance aspects of scientific literacy. Scientific literacy mainly focuses on facts, concepts, principles, laws, theories, models, and hypotheses. Besides, it also includes a sense of belief, curiosity, imagination, thinking, understanding of cause-and-effect relationships, self-assessment, objectivity, and open-mindedness towards discovery. These aspects facilitate the use of several approaches in constructing knowledge [23]. Furthermore, textbooks essentially encourage students to investigate, where they are directed to think about phenomena or situations that happened, respond to questions, or collect information [16]. Generally, science textbooks significantly affect science education in schools, so that textbook that emphasizes scientific literacy can better facilitate an understanding of scientific phenomena and concepts [24].

However, recent studies revealed that many textbook writers have not properly involved the scientific literacy aspect in the textbook content. Current science textbooks are mostly used by teachers in explaining knowledge, and involving students in the problem-solving process [8, 25]. The presentation of science as knowledge and interaction of science, technology, and textbook society is still contrasting [26, 27]. Studies that investigate science textbooks, such as the physics, chemistry, and electronic textbooks, discover that the science textbooks tend to emphasize the aspects of science as the body of knowledge, by providing facts, concepts, principles, laws, theories, and models, as well as emphasize that students can remember information through questions. Meanwhile, the aspects of science as a way of investigation, science as a way of thinking, and the interaction of science, technology, and society are not yet fully discussed in the textbook [28–33].

Similarly, the questions provided in the textbooks mostly only represent the aspects of science as a body of knowledge. As a result, science textbooks always encourage students to memorize [34, 35]. Furthermore, the topic of Science-Technology-Society-Environment remains inadequate discussed in the textbook, obstructing students' scientific literacy skills development [1, 36]. Additionally, in the rural area of Indonesia, the students have minimum access to electronic textbooks due to the limited telecommunication networks [30].

Most research explores the improvement of scientific literacy using the proper learning approaches [37], strategies [2], methods [38, 39], and learning models [40–45]. Meanwhile, the presence of great textbooks is also essential in scientific literacy learning. There is a limited number of studies that assess and investigate the scientific literacy of a textbook. Even with a great learning approach, strategy, method, model which enhances the interaction between teachers and students, a textbook that contains all aspects of scientific literacy is still required to enhance students' scientific literacy. Therefore, a scientific literacy instrument evaluation to measure aspects of scientific literacy is required, especially in science textbooks [46].

Thus, this study comprehensively investigates aspects of scientific literacy in Biology textbooks to find out how many aspects of scientific literacy are contained in the book. Theoretically, it is important to examine the ability of the teaching aid to present the right information to students [13]. Although various studies in various indicator domains have been carried out to improve scientific literacy for teachers and students, studies that investigate the teaching materials have not been carried out. Therefore, an independent evaluation of the textbooks should be carried out [25].

This evaluation is very beneficial for teachers and lecturers in developing Biology textbooks in the future by properly involving the balanced aspects of scientific literacy.

2 Methods

Design and Objects of Research

This research is a quantitative descriptive study using content analysis method, namely analyzing the contents of documents in Biology textbooks. This analysis aims to see how far the aspects of scientific literacy in the book Biology in Indonesia are. The object of this research is a biology textbook used at the high school level in Indonesia. A total of seven Biology textbooks used in class XI of senior high schools in Indonesia were analyzed based on the results of our initial survey and presented in Table 1.

Table 1. The analyzed Class XI Biology book

Book	Title	Publisher	Year	Pages
Book A	Biology Student Book for Senior High School Specialization in Mathematics and Natural Sciences *(Buku Siswa Biologi untuk SMA/MA Peminatan Matematika dan Ilmu-ilmu Alam)*	Mediatama	2014	296
Book B	Biology for Class XI of Senior High School	Yudhistira	2018	398
Book C	Biology Student Book for Senior High School 2013 Curriculum Specialized for Mathematics and Natural Sciences Majors *(Buku Siswa Biologi untuk SMA/MA Kurikulum 2013 yang Disempurnakan Peminatan Matematika dan Ilmu-ilmu Alam)*	Erlangga	2016	318
Book D	Biology Student Book for Class XI of Senior High School	Intan Pariwara	2016	388
Book E	Exploring the World of Biology for Senior High School Specialized for Mathematics and Natural Sciences Majors *(Menjelajah Dunia Biologi untuk SMA/MA Peminatan Matematika dan Ilmu Alam)*	Platinum	2017	258
Book F	Biology for Senior High School Students Specialized for Mathematics and Natural Sciences Majors	Yrama Widya	2016	294
Book G	Biology for Class XI of Senior High School Specialized for Mathematics and Natural Sciences Majors	Quadra	2014	336

Research Instruments

The instrument used was a questionnaire for assessing aspects of scientific literacy in Biology textbooks using Likert Scale. The scientific literacy indicators measured in this study followed the indicators used in previous studies [13, 16, 23]. Those indicators are presented in Table 2.

Data Collection Technique

The data collection technique in this study was using the observation method by conducting a direct analysis of the aspects of scientific literacy in 7 Biology textbooks for high school in Indonesia. The analysis was carried out by two expert observers in the field of education using scientific literacy assessment questionnaires in textbooks. The contents of the textbooks analyzed were taken from all the material in each textbook. The analysis was carried out by; reading, observing, and understanding the elements of the text contained in the textbook. The analysis was also carried out on paragraphs of material for each chapter, pictures, tables, descriptions, opinions and short questions in each Biology textbook. The forms of investigation steps in the laboratory or direct activities in Biology textbooks are also analyzed completely [16]. The part that was not

Table 2. Indicators of Scientific Literacy Aspects in Textbooks

No	Indicators	Sub indicators
1	Science as a body of knowledge	a. Present scientific facts, concepts, principles, and laws b. Present scientific hypotheses, theories, and models c. Ask students to remember knowledge or information
2	Science as a way of thinking	a. Require students to answer questions through the use of materials b. Require students to answer questions through the use of charts, tables, and so forth c. Require students to make calculations d. Require students to explain answers e. Involve students in experiments or thinking activities
3	Science as a way of investigation	a. Describe how a scientist performs an experiment b. Show the historical development of an idea c. Emphasize the empirical nature and objectivity of science d. Illustrates the use of assumptions e. Show how science works with deductive and inductive considerations f. Provide a cause-and-effect relationship g. Discuss facts and evidence h. Present scientific methods and problem-solving
4	Interaction of science, technology, and society	a. Describe the usefulness of science and technology for society b. Show the negative effects of science and technology on society c. Discuss social problems related to science or technology d. Mention careers and jobs in the field of science and technology

analyzed is a page that only contains questions, reviews, vocabulary, and includes learning objectives and suggestions. The results of the analysis by the two expert observers were put in the science literacy assessment sheet for the Biology textbook.

Data Analysis Technique

Data analysis in this study used descriptive analysis. The obtained data were the results of the assessment of science literacy in biology textbooks for high school in Indonesia. The

Table 3. Criteria for Coefficient of Agreement for the Textbooks Observers

Interval	Criteria
0.81–1.00	very good
0.61–0.80	good
0.41–0.60	Pretty good
0.21–0.40	not good

Table 4. Criteria for Percentage of Biology Book Science Literacy Assessment Results

Interval (%)	Criteria
85% < X ≤ 100%	Very good
75% < X ≤ 84%	Good
60% < X ≤ 74%	Pretty good
25% < X ≤ 59%	Not good

results of the scientific literacy assessment in each biology textbook were determined to find out the reliability of the Kappa value which is the coefficient of agreement between two observers (P1 and P2) using the Cohen's Kappa formula. Results of the observation agreement coefficient were interpreted based on Landis & Koch (1977) presented in Table 3.

$$KK = \frac{P_0 - P_e}{1 - P_e}$$

Information:
KK = Observation agreement coefficient
Po = Proportion to the frequency of agreements
Pe = Possible agree

After finding out the agreement criteria of 2 observers, the data was then analyzed by calculating the percentage of the results of the scientific literacy assessment. The percentage result is intended to find out how much the percentage of the scientific literacy level in the Indonesian Biology textbook. The percentage of the results of the assessment of scientific literacy aspects from 2 observers was then interpreted based on the criteria contained in Table 4.

3 Results and Discussion

1) The textbooks used in the study are selected based on the prevailing curriculum in Indonesia and the most widely used in senior high schools. The content analysis on the most frequently used biology book included the analysis on their paragraphs, pictures, tables, short comments, questions, laboratory steps, and activities instruction.

The Kappa Test (KK) results and the average score of scientific literacy from 7 Biology textbooks for Senior High schools in Indonesia were obtained from 2 educational

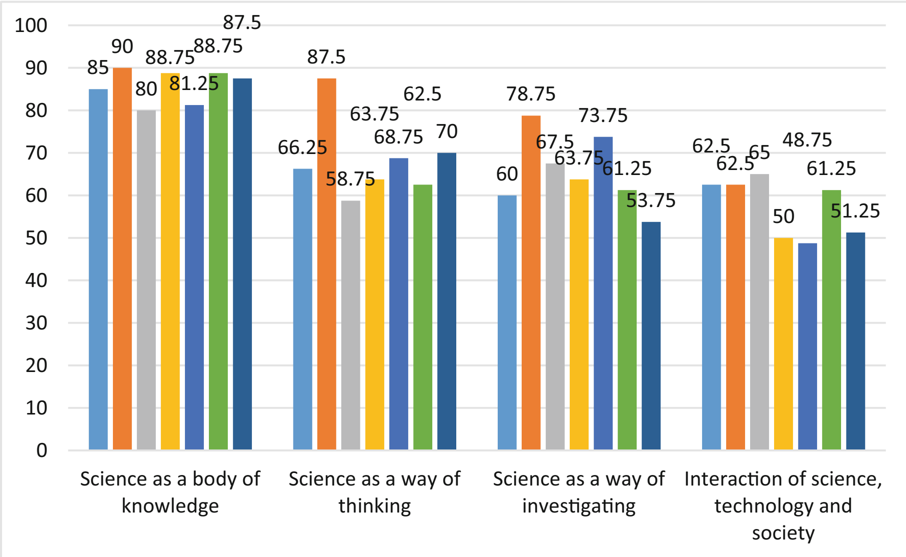

Fig. 1. Science Literacy Aspects in Indonesian Biology Textbooks

expert observers. The results show that science as a body of knowledge has the highest percentage, compared to the aspect of science as a way of thinking, science as a way of investigating, and the interaction of science, technology, and society, as presented in Fig. 1.

Science as a body of knowledge aspect attain KK value of 0.67, with a percentage of 85.89%, indicating that this aspect has been properly and sufficiently included in the textbook. Science as the body of knowledge aspect is presented in biology knowledge content. More than 80% of facts, concepts, principles, hypotheses, theories, and models are presented in the seven biology textbooks samples. It signifies that in textbooks scientific findings are found as facts of knowledge. The textbooks also present the findings from a large number of extraordinary biological scientists [48]. Theoretical knowledge is practiced and adopted in daily life so that learning can be easier and more concrete, allowing the transformation of theory into practice [49]. Therefore, scientific literacy can also be improved as a whole, one of which is through scientific information literacy in the form of learning or scientific discoveries [50].

The aspect of science as a way of thinking in biology textbooks obtained a KK score of 0.73, with a percentage of 68.21%, signifying that the coverage of this aspect within the textbooks can be classified as sufficiently good. One biology textbook has excellent coverage of this aspect, while the other six textbooks only present adequate inclusion. Science as a way of thinking aspect guide students' way of thinking. The textbooks are observed to provide great questions through the use of materials, charts, and tables, while asking students to make calculations, asking to explain answers, and involving students in experiments or thinking activities. This is in accordance that the variety of teaching materials that should be used in the learning process, consisting of textbooks containing reading and writing exercises and various choices for students especially regarding knowledge, reasoning, observation, and investigation, activities [51]. The encouragement of scientific literacy has good effects in the long term [2].

The science as a way to investigate aspects obtain a KK score of 0.55; with a percentage of 65.54%, representing that the textbook adequately good coverage of this aspect. Only book B sample that has good coverage of science as a way to investigate. Meanwhile, Book G has sufficiently good coverage since it provides less content that directs students to the investigation process. Good scientific literacy requires a process of investigation in learning, directed in the textbook [2]. In scientific literacy, the application of laboratory-based inquiry is important because it creates more practical, experiential, affective, and sustainable learning [49].

The aspect of the interaction of science, technology, and society obtain KK results of 0.60, with a percentage of 57.32%. This shows that the coverage of science, technology, and social interaction aspect in Indonesian biology textbooks is poor. The D, E, and G samples even present below 60% coverage on this aspect. This is because the currently used biology textbooks provide minimum discussion on the science usefulness, negative effects and positive, social problems, careers, and jobs related to science and technology, as well as the newest information. Therefore, the aspect of science, technology, and society in the biology textbook should always be updated following the development of science and technology. The lack of information on science, technology, society, and the underlying conceptions of science and technology, may hinder the continuation of scientific literacy [36].

Scientific literacy is a better standard in measuring students' inquiry abilities, especially in the formation of conclusions [2]. Elements of strong scientific literacy in the renewal of teaching materials for students have a significant positive impact on learning outcomes [52]. The non-optimal selection of learning sources will affect students' science achievement, resulting in low scientific literacy skills [53]. On the other hand, if students have reached the stage of understanding science, the development of science, and their interaction in everyday life, literacy skills will also be built [8].

Interestingly, the aspect of scientific literacy, technology, and society attain the smallest percentage, compared to the three other aspects. This is caused by the uneven availability of facilities and technology in Indonesia [54], followed by a minimum learning process based on science, technology, engineering, mathematics (STEM) [55]. STEM integrates all aspects and is the solution in the real world. So it is necessary to explicitly integrate STEM with curriculum standards, learning process, and learning content [56]. Besides, language is very important in the structure of science and forms the construction and communication of scientific ideas. Science language is the integration of text, visual images (such as diagrams, pictures, graphs, maps, tables, graphs), and mathematical expressions (numbers and equations) [57, 58]. The difference between the visual images comprising the PISA and the textbook assessment items according to the dimension of the visual frequency of inclusion in the PISA and the textbook items, their type (such as photos, diagrams, tables). For instance, the visual images serve as concrete representations of verbal descriptions display redundant information for the relevant question to graphics providing the partial information insufficient to answer questions. Examples of required response formats are graphic, or table completion, visual cues, free graphic response, verbal or numeric response [57].

In the teaching material evaluation, the analysis was carried out separately on each indicator to cover all indicator domains. As a result, competency indicators should always be supplemented with more engaging materials (learning resources) and learning methodologies that incorporate the most up-to-date material content. This is because different domains have different learning materials and methodologies [59]. In a textbook, images can visually express scientific claims independently of the text, while their wide variety and origins require an assessment of the way they are currently used to justify scientific claims in a particular scientific field. Likewise, given the differences, like the images, analysis is needed to determine on which side the philosophical differences between the data and phenomena of these different types of images fall. Although some in the textbooks contain images and repeated texts to make them appear as the main source [60]. Students are interested in the role of images as a source of training and knowledge production in scientific disciplines [57].

Textbooks used to support science teaching in high schools must provide a balance of the four aspects of scientific literacy. Therefore, an improvement that focuses on high school science textbooks based on science literacy needs to be carried out [26]. The teachers need to be trained to choose teaching materials and science literacy points considered in selecting textbooks for students. Besides, teachers are also at the forefront of students' scientific literacy development. Meanwhile, the government as a centralized policymaker should focus primarily on policies that increase equity in education [61]. Through textbooks, it is hoped that they can contribute to designing the social future of students, because the main purpose of textbooks is to provide knowledge content and cultivate practices for readers as well as the values of certain disciplines [62].

The education experts must continue to enhance the quality of teaching materials to improve scientific literacy in Indonesia. The improvement of teaching materials in Indonesia must be carried out continually following the recent curriculum in Indonesia to achieve the national education goals.

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The education experts must continue to enhance the quality of teaching materials to improve scientific literacy in Indonesia. The improvement of teaching materials in Indonesia must be carried out continually following the recent curriculum in Indonesia to achieve the national education goals.

4 Conclusion

According to the obtained data, the scientific literacy coverage in high school biology textbooks in Indonesia has been categorized as good in the aspect of science as the body of knowledge and adequately good in the aspect of science as a way of thinking and investigating. However, the textbooks have poor coverage on the aspects of the interaction of science, technology, society. It is necessary to revise and improve the high school biology textbooks following the aspects of scientific literacy. Indicators of scientific literacy in biology textbooks in Indonesia have recently been updated to support the current curriculum in Indonesia. Therefore, updates are also required on the content, context, and process of biology textbooks, especially on every aspect of scientific literacy. The revision in the interaction of science, technology, and society is urgently required since this aspect follows the progress of the current era. Collaboration of education experts with education practitioners, supported by the Indonesian ministry of education, culture, research, technology, and higher education, is needed to design textbooks that have better aspects of scientific literacy.

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