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Developing a Comprehensive Assessment Tool for Elementary Students' Scientific Literacy

Hafiziani Eka Putri*
*Elementary School Teacher Education Study Program, Purwakarta Campus,
Universitas Pendidikan Indonesia, Indonesia
E-mail: hafizianiekaputri@upi.edu

Fitri Nuraeni**
**Elementary School Teacher Education Study Program, Purwakarta Campus,
Universitas Pendidikan Indonesia, Indonesia
E-mail: fitrinuraeni@upi.edu

Nenden Permas Hikmatunisa***
***Elementary School Teacher Education Study Program, Purwakarta Campus,
Universitas Pendidikan Indonesia, Indonesia
E-mail: nendenpermas17@upi.edu

Ravy Hun****
******Battambang Teacher Education College, Cambodia
E-mail: hun.ravy.btec@moeys.gov.kh

Salis Elmadani*****
*******Elementary School Teacher Education Study Program, Purwakarta Campus,
Universitas Pendidikan Indonesia, Indonesia
E-mail: saliselmadani15@upi.edu

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Abstract

Scientific literacy embodies the essential scientific knowledge and skills that students require for comprehending and applying scientific concepts in their daily lives. This study aimed to design an assessment tool for gauging elementary school students' scientific literacy. Adopting the Research and Development (R&D) approach, this study incorporates a 3D (Define, Design, and Develop) framework. The scientific literacy indicators devised encompass the ability to explain phenomena scientifically, evaluate and design scientific inquiry, and interpret data and evidence scientifically. The outcome of this research manifests as a Scientific Literacy Instrument comprising six open-ended questions accompanied by alternative answer schemes. The appropriateness of all items demonstrates a moderate level of validity. The reliability of the test items indicates a commendable degree of consistency. The complexity of the questions ranges from moderate to challenging. The discriminating power of each item indicates a noteworthy level of differentiation. Thus, the scientific literacy assessment tool formulated in this study serves as an effective

means of evaluating students' scientific literacy in the context of elementary school science education.

Keywords: *instrument, scientific literacy, science learning.*

Abstrak

Literasi sains merupakan pengetahuan dan keterampilan ilmiah yang perlu dipahami dan diterapkan siswa dalam kehidupan sehari-hari. Tujuan penelitian ini adalah untuk mengembangkan instrumen kemampuan literasi sains yang dapat digunakan pendidik untuk mengukur kemampuan literasi sains siswa dalam pembelajaran sains di sekolah dasar. Metode penelitian yang digunakan adalah Research and Development (R&D) dengan desain 3D (Define, Design, dan Develop). Indikator literasi sains yang dikembangkan antara lain menjelaskan fenomena, mengevaluasi dan merancang pertanyaan, serta menafsirkan data dan bukti secara ilmiah. Penelitian ini menghasilkan Instrumen Kemampuan Literasi Sains yang terdiri dari 6 soal essay dengan alternatif kunci jawaban. Hasil perhitungan validitas seluruh item mempunyai interpretasi sedang. Reliabilitas soal tes mempunyai interpretasi yang baik. Tingkat kesukaran butir soal interpretasi sedang hingga sulit. Daya pembeda tiap item diartikan dari baik sampai sangat baik. Dengan demikian instrumen tes kemampuan literasi sains yang dikembangkan dalam penelitian ini dapat digunakan sebagai instrumen untuk mengukur kemampuan literasi sains siswa di sekolah dasar.

Kata kunci: *instrumen, literasi sains, pembelajaran sains*.

INTRODUCTION

Interpreting learning solely as the transfer of knowledge is overly restrictive. In reality, learning goes far beyond mere knowledge transfer, encompassing a wide array of cognitive, affective, and psychomotor domains (Emda, 2017; Nafiati, 2021; Nuriyah, 2016). Consequently, the desired outcome of contemporary education extends to developing well-prepared individuals to navigate the complexities of the Society 5.0 era. To thrive in this era, every student must acquire proficiency in at least five fundamental literacies: digital, numerical, written, scientific, and financial literacy. The attainment of these five essential literacies by students aligns with the objectives of elementary education as articulated by the government within the framework of the national literacy movement program (Kemendikbud, 2017).

Scientific literacy, among the set of five essential literacies, stands out as a competency that should be nurtured in early childhood. This literacy is essential not only for the emergence of industrial innovations but also for instilling a sense of responsibility and an awareness of environmental conservation. This is imperative since many impact of technological advancements lead to environmental degradation, such as emissions from vehicles contributing to air pollution and global warming, the conversion of land for housing reducing water catchment areas, textile waste resulting in water pollution, sand mining causes erosion, the use of pesticides leading to soil pollution, and various other forms of harm to the natural world (Gustina, 2016; Pratama & Parinduri, 2019; Putra, 2016; Rachmat & Pamungkas, 2014; Supriatna et al., 2021; Syaifulloh, 2021).

The cultivation of an early awareness regarding the importance of nature conservation can be achieved by incorporating scientific literacy education in elementary schools' natural science curricula. Science education is uniquely positioned to facilitate direct engagement

with the natural environment (Fahmi et al., 2021). According to DeBoer (as cited in Mawarni, 2017) Paul de Hart Hurt, the pioneer in defining the term "scientific literacy," explained that it encompasses endeavors to enhance one's comprehension and application of scientific knowledge in everyday life. This concept of scientific literacy extends beyond prescribed curricular content, placing a significant emphasis on the ability to employ acquired knowledge in addressing real-life challenges. Consequently, adopting scientific literacy education yields multifaceted benefits, enhancing various aspects of student development, particularly in terms of scientific literacy, and empowering students to make meaningful contributions to the progress of society (Jenice & Downey, 2013; Setiawan, 2020).

The importance of instilling scientific literacy in elementary school science education cannot be overstated. The abilities students develop during elementary school serve as the building blocks for their future educational levels (Mardhiyyah et al., 2016). Pestel & Engeldinger (as cited in Situmorang, 2016) emphasize the significance of scientific literacy by highlighting its sustainable learning outcomes involving continuous and ongoing actions. Nevertheless, in reality, this role has yet to manage to capture the full attention of the entire academic community. This fact is evidenced by Indonesia's 2018 PISA (Program for International Student Assessment) ranking, where it placed 73rd out of 79 countries with a score of 396, falling below the OECD (The Organization for Economic Co-operation and Development) average of 489 in the field of scientific literacy. In 2018, only about 40% of Indonesian students could, at a minimum, recognize and explain scientific phenomena, a percentage that falls well short of the OECD's 78% average. Furthermore, while some high-achieving students can apply their understanding to various contexts, their proportion needs to be bigger to warrant significant attention (OECD, 2019). The outcomes of the 2021 AKMI (Indonesian Madrasah Competency Assessment), conducted by the Ministry of Religion, underscore that students' scientific literacy abilities are still low (Ditjen Pendis, 2021).

Scientific literacy encompasses three distinct domains, as outlined by the (OECD, 2017): 1) Context: revolves around the capacity to remember and apply scientific knowledge in various contexts, such as recognizing and formulating explanations, making predictions or explanatory hypotheses, and engaging in discussions about possibilities; 2) Knowledge: involves the ability to distinguish between questions that can be scientifically investigated and those that cannot; and 3) Competence: pertains to the skill set required for scientifically explaining natural phenomena, assessing and crafting scientific inquiries, and interpreting data and evidence using a scientific approach. Measuring proficiency in these three domains of scientific literacy is not solely the responsibility of official OECD institutions; it can also be achieved straightforwardly by teachers in the classroom. They can develop assessments of students' scientific literacy using test questions, which can be teacher-created tests. As pointed out by Calongesi (as cited in Segara, Utami, & Marzuqi, 2021), tests are a planned means of evaluating students' progress in achieving learning objectives. Given the importance of these assessments, tests must possess certain qualities. Arikunto (as cited in Sepriyanti, Jannah, & Sari, 2018) notes that the characteristics of a well-constructed test include validity, reliability, cost-effectiveness, practicality, and objectivity.

All things considered; it becomes evident that scientific literacy skills are significant for elementary school students. However, research findings reveal that, in practice, these abilities remain at a rather modest level. This might be due to lack of assessment instruments and

practices that are oriented to scientific literacy indicators. In addition, currently most teachers still have difficulties in constructing assessments to examine students' scientific literacy and higher order thinking skills. One contributing factor to solving this limited proficiency is more available instruments for assessing scientific literacy (Ditjen Pendas, 2021; OECD, 2017). However, the availability of such instruments is still limited to higher grade such as TOSLS Cognitive Instrument for undergraduate degree (Pratiwi et al., 2023), ALCE instrument for ninth-grade students (Coppi et al., 2023), and some other focus more to learning models to improve scientific literacy (Maghfiroh et al., 2023); Putra et al., 2023); Rusmansyah et al., 2023). Consequently, we conducted a study to create an instrument tailored for evaluating the scientific literacy competencies of elementary school students. The objective is for educators to subsequently employ this instrument to enhance the scientific literacy aptitude of elementary school students.

The primary aim of this research is to design a test tool that educators can utilize to gauge students' scientific literacy skills within the context of science education in elementary schools. This scientific literacy assessment instrument, in this study, focuses primarily on ecosystems, a topic covered in the curriculum for fifth-grade students. An ecosystem is a natural system arising from the interplay between living organisms (biotic) and non-living elements (abiotic) within their environment (Bariyah & Sugandi, 2022; Effendi et al., 2018). By delving into the study of ecosystems, it is anticipated that students will not only acquire a deeper understanding of science but also develop the capacity to apply this knowledge to address everyday challenges, which extend to interactions among individuals, living organisms, and non-living components in their surroundings.

METHODS

In this study, the research approach employed is Research and Development (R&D). According to Sugiyono (2022), R&D is a research method that serves the purpose of generating and evaluating the effectiveness of various products. The R&D model applied in developing this assessment tool follows a 3-D framework. This 3-D model comprises three phases: define, design, and develop (Rosidi et al., 2018).

During the define stage, the research team conducted investigations, observations, and interviews to gather preliminary data. Subsequently, in the design phase, the researchers created scientific literacy assessment instruments. The overarching goal of this research is to create a product for assessing the scientific literacy skills of fifth-grade elementary school students focusing on the theme of Ecosystems.

The initial data collection method commenced with interviews with elementary school science teachers. The interviews include teacher's perceptions about scientific literacy and its assessments. To dig deeper into the initial condition, the interviews also aim to identify teachers' difficulties in measuring students' scientific literacy. According to data obtained through interviews, the item test is constructed following scientific literacy indicators (OECD, 2017) that are relevant to Ecosystem theme. The indicators can be seen on Table 1.

Subsequently, expert judgment was conducted to obtain insights and examine the test instruments. This validation process involved using validator questionnaires and trial runs of the assessment tools. Expert judgment is a crucial validation technique in research and development (U.S. Congress, Office of Technology Assessment as cited in Sugiyono, 2013).

Validation for the development of this scientific literacy assessment tool was undertaken by a science education lecturer at Esa Unggul University and a senior fifth-grade teacher at a public elementary school in Purwakarta that has teaching experience more than twenty years.

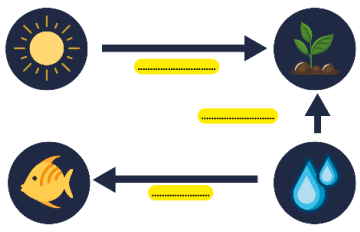
Data analysis involved both qualitative and quantitative techniques. Qualitative data analysis assessed the initial information gathered through interviews, providing insights into the field conditions and the requirements for suitable test instruments. Quantitative data analysis encompassed the examination of validation sheets and instrument test results using ANATES 4.0 software. The testing phase involved sixth-grade elementary school students, given their prior exposure to ecosystem topics.

RESULTS AND DISCUSSION

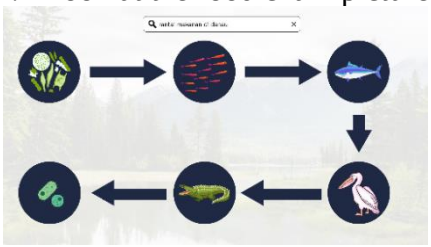
During the initial phase, referred to as the "define" stage, we acquire preliminary insights by conducting teacher interviews. The outcomes of these interviews reveal the following: 1) teachers in schools commonly employ a lecture-based approach and question-and-answer sessions in their science instruction, thus failing to utilize student-centered learning activities fully; 2) the assignments provided to students consist exclusively of textbook questions, which do not sufficiently address the enhancement of students' scientific literacy; 3) teachers occasionally introduce examples related to ecosystems; and 4) following the instruction on ecosystems, there is no substantial improvement observed in students' scientific proficiency. Consequently, there is a pressing need to create assessment tools to elevate students' scientific literacy skills. These instruments should incorporate a variety of questions, moving beyond sole reliance on textbook-based queries.

During the second phase, referred to as the "design" stage, we formulate the instrument product, which will take the form of seven descriptive questions by the indicators of scientific literacy. The primary topic covered pertains to ecosystems and encompasses various aspects, including 1) grasping the concept of ecosystems; 2) categorizing animals based on their dietary habits; 3) understanding animal life cycles; 4) comprehending food chains; 5) exploring symbiotic relationships; and 6) assessing ecosystem equilibrium. In this stage, a correlation is established between the competency indicators for scientific literacy abilities, Bloom's taxonomy, and the formulated questions. The details of this correlation are presented in Table 1 below.

Table 1. Mapping of Scientific Literacy Indicator, Bloom's Taxonomy, and Test Items

Test Item Number	Scientific Literacy Indicator	Indicator Description	Question
1&2	Explain phenomena scientifically	Scientifically describe phenomena and predict potential changes that may occur. (C3)	1. Look at the picture below!  Complete the diagram above by labeling the roles of ecosystem components

<table>
<tr><th>Test Item Number</th><th>Scientific Literacy Indicator</th><th>Indicator Description</th><th>Question</th></tr>
<tr><td></td><td></td><td></td><td>correctly. Next, explain what might happen if the water component in the picture above is missing!

2. Look at the food chain picture below!
 
Among the six components, which are producers, consumers I, consumers II, consumers III, consumers IV, and decomposers? Then explain in detail the meaning of the picture above!</td></tr>
<tr><td>3&4</td><td>Interpret data and evidence scientifically</td><td>Understand the type of data and evidence to make conclusions. (C4)</td><td>3. Look at the table below!
<table><tr><th colspan="3">Cases of Fish Deaths in Jatiluhur</th></tr><tr><th>Year</th><th>Weight of Dead Fishes</th><th>Loss</th></tr><tr><td>2006</td><td>3,500 ton</td><td>3.5 billion</td></tr><tr><td>2022</td><td>80.5 ton</td><td>unknown</td></tr></table>a. Based on existing data, have cases of mass fish deaths decreased from 2006 to 2021? Include the reasons!
b. Based on existing data, what is the comparison of losses from mass fish deaths in 2006 to 2021?
4. Look at the picture below!
 
Image A is the skull of a plant-eating animal, while image B is the skull of a meat-eating animal. Based on this explanation, answer the following questions correctly!
a. Based on the type of food, what category does the animal in picture A belong to? Also explain the shape and function of the teeth!
b. Based on the type of food, what category does the animal in picture B</td></tr>
</table>

<table>
<tr><th>Test Item Number</th><th>Scientific Literacy Indicator</th><th>Indicator Description</th><th>Question</th></tr>
<tr><td></td><td></td><td></td><td>fall into? Also explain the shape and function of the teeth!</td></tr>
<tr><td>5, 6 & 7</td><td>Evaluate and design scientific inquiry</td><td>Distinguish between scientific and non-scientific questions (C5)</td><td>5. Look at the table below showing the data obtained from the experiment results of the abiotic components in a natural terrestrial ecosystem.
<table>
<tr><th>No</th><th>Abiotic Component</th><th>Condition</th></tr>
<tr><td>1</td><td>Temperature</td><td>28^{o} C</td></tr>
<tr><td>2</td><td>Light</td><td>Sufficient</td></tr>
<tr><td>3</td><td>Wind</td><td>Breezy</td></tr>
<tr><td>4</td><td>Soil</td><td>Wet</td></tr>
<tr><td>5</td><td>Water</td><td>Lack</td></tr>
</table>
Based on the data in the table above, which results of abiotic components need to be more accurate? Moreover, what should the results of the measurement be? Include the reasons!
6. Read the dialogue below!
Dikta: "Father, where are we?"
Father: "We are at the Jatiluhur Reservoir, Dikta"
Dikta: "Father, look, something is coming out of that thing!"
Father: "That is called a cocoon, Dikta. The butterflies that fly up there come from cocoons."
Dikta: "How can a cocoon become a butterfly, father?"
Based on the dialogue above, answer the following questions correctly!
a. Which questions raised by Dikta are included in scientific questions? Explain why!
b. Which of the questions raised by Dikta is not a scientific question? Explain why!
7. Analyze the following text!
Jatiluhur Reservoir Water Quality
The main source of raw water for the DKI Jakarta area and its surroundings comes from the Jatiluhur Reservoir. As much as 85% of the raw drinking water supply for PDAM and PAM Jaya depends on the Jatiluhur Reservoir in Purwakarta, West Java. However, based on research entitled Water Quality Status of the Jatiluhur</td></tr>
</table>

Test Item Number	Scientific Literacy Indicator	Indicator Description	Question
			Reservoir and Threats to Vital Business Processes published in the Water Resources Journal Volume 12 of 2016 belonging to the Ministry of PUPR, the water quality in the Jatiluhur Reservoir has been seriously polluted. If water quality decreases, it will affect the reservoir ecosystem (Adharsyah, 2019). Design 2 scientific questions based on the text above!

Based on the information provided in the table above, in the third phase, referred to as the "develop" stage, there is a necessity to create a set of questions that spans from Lower Order Thinking Skills (LOTS) to Higher Order Thinking Skills (HOTS). The LOTS category encompasses C1 (remembering), C2 (understanding), and C3 (applying). On the other hand, the HOTS category encompasses C4 (analyzing), C5 (evaluating), and C6 (creating) (Rurisfiani et al., 2019).

Following the development of the scientific literacy assessment tool, content validation was conducted on November 29, 2022. This validation involved an expert in science education, Dr. Oktian Fajar Nugroho, M. Pd. Subsequently, on December 14, 2022, the assessment tool was presented to Mrs. Eva Erviena, S. Pd., a fifth-grade homeroom teacher at an elementary school in Purwakarta, for further validation. The instrument was also trialed on December 13-14, 2022, involving 27 sixth-grade students at a local public elementary school in Purwakarta. Quantitative data from these activities were processed using ANATES 4.0 software and are summarized in Table 2.

Table 2. The Results of Scientific Literacy Test Instrument

Item Number	Validation Score from Lecturer					Validation from Homeroom Teacher	Item Correlation	Item Significance	Test Correlation
	1	2	3	4	5				
1					V	suitable for use	0.612	Significant	0.53
2					V	suitable for use	0.340	-	
3					V	suitable for use	0.578	Significant	
4					V	suitable for use	0.653	Significant	
5					V	suitable for use	0.614	Significant	
6					V	suitable for use	0.646	Significant	
7					V	suitable for use	0.653	Significant	

Regarding the content, this assessment tool has undergone validation, and it has been confirmed that all items and question indicators align with a 100% matching rate, rendering it suitable for use. However, the validity test results indicate that one item, number 2, exhibited a correlation of 0.340, falling into the low category and lacking significance. As a result, the

researcher adjusted question number 2 and reevaluated the data. The outcomes of this data reprocessing are once again presented in Table 3 below.

Table 3. Validity of the Scientific Literacy Test

Item No.	Item correlation	Item significance	Test Correlation
1	0.587	Significant	0.58
2	0.600	Significant	
3	0.691	Significant	
4	0.603	Significant	
5	0.685	Significant	
6	0.685	Significant	

According to Guilford's coefficient distribution (as referenced in Putri et al., 2019), the final data from the validity test of the scientific literacy assessment tool, as shown in Table 3 above, reveals an overall correlation score of 0.58. This value demonstrates that the test validity falls within the sufficient category. Each test item displays varying validation correlation values, ranging from 0.587 to 0.691, all yield statistically significant test results. These values indicate that the validity of each item is categorized as medium. Subsequently, a reliability test was conducted on the scientific literacy assessment tool, yielding a reliability value of 0.74, signifying a high level of reliability (Mukti et al., 2023). These results from the reliability test also hold statistical significance at a 95% confidence level.

Furthermore, according to To's criteria for the instrument's difficulty index (Putri et al., 2019), the difficulty levels were assessed using ANATES 4.0 software. The results indicate varying degrees of difficulty, ranging from 28.57 to 50.00. Among the six questions, they span different levels of difficulty, including both medium and challenging levels. Regarding the classification of the questions' differentiating power coefficient, as per To (as cited in Putri et al., 2019), the test results for differentiating power vary between 32.14 and 64.29, categorizing them as having good and very good differentiating power. For a comprehensive breakdown of this data, please refer to Table 4.

Table 3. Difficulty Level and Discriminating Power of Scientific Literacy Test Instrument

Item	Difficulty Level		Discriminating Power		
Number	DL (%)	Interpretation	T	DP (%)	Criteria
1	50.00	Medium	3.54	35.71	Good
2	42.86	Medium	3.87	35.71	Good
3	58.93	Medium	6.35	39.29	Good
4	41.07	Medium	3.06	32.14	Good
5	28.57	Challenging	6.00	42.86	Good
6	32.14	Medium	4.50	64.29	Very Good

Scientific literacy represents one of the fundamental literacies that should be cultivated in students competencies. Scientific literacy encompasses three key domains: context, knowledge, and competence (OECD, 2017). It signifies that individuals with high scientific literacy not only possess comprehension but also can apply scientific principles to their daily

lives. In real-world scenarios, such individuals can effectively analyze and resolve problems when faced with them. It aligns with the concept that scientific literacy revolves around how students employ their knowledge to define phenomena and generate novel ideas and concepts when addressing scientific issues (Afriana et al., 2016; Wulandari & Solihin, 2016). The aspiration is that this capacity will furnish the means for enhancing human resources and the environment. Nevertheless, the AKMI results indicate that students' scientific literacy skills remain at a relatively low level (Ditjen Pendas, 2021).

Given this context, a test instrument has been developed to enable teachers to gauge students' scientific literacy achievements. An effective test must satisfy various criteria, including validity, reliability, an appropriate level of difficulty, and the ability to discriminate well between levels of proficiency (Arifin, 2017; Solichin, 2017; Suwarto, 2022). This instrument has undergone validation by expert lecturers and elementary school teachers. Moreover, it has been used in trial run with students, yielding the following outcomes. The validity test demonstrated a correlation value ranging from 0.587 to 0.691, signifying a moderate level of significance. This correlation value for validity test shows that this instrument is appropriate to use, because instruments have validity value between 0.4 to 0.8 (Qomariyah, 2023). The instrument exhibited high reliability, with correlation coefficients falling within the range of 0.70 to 0.90. High reliability shows that this instrument applicable to other situations and conditions.

The difficulty level varied from 28.57 to 50.00, placing the questions at an intermediate to challenging difficulty level. Question 5 falls under challenging category due to the questions asked by students to analyze various information given in the table, in which they are not familiar with this type of question. The questions displayed varying degrees of discriminating power, ranging from 32.14 to 64.29, achieving good and very good discrimination criteria. This finding implies that questions able to differentiate low, middle and high achiever students in terms of scientific literacy. Consequently, six out of the seven questions included in the assessment can effectively serve as instruments for evaluating the scientific literacy skills of elementary school students.

CONCLUSION

After processing and analyzing the results, it can be inferred that the scientific literacy test instrument focused on ecosystems aligns well with the intended indicators. It demonstrates moderate validity and high reliability. The test's difficulty level ranges from moderate to difficult, and its questions exhibit a discriminating power that varies between good and very good. Consequently, the scientific literacy assessment tool crafted in this study is suitable for adoption by educators and other researchers to assess the scientific literacy of elementary school students in the context of science education. On the other hand, this research has several limitations, such as the instrument is limited to ecosystem theme for fifth-grade elementary school level, therefore further research can develop scientific literacy instruments for other themes and grade level.

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