Scientific Literacy Profile of Prospective Science Teacher Students

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ABSTRACT

Objective: This research aims to describe and analyze the scientific literacy achievements of prospective science teacher students. Scientific literacy is one of the skills that prospective science teacher students must master to promote scientific literacy at the primary and secondary education levels. Method: This research is a quantitative descriptive research. Data was collected using a purposive sampling technique so that a sample of 65 students from the Bachelor of Science Education Study Program at Ganesha University of Education was obtained. The research instrument used was the Test of Scientific Literacy Skills (TOSLS) which consisted of 28 multiple-choice questions. This research is a preliminary study of research and development (R&D) of innovative science learning models to increase students' scientific literacy. Results: The results of the research show that the literacy achievement of prospective science teacher students is very low with the scientific literacy achievement in the aspect of identifying and assessing inquiry methods that contribute to scientific knowledge at very low and the aspect of compiling, analyzing, and understanding quantitative data and scientific information of very low. Novelty: This research provides an overview of the scientific literacy achievements of prospective science teacher students which can be used as a basis for developing innovative science learning models to increase the scientific literacy of prospective science teacher students.

INTRODUCTION

Various complex problems as a result of the rapid development of science and technology in this era of globalization require everyone to master 21st-century skills. Scientific literacy is identified as one of the 21st-century science skills (Hanifha et al., 2023; Lu-ong, 2023) which is very important to master because society is often faced with various problems related to science and technology in daily life (Kelp et al., 2023). According to Nuangchalerm, et al. (2022), scientific literacy is not only related to reading or writing skills but also related to the skills of knowing and understanding science and being able to communicate science. Scientific literacy refers more to what scientific knowledge people must master to live more effectively and be responsible (Al Sultan et al., 2021). Scientific literacy is more focused on the application of knowledge and skills in various situations to make decisions and solve problems in everyday life (Husamah et al., 2022; Sholahuddin et al., 2021).

Scientific literacy is a socially constructed concept that changes according to context and time so scientific literacy has various meanings (Čipková et al., 2020). There is no universally accepted definition of scientific literacy to date (Wang et al., 2024). Scientific literacy is the knowledge and understanding of scientific concepts and processes necessary for personal decision-making, participation in civic and cultural
affairs, and economic productivity. The Program for International Student Assessment (PISA) define scientific literacy as a skill possessed by reflective citizen to engage in issue and ideas related to science (OECD, 2019). There are two main aspects of scientific literacy, including the ability to identify and assess inquiry methods that contribute to scientific knowledge; and the ability to compile, analyze, and understand quantitative data and scientific information. A scientifically literate person can participate in scientific discussions as demonstrated through three scientific literacy competencies, namely: explaining phenomena scientifically, evaluating and designing scientific investigations, and interpreting data and evidence scientifically (OECD, 2019).

The progress of a country is largely determined by the level of scientific literacy among its citizens. Scientific literacy provides a strong foundation of knowledge for the citizens of a country and is the foundation for the country's progress in various areas of life. By mastering scientific literacy, citizens have a wider opportunity to adapt (Adnan et al., 2021) and be more aware and informed so that it is easier and more effective to make personal decisions in everyday life (Kelp et al., 2023; Mahardika et al., 2022; Ploj Virtič, 2022) and can solve various problems related to science and technology (Kahar et al., 2022; Yuliana et al., 2021). The role of scientific literacy is so important that it has become the primary objective of science education reform in various countries (Chang et al., 2024; Forbes et al., 2020) as well as a measure of the quality of a given education country (Dewi et al., 2021). Balitikian et al. (2024) emphasized the increasing importance of scientific literacy in today's dynamic world, making it a top priority for science education reform. Educators also agree that scientific literacy must be fostered as early as possible through science education to create scientifically literate citizens in the future (Cansiz & Cansiz, 2019). The scientific literacy achievements of Indonesian students are still low (Adnan et al., 2021; Mahardika et al., 2022; Rusmansyah et al., 2023). From the PISA report, it can be seen that the scientific literacy achievements of Indonesian students are always below the average PISA score, with a ranking in the bottom 10 (Sholahuddin et al., 2021). PISA 2022 data shows that the scientific literacy ability of Indonesian students has decreased from 396 in 2018 to 383 in 2022 (OECD, 2023). The low achievement of students' scientific literacy shows that the quality of Indonesian education still needs to be improved.

Many factors influence students' low scientific literacy skills, one of which is the teacher factor. This is closely related to the role of teacher reform as an important element in education (Al Sultan et al., 2021) as well as an agent of change in society (Sholahuddin et al., 2021). Teachers are key agents in facilitating students to develop scientific literacy skills (Adnan et al., 2021; Pahrudin et al., 2019; Suwono et al., 2022). Therefore, science teachers must have good scientific literacy, which allows them to be strongly involved in developing their students' scientific literacy (Fakhriyah et al., 2019; Sargioti & Emvalotis, 2020; Stylos et al., 2022). Teachers must continue to develop and improve their abilities to increase students' scientific literacy in the future (Wahab et al., 2023).

Preparing prospective science teachers who are well-literate is the main task of higher education so that graduates can later create innovative learning that supports the development of students' scientific literacy. With this argument, assessing the extent of the scientific literacy achievements of prospective science teacher students is very important. Several studies on the profile of scientific literacy of prospective teacher students in various regions of Indonesia have been conducted, which overall show that
their literacy skills are still low. The scientific literacy achievements of prospective physics teachers in Lampung are still low and need to be improved (Pahrudin et al., 2019); the average scientific literacy of prospective biology teachers in Palembang is 39.67 in the very poor category (Antika & Marpaung, 2023); and the achievements the scientific literacy of prospective elementary education teacher students in the city of Malang is 45.28% in the very low category (Muslihasari et al., 2023). 

The quality of science teaching has a significant impact on student performance, including their achievements in scientific literacy. Empirical studies of previous research show that students' low scientific literacy achievements are caused by science learning not being linked to real-life contexts and not starting from problems that exist in students' daily lives (Adnan et al., 2021). There are still many Biology teacher candidates who do not understand scientific concepts in depth (Antika & Marpaung, 2023). Meanwhile, AlAli & Wardat (2024) found that students already have sufficient theoretical skills and scientific concepts but still experience problems in explaining phenomena or problems well. The constructivism paradigm needs to be applied to increase students' scientific literacy (Adnan et al., 2021). Pahrudin et al. (2019) suggests getting students used to solving scientific literacy-based questions to develop the scientific literacy of prospective Physics teachers.

There has not been much research regarding the profile of scientific literacy among prospective science teacher students. Based on this explanation, this research aims to analyze the scientific literacy profile of prospective science teacher students. This research is very important to carry out as a basis for determining strategies for improving the quality of the learning process to increase the scientific literacy of prospective science teacher students. The results of this research contribute to providing valuable information regarding the literacy achievements of prospective science teacher students as a basis for consideration and contribution of thought to decision makers in an effort to improve the scientific literacy of prospective science teacher students.

**RESEARCH METHOD**

This research is quantitative descriptive research, namely a form of research that aims to explain or describe a condition as it is without manipulating or changing the independent variables. This research aims to describe the scientific literacy achievements of prospective science teacher students. The research is also preliminary research which aims to find the information needed to study problems properly (Wahab et al., 2023), especially those related to increasing the scientific literacy of prospective science teacher students. The research was carried out in the even semester of the 2022/2023 academic year at the Bachelor of Science Education Study Program, Ganesha Education University. The sampling technique used was purposive sampling to obtain a sample of 65 prospective science teacher students. The research flowchart is shown in Figure 1.
The instrument used to obtain student scientific literacy data is the Test of Scientific Literacy Skills (TOSLS), developed by Gormally et al. (2012), which consists of 28 multiple-choice questions. The results of the TOSLS trial conducted by Gormally et al. (2012) shows that TOSLS is valid and reliable as a scientific literacy diagnostic test. There are several considerations for using TOSLS as an appropriate instrument in this research, including TOSLS is easier to administer with coverage of literacy aspects that are considered broad, so it is suitable for use in various fields of science, and the results are more relevant to science education (Shaffer et al., 2019). TOSLS is also very adequate because its aim is not to assess the science content in a science course but rather to emphasize the application of scientific information and methods to solve the problems we face every day, so this test is very relevant to our understanding of scientific literacy (Čipková et al., 2020). The assessment of scientific literacy focuses more on two indicators: understanding inquiry methods that lead to scientific knowledge, which consists of four sub-indicators; and organizing, analyzing, and interpreting quantitative data and scientific information, which consists of five sub-indicators (Gormally et al., 2012). The indicators, sub-indicators, and question numbers used to measure each sub-indicator are shown in Table 1.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Sub-Indicators</th>
<th>Question Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Understand inquiry methods that lead to scientific knowledge</td>
<td>1. Identify valid scientific arguments.</td>
<td>1, 8, 11</td>
</tr>
<tr>
<td></td>
<td>2. Evaluate the validity of the source.</td>
<td>10, 12, 17, 22, 26</td>
</tr>
<tr>
<td></td>
<td>3. Evaluate the use and misuse of scientific information.</td>
<td>5, 9, 27</td>
</tr>
<tr>
<td></td>
<td>4. Understand the elements of research design and how they influence scientific findings and conclusions.</td>
<td>4, 13, 14</td>
</tr>
<tr>
<td>B. Organize, analyze, and interpret quantitative data and scientific information</td>
<td>5. Create graphs as data representations.</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>6. Read and interpret graphically represented data correctly.</td>
<td>2, 6, 7, 18</td>
</tr>
<tr>
<td></td>
<td>7. Solve problems using quantitative skills, including probability and statistics.</td>
<td>16, 20, 23</td>
</tr>
<tr>
<td></td>
<td>8. Understand and interpret basic statistics.</td>
<td>3, 19, 24</td>
</tr>
<tr>
<td></td>
<td>9. Justify inferences, predictions, and conclusions based on quantitative data.</td>
<td>21, 25, 28</td>
</tr>
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The test is carried out for 45 minutes in a classroom and is closely guarded. Students are not allowed to use any tools while taking the test. Students get a score of 1 if the
answer is correct and 0 if the answer is wrong or they do not answer. The scientific literacy scores obtained by students were then analyzed descriptively in a score range of 1–100 based on the following formula:

\[
\text{Student's Scientific Literacy} = \frac{\text{Correct Answer Score}}{\text{Maximum Score}} \times 100
\]

Students' scientific literacy achievements are grouped into several categories based on Arikunto's (2021) score interpretation criteria, namely very high (80–100), high (66–79), fair (56–65), low (40–55), and very low (30–39).

RESULTS AND DISCUSSION

Results

The scientific literacy achievements of prospective science teacher students were measured using the scientific literacy instrument developed by Gormally et al. (2012), which consists of 28 questions in multiple-choice form. The scientific literacy indicators measured are understanding inquiry methods that lead to scientific knowledge and interpreting quantitative data and scientific information. Each indicator consists of four sub-indicators and five sub-indicators. The scientific literacy achievements of prospective science teacher students for each indicator and sub-indicator are shown in Table 2.

Table 2. Recapitulation of scientific literacy achievements of science teacher prospective students.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Sub-Indicator</th>
<th>Average Score For Each Sub-Indicator</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Understand inquiry methods that lead to scientific knowledge</strong></td>
<td>1. Identify valid scientific arguments.</td>
<td>35.38</td>
<td>Very Low</td>
</tr>
<tr>
<td></td>
<td>2. Evaluate the validity of the source.</td>
<td>30.15</td>
<td>Very Low</td>
</tr>
<tr>
<td></td>
<td>3. Evaluate the use and misuse of scientific information.</td>
<td>47.18</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>4. Understand the elements of research design and how they influence scientific findings and conclusions.</td>
<td>38.46</td>
<td>Very Low</td>
</tr>
<tr>
<td><strong>Average Indicator A</strong></td>
<td></td>
<td>37.79</td>
<td>Very Low</td>
</tr>
<tr>
<td><strong>B. Organize, analyze, and interpret quantitative data and scientific information</strong></td>
<td>5. Create graphs as data representations.</td>
<td>43.08</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>6. Read and interpret graphically represented data correctly.</td>
<td>35.38</td>
<td>Very Low</td>
</tr>
<tr>
<td></td>
<td>7. Solve problems using quantitative skills, including probability and statistics.</td>
<td>33.33</td>
<td>Very Low</td>
</tr>
<tr>
<td></td>
<td>8. Understand and interpret basic statistics.</td>
<td>24.62</td>
<td>Very Low</td>
</tr>
<tr>
<td></td>
<td>9. Justify inferences, predictions, and conclusions based on</td>
<td>26.15</td>
<td>Very Low</td>
</tr>
</tbody>
</table>
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<table>
<thead>
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<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Indicator B</td>
<td>32.51</td>
<td></td>
<td>Very Low</td>
</tr>
<tr>
<td>Average Score</td>
<td>34.40</td>
<td></td>
<td>Very Low</td>
</tr>
</tbody>
</table>

quantitative data.

Overall, the scientific literacy achievements of prospective science teacher students are in the very low category, with an average score of 34.40. Students' scientific literacy achievement in the indicator of understanding inquiry methods that lead to scientific knowledge was 37.79 in the very low category, and organizing, analyzing, and interpreting quantitative data and scientific information was 32.51 in the very low category. Students' scientific literacy achievements for each sub-indicator are shown in Figure 2.

From Figure 1, it can be seen that the average score of students' scientific literacy achievement in all sub-indicators is below a score of 48 in the low and very low categories. Of the nine sub-indicators, only sub-indicator 3 (evaluating the use and misuse of scientific information) and sub-indicator 5 (making graphs to represent data) are in the low category, while the other seven sub-indicators are in the very low category or below a score of 40. Achievement of student scientific literacy The lowest science teacher candidate occurred in sub-indicator 8 (understanding and interpreting basic statistics) at 24.62 in the very low category, and the highest scientific literacy achievement occurred in sub-indicator 3 (evaluating the use and misuse of scientific information) at 47.18 in the low category.

Discussion
The scientific literacy achievements of prospective science teacher students were measured using the TOSLS instrument developed by Gormally et al. (2012), which focused on two aspects (indicators), namely understanding inquiry methods that lead to scientific knowledge and organizing, analyzing, and interpreting quantitative data.

Figure 2. Scientific literacy profile of prospective science teacher students.
and scientific information. There are nine components (sub-indicators) assessed in this instrument, as listed in Table 1.

The results of the descriptive data analysis show that the scientific literacy achievements of prospective science teacher students at Ganesha University of Education are still very low, with an average score of 34.40. This finding is in line with the findings of previous research, including that the average scientific literacy of prospective biology teacher students in Palembang is 38.67 in the very poor category (Antika & Marpaung, 2023) and the scientific literacy of prospective elementary education teacher students in Malang is still low with an average of 45.28% (Muslihasari et al., 2023). The scientific literacy abilities of prospective elementary education teacher students in Tuban are in a low category with scientific literacy achievements of less than 50% on all indicators. The results of this research are also supported by research conducted by Firdaus et al. (2023), which states that the scientific literacy abilities of prospective biology teacher students in Mataram are generally still low, and the scientific literacy achievements of prospective physics teacher students in Lampung are still not satisfactory and therefore need to be improved (Pahrudin et al., 2019).

The scientific literacy achievements of prospective science teacher students on the indicator of understanding inquiry methods that lead to scientific knowledge are still very low. This indicator is closely related to students' ability to carry out scientific criticism of experiments, data, and results to make decisions about unstructured problems that are common in science or the ability to analyze the strength of arguments based on evidence (Gormally et al., 2012) and basic skills that are necessary for a comprehensive understanding of scientific inquiry techniques and their application (Lu-ong, 2023). The low literacy achievement of students in understanding inquiry methods that lead to scientific knowledge shows that students are still unable to identify valid scientific arguments (very low), are still weak in evaluating the validity of sources (very low), are still unable to evaluate the use and misuse of scientific information (low), and do not understand the elements of research design and how they influence scientific findings and conclusions (very low). The low achievement of students' scientific literacy on the indicator of understanding inquiry methods that lead to scientific knowledge is supported by findings from Muslihasari et al. (2023), Antika & Marpaung (2023), and Adnan et al. (2021).

Students' scientific literacy achievements in the indicators of organizing, analyzing, and interpreting quantitative data and scientific information are also still in the very low category. The low achievement of students' scientific literacy on this indicator shows that students are not yet skilled in making graphs as data representations (low), are not skilled at reading and interpreting graphically represented data correctly (very low), are not yet able to solve problems using quantitative skills, including probability and statistics (very low), are still weak in understanding and interpreting basic statistics (very low), and are still having difficulty justifying inferences, predictions, and conclusions based on quantitative data (very low). These findings are in line with the results of research from Firdaus et al. (2023), namely that students are weak in the aspects of creating tables or graphs, justifying conclusions, predictions, and conclusions based on quantitative data, and solving problems using quantitative skills (including probability and statistics). This finding was confirmed by Muslihasari et al. (2023) and Antika & Marpaung (2023), who found that literacy achievement in the aspects (sub-indicators) assessed in the indicator of organizing, analyzing, and interpreting
quantitative data and scientific information was limited to the low and very low categories. Of the nine sub-indicators, the lowest scientific literacy achievement for prospective science teacher students occurred in the sub-indicator of understanding and interpreting basic statistics, with an average score of 24.63 (very low).

The low scientific literacy achievements of prospective science teacher students are closely related to the ongoing learning process, which has not supported the development of aspects of scientific literacy. Science learning that is only oriented toward the general context listed in textbooks or is only content-based (Sholahuddin et al., 2021; Zulirfan et al., 2023) and is not linked to real-life contexts (Adnan et al., 2021) causes students' weak understanding of inquiry methods and students' low ability to organize, analyze, and interpret quantitative data and scientific information. Due to the demands of exams that are only based on curriculum standards, lecturers tend to focus more on instilling scientific knowledge and rote learning (Wang et al., 2024). The absence of a clear connection between the material studied in class and real problems developing in society, including community culture, has an impact on students' low scientific literacy achievements (Chen & Liu, 2018; Ratini et al., 2018). The disconnection of material with environmental phenomena also causes students to have difficulty solving complex problems because complex problems cannot be separated from critical thinking and problem-solving skills (Fakhriyah et al., 2019).

The use of inappropriate learning models also has an impact on students' low scientific literacy achievements. As stated by Sholahuddin et al. (2023) the use of inappropriate learning strategies results in students' scientific literacy not being properly trained. The learning model applied so far has only focused on developing cognitive (textual) abilities (Sholahuddin et al., 2021). Teaching methods are still teacher-centered, so science learning becomes less meaningful (Nasor et al., 2023). The learning process begins with a material presentation and continues with class discussion. The lecturers presented several examples of problems in society related to science, but students were not encouraged to investigate until they found solutions to these problems (Sholahuddin et al., 2021).

Students are also not yet trained to solve problems based on scientific literacy. Students' ability to solve problems based on scientific literacy is very dependent on the ability of lecturers to facilitate learning in class (Adnan et al., 2021), namely by training students to solve problems based on scientific literacy (Wahab et al., 2023). Unfortunately, most of the problems given by lecturers so far have not been based on scientific literacy, so students are not used to solving problems based on scientific literacy (Fuadi et al., 2020). To increase students' scientific literacy, constructivist learning principles must be applied in the classroom (Adnan et al., 2021; Lu-ong, 2023). Scientific inquiry has become a fundamental aspect of science education reform worldwide (Teig, 2024). The inquiry-based learning model is a student-centered learning model that is widely applied to increase students' scientific literacy (Suwono et al., 2022). The inquiry-based learning model can create a dynamic learning environment that can increase students' understanding of scientific principles (Alqawasmi et al., 2024) and students are actively involved in authentic research cycles (Meulenbroeks et al., 2024). Adnan et al. (2021) emphasize that inquiry methods supported by innovative media and learning resources can increase students' scientific literacy. With inquiry-
based learning, students become more skeptical because they build new knowledge actively through group discussion activities (Wiyarsi et al., 2021). Several empirical studies have proven the effectiveness of inquiry-based learning to increase scientific literacy at various levels of education (Aditomo & Klieme, 2020; Adnan et al., 2021; Romero-Ariza et al., 2020; Suwono et al., 2022; Wang et al., 2022).

Contextual learning is a learning method that can develop students' scientific literacy by highlighting various scientific contexts and issues in the surrounding environment (Wahab et al., 2023). Learning scientific concepts in local culture and environment provides a more relevant and meaningful learning experience for students (Verawati & Wahyudi, 2024). Science learning in a popular context that is close to students' lives can increase scientific literacy (Zulirfan et al., 2023). One way is to learn science in a local cultural context. The cultural background of students or the community where the school is located greatly influences the learning process in the classroom (Lasmana, 2024). Integrating locally based knowledge in science learning allows students to interact with scientific inquiry (Uslan et al., 2024). Optimal use of local cultural traditions in the context of science teaching will make it easier for students to connect the science they learn in the classroom with what they see in everyday life (Chen & Liu, 2018), and science learning will become very interesting and personally relevant for students (Zidny & Eilks, 2022). Various empirical studies have shown that culture-based science learning has a positive impact on the development of students' scientific literacy (Dewi et al., 2019; Dewi et al., 2021; Heliawati et al., 2022; Yuliana et al., 2021; Zidny & Eilks, 2022). Thus, an inquiry-based learning model that utilizes local culture as a context for science learning will be more effective in increasing students' scientific literacy.

CONCLUSION

**Fundamental Finding**: The research results show that the literacy achievement of prospective science teacher students is very low, with scientific literacy achievement in the aspect of identifying and assessing inquiry methods that contribute to scientific knowledge of very low and the aspect of compiling, analyzing, and understanding quantitative data and scientific information of very low. Efforts to increase the scientific literacy of prospective science teacher students are very important. **Implication**: The low scientific literacy achievements of prospective science teacher students are caused by several factors, including the implementation of inappropriate learning models so that they do not facilitate the development of students' scientific literacy; local culture has not been utilized as a context for science learning, so that science learning has become less contextual; and there has been no training in problem-solving based on scientific literacy. **Limitation**: This research is limited to describing and analyzing the scientific literacy achievements of prospective science teacher students based on the TOSLS scientific literacy test with two scientific literacy indicators, namely understanding inquiry methods that lead to scientific knowledge and organizing, analyzing, and interpreting quantitative data and scientific information. **Future Research**: The research findings are useful for other researchers in determining interventions that should be implemented to train various aspects of scientific literacy and can be used as a basis for developing an innovative science learning model that can improve students' scientific literacy as a whole.
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