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Analysis of the Scientific Literacy Skills of Prospective Chemistry Teacher Students on Acid-Base Material

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Abstract: Scientific literacy skills are essential in the chemistry learning process, especially for prospective chemistry teacher students. Scientific literacy is one of the demands in 21st Century learning. The scientific literacy skills of prospective chemistry teacher students analyzed in this study are the knowledge aspect consisting of 3 sub-aspects, namely content, epistemic, and procedural. The purpose of this study was to determine the initial scientific literacy abilities of prospective chemistry teacher students in the knowledge aspect, especially in 3 sub-aspects, namely content, epistemic, and procedural. This study used a quantitative descriptive method. The sample in this study was 40 students of the Chemistry Education study program who were taken using a purposive sampling technique. The research instrument used was a scientific literacy test. The data collection technique used in this study was through a scientific literacy skills test based on the 2015 PISA Framework, which consisted of 15 questions that were tested on students. The scientific literacy test instrument related to the knowledge aspect was divided into 3 aspects, namely content, epistemic, and procedural, each aspect consisting of 5 questions. The chemical material tested in the science literacy test is acid-base material, because this acid-base material is a chemical material that still contains several abstract material concepts. The data analysis technique used in this study used a percentage formula and interpreted the average score of the test results according to the science literacy scoring guidelines. Based on the results of the study, the scientific literacy aspect of the knowledge of prospective chemistry teachers was divided into three parts, namely the content aspect with a medium category with an average score of 17.19%. In the epistemic aspect, the average score was 12.32% with a low category, and the procedural aspect with an average score of 12.65% with a low category.

Keywords: Science literacy, prospective teachers, chemistry, knowledge aspects.

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INTRODUCTION

The 21st century is marked by rapid advancements in science and technology. Based on this argument, it is evident that in the current era of the Industrial Revolution 4.0—characterized by extraordinary developments in internet technology—the world of education faces increasingly complex challenges. Education is one of the key sectors expected to produce human resources with full capacity to address various life challenges. One inevitable challenge faced by university students is the need to understand scientific facts and the interrelationship between science, technology, and society. Students who possess such knowledge and are able to apply it to solve real-life problems are referred to as scientifically literate students.

Scientific literacy can be defined as an individual's ability to understand science, communicate science (both orally and in writing), and use scientific knowledge to solve problems while demonstrating a high level of awareness and sensitivity toward themselves and their environment when making decisions based on scientific considerations (Uus Toharudin et al., 2018).

Scientific literacy is highly essential in the current era of globalization because education should focus on processes that prepare students to face the highly advanced modern age. This includes addressing environmental issues, the development of information technology, the integration of science and technology, knowledge-based economies, the rise of creative and cultural industries, shifts in global economic power, and the influence and impact of science-based technologies. In this context, mastery of reading, writing, mathematics, and scientific literacy requires special attention, particularly for prospective teachers. They need to possess strong scientific literacy skills so they can deliver content more deeply and cultivate scientifically literate students. In other words, learning activities should not be limited to managing knowledge, but should also emphasize learning and the application of knowledge.

Scientific literacy—or the application of knowledge in the learning process—in Indonesia, as measured by PISA (Programme for International Student Assessment), shows that Indonesian students' scientific literacy remains relatively low both nationally and internationally. The most recent data on Indonesian students' literacy ability in 2022 places Indonesia in 69th position or 12th from the bottom in the 2022 PISA rankings, with a total score of 1,108 comprising a math score of 366, a science score of 383, and a reading score of 359 (PISA, 2022). This clearly indicates that students' scientific literacy abilities are still relatively low.

In the process of teaching chemistry, researchers have yet to precisely identify which aspects contribute to the low level of scientific literacy. Therefore, in this study, the researcher aims to elaborate on the aspects of scientific literacy, which include context, epistemic, and procedural components. These three aspects were chosen so that students can not only comprehend theories, facts, and concepts but also apply their knowledge. This aligns with the scientific literacy knowledge domain in PISA, which seeks to assess the extent to which students can apply their knowledge in relevant contexts (Wulandari & Sholihin, 2016). The context aspect (application) emphasizes the ability to apply scientific concepts to solve everyday problems (Pertiwi et al., 2018). The content aspect involves activities such as discovering the key to understanding nature and its changes, and formulating questions to seek solutions through collaborative efforts.

Several factors contribute to students' low scientific literacy, including misconceptions about certain topics, a lack of interest and motivation in reading activities, abstract learning processes, and a lack of contextual learning. A prospective teacher must have strong scientific literacy skills because a teacher plays a crucial role in educating the nation's future generations. Teachers must be competent in helping students achieve success. One of the key competencies that must be developed is scientific literacy (Heryani et al., 2020). Therefore, learning approaches that enhance scientific literacy are essential. Without it, future generations of teachers will struggle to compete on a global scale.

Chemistry is still perceived as a difficult subject by many students, which is why every prospective chemistry teacher must have a strong grasp of scientific knowledge. One of the essential competencies for a chemistry teacher candidate is a high level of scientific literacy. Through scientific literacy, prospective chemistry teachers can apply chemistry in various fields of life, find solutions to problems, and make informed decisions to improve quality of life (Hendri & Hasriani, 2019). A teacher's understanding of scientific literacy is a key factor in enhancing students' scientific literacy, especially in chemistry learning. Hence, scientific literacy is a crucial requirement for prospective teachers to master.

One of the chemistry topics often perceived as difficult by many students is acid-base content due to its microscopic and abstract concepts (Sirhan G, 2007). As a result, students often experience misconceptions about acid-base concepts and there is a lack of interactive learning media to help teachers explain or visualize these abstract and microscopic ideas. This is evidenced by the fact that the level of scientific literacy among prospective science teachers remains low, especially in chemistry subjects.

For instance, a study conducted by Sumanik et al. (2021) analyzed the scientific literacy profiles of prospective chemistry education teachers, involving 22 students. The study assessed the knowledge aspect of scientific literacy divided into three components: (1) content aspect (N-gain = 0.37), categorized as moderate; (2) procedural aspect (N-gain = -0.10), categorized as low; and (3) epistemic aspect (N-gain = 0.24), also categorized as low. Overall, the knowledge aspect of scientific literacy was classified as low (N-gain = 0.228).

Another study conducted by Fadilah et al. (2020) analyzed the characteristics of scientific literacy abilities in the context of earthquake disaster knowledge among science education students in the procedural and epistemic domains. The study involved 70 students and found that their mastery of procedural and epistemic knowledge domains was very low, with scores of 38.18 and 19.12 respectively. In the procedural knowledge domain, students showed some understanding of determining variables but struggled with graphing and interpreting graphs. In the epistemic knowledge domain, students were relatively more competent in conducting analysis and making inferences.

Based on these findings, prospective teachers need to possess strong scientific literacy skills so that their students can also achieve high scientific literacy. Students should not only acquire knowledge but also develop critical thinking skills, problem-solving abilities, and character development. Therefore, this study aims to describe the initial scientific literacy ability of students in the Chemistry Education Study Program at UIN Ar-Raniry Banda Aceh. The results of this study are expected to provide an overview of the initial scientific literacy abilities of prospective chemistry teachers, allowing for an analysis of these abilities and the formulation of steps to improve the scientific literacy of future chemistry educators.

METHODS

This research employed a quantitative descriptive method, a form of research that explains or describes an event without manipulating or changing the independent variables, but rather depicts the situation as it is. Quantitative research provides more measurable information. Therefore, this study was conducted to describe students' scientific literacy skills as they exist. This research method also describes a form of research that describes, examines, and explains the existence of a study object and draws conclusions about an observable event using numbers. In quantitative descriptive research, only the content of the variables studied is described and no specific hypothesis is tested. Therefore, this study was conducted to describe students' scientific literacy as it exists, without reference to other variables.

The subjects in this study were 40 students in the Chemistry Education study program who had taken Basic Chemistry I. The data collection technique used in this study was distributing scientific literacy questions based on the 2015 PISA Framework, totaling 15 questions. The scientific literacy questions for the knowledge aspect were divided into three aspects: content, procedural, and epistemic, each consisting of five questions. The test instrument has been validated by two expert lecturers in their respective fields. The chemistry material tested in the science literacy test is acids and bases. Acids and bases were chosen because this material, which is still a chemical topic, still contains several abstract concepts. Furthermore, it meets the basic principles of PISA content (Hayat and Yusuf, 2010). The PISA content includes: (1) Concepts must be relevant to everyday life; (2) Concepts relate to process competencies; (3) Concepts are relevant for the next decade.

Data were analyzed by processing student test results. The stages in processing test data include assigning a science literacy test score, finding the average test result, and interpreting the average test score according to the science literacy scoring guidelines. The score is obtained from formula (1):

$$\text{Score} = \frac{\textit{Skor yang diperoleh}}{\textit{Skor total}} \times 100$$

The resulting score is then divided by the total number of students who took the test to obtain the average percentage of test results for each aspect measured. The average test results are obtained from formula (2).

$$\bar{x} = \frac{\Sigma x}{n} \times 100$$

Information:
$\bar{x}$ = Average test results
n = Many students
Σx= Total scores of all students

RESULTS

This study describes the assessment of the results of the scientific literacy ability test of prospective chemistry teacher students which is measured based on 3 aspects, namely the content aspect, the procedural aspect, and the epistemic aspect. The results of the data analysis in Table 1 show the achievement in each aspect of scientific literacy. The highest percentage achievement in the content knowledge aspect was 17.19% and the lowest percentage achievement in the epistemic knowledge aspect was 12.32%, while in the procedural aspect the percentage was 12.65%.

Table 1. Average Score Data for Science Literacy Aspects

No	Aspect	Average (%)
1	Konten	17,19%
2	Epistemik	12,32%
3	Procedural	12,65%

The data in Table 1 shows that overall, based on the average scientific literacy score, students' scientific literacy skills are in the low category. Table 1 data explains that students generally only understand or comprehend when answering questions with the content knowledge type, followed by the procedural knowledge type. Questions with the epistemic type yielded less satisfactory results and appeared to be the lowest. The content aspect received the highest percentage of literacy scores because the assessment in this aspect relates to material that is generally theoretical. Students were less able to answer questions with the procedural and epistemic knowledge aspects because in this aspect, the emphasis is more on scientific investigation activities, so it is necessary to provide models or methods in project-based learning such as the Project Based Learning (PjBL) learning model.

DISCUSSION

Content Knowledge Aspect

The content knowledge aspect refers to scientific knowledge used to understand scientific phenomena. According to Vashti (2020), content knowledge relates to theories and concepts applied to comprehend a phenomenon. In this regard, it is closely associated with the competence to identify scientific questions, which heavily relies on one's ability to apply content knowledge to identify a problem (Wulandari et al., 2016).

Students were given questions about basic theories or concepts of acids and bases. The science literacy questions under the content aspect are related to facts, concepts, ideas, and theories. Indicators for this aspect include understanding the concept of acids and bases, understanding acid-base theories, knowing the concept of pH and the pH scale, understanding acid-base reactions, and applying acids and bases in daily life. Based on the data in Table 1, almost all students fall into the medium category. The average achievement in this content aspect was 17.19%, indicating that the majority of students were able to correctly answer questions related to acid-base content. This is evident from the students' scores, which show that most of them answered the given questions correctly. Students were generally familiar with the basic knowledge of acid-base concepts such as acid-base theories, properties of acidic and basic solutions, types of acids and bases, acid-base reactions, and the application of acid-base principles in ecosystems. Thus, students only needed to recall the basic material they had previously understood and mastered.

However, further efforts are still needed to improve students' science literacy in the content aspect, particularly on questions involving the application of acid-base principles in ecosystems. This can be achieved through contextual learning using case studies, project-based learning, collaboration with environmental organizations and practitioners, and the use of interactive learning media.

Procedural Knowledge Aspect

Procedural knowledge emphasizes understanding concepts and procedures in data collection and analysis to explain phenomena (OECD, 2018). It provides an overview of the scientific processes individuals undertake to obtain new information or insights. According to Table 1, the students' procedural knowledge is categorized as low, with an average score of 12.65%. Students demonstrated a decrease in correct answers across all five procedural questions.

Indicators in the procedural knowledge questions included:

1. Applying solutions derived from acid-base concepts to a case/problem;
2. Interpreting experimental data involving pH indicators;
3. Identifying the strength of acids and bases from experimental data;
4. Providing solutions to real-life problems related to acid-base concepts.

Based on these indicators, it can be concluded that students' average performance in procedural literacy is low. This shows that procedural literacy requires more than memorization—it demands reasoning ability to understand issues, draw appropriate conclusions, and analyze data from experiments and real-life cases related to acids and bases.

Efforts to improve science literacy in the procedural aspect may include using inquiry-based or discovery learning approaches, applying the STEM approach in acid-base projects, utilizing virtual lab media, implementing problem-based learning (PBL), and incorporating procedural assessments such as accuracy in measurement, preparation of procedures, safety practices, and proper data recording methods.

Epistemic Knowledge Aspect

Epistemic knowledge is defined as ideas derived from scientific evidence and facts (Zakaria et al., 2018). It refers to knowledge about science that is based on evidence or facts to draw conclusions and make informed decisions (OECD, 2023a). Fadilah (2020) describes epistemic knowledge as the ability to use scientific evidence to construct new knowledge.

This aspect relates to students' understanding of the scientific principles underpinning knowledge in the field of science—particularly chemistry related to acids and bases—and their ability to evaluate and apply scientific knowledge in everyday life. The literacy questions under the epistemic aspect aim to assess students' abilities to understand, evaluate, and apply scientific knowledge regarding acids and bases. These

questions encourage students to think critically, use scientific knowledge to explain phenomena, and relate such knowledge to broader social and environmental issues.
According to Table 1, the epistemic aspect scored the lowest, with an average percentage of 12.32%. Students also showed a decline in correct responses in this section. Indicators for the epistemic questions included: analyzing acid-base concepts and their roles in daily life, linking the concept of pH to acidic and basic properties in social and environmental contexts, using scientific knowledge to solve practical problems, and critiquing and evaluating information related to acid-base experiments.

Many students struggled to answer questions in this aspect, as reflected by the low average percentage. This may be attributed to students' limited ability to apply their knowledge in relevant real-life contexts (Imansari & Sumarni, 2018). The epistemic questions require not only memorization but also critical thinking skills to understand issues or phenomena related to acid-base concepts and to draw valid conclusions.

Therefore, a deeper understanding of the subject matter is needed, which can be achieved through extensive reading and solving science literacy-based questions to help students tackle more complex problems. Based on the indicators, it can be concluded that students' ability to link existing evidence or facts to form conclusions or make decisions is still very limited. Students are expected not only to master the basic concepts of acids and bases but also to analyze questions involving the use of scientific knowledge to understand acid-base-related phenomena, evaluate scientific processes and methods, and apply knowledge of pH to make practical decisions.

Students tend to struggle with analyzing questions and connecting them to previously learned concepts. For example, when asked to predict the pH range in a given scenario, students are required to combine memorized knowledge with accurate analysis. This type of question demands critical thinking to arrive at correct and precise answers.
Several solutions can be proposed to improve science literacy in the epistemic aspect, such as implementing source-based and research-based learning where students are tasked with finding and analyzing scientific sources (articles and textbooks), using case studies relevant to environmental issues, and utilizing appropriate interactive learning media. This aligns with research by Zakiyah et al. (2024), which showed that the use of engaging instructional modules in chemistry learning can increase student motivation and consequently enhance science literacy skills, particularly in reading aspects.

CONCLUSION

Based on the results and discussion presented, it can be concluded that the science literacy of prospective chemistry teachers in the knowledge domain is divided into three aspects: the content aspect, which falls into the moderate category with an average score of 17.19%; the epistemic aspect, which is categorized as low with an average score of 12.32%; and the procedural aspect, also in the low category with an average score of 12.65%. Several factors must be considered to improve science literacy skills, including students' learning interest—which is the most crucial factor—their curiosity, as well as their learning styles and habits. These factors can serve as strong supports for enhancing students' science literacy skills if managed properly. In terms of the learning process, educators can adopt a variety of methods as potential solutions to improve students' science literacy. These include providing continuous instruction in science literacy, organizing the scope of learning materials effectively, and planning the learning process through the implementation of various instructional models such as Problem-Based Learning (PBL), Project-Based Learning (PjBL), contextual learning with case studies, collaboration with organizations and environmental practitioners, and the use of appropriate and interactive learning media. Such approaches are expected to significantly enhance students' science literacy abilities.

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