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Research Article

An Exploration of Scientific Literacy on Physics Subjects within Phenomenon-based Experiential Learning

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Abstract

*Scientific literacy is the ability to involve yourself in problems related to science. This research explores students' scientific literacy skills in experiential learning based on phenomena on the concept of expansion. This research was conducted with a mix-method approach with an embedded experimental model design. The data were collected through scientific literacy tests (r = 0.53), and open-ended questions interviews with the students, then analyzed using the Mann-Whitney U-Test quantitatively, and using the Bybee (1997) assessment rubric qualitatively. Based on the results, it was found that the majority of students experienced an increase in their scientific literacy from the SI (*Scientific Illiteracy) *category (96.88%) into CSL* (Conceptual Scientific Literacy) *(46.88%). We concluded that phenomenon-based experiential learning was effective in improving students' scientific literacy. So, we need more effort to improve and increase students' scientific literacy skills by integrating scientific literacy competencies while implementing science learning in schools.*

Keywords: *Scientific literacy; Phenomenon based experiential learning; Expansion*

Eksplorasi Literasi Ilmiah pada Mata Pelajaran Fisika dalam Pembelajaran Eksperiensial Berbasis Fenomena

Abstrak

Literasi saintifik merupakan kemampuan melibatkan diri dalam permasalahan yang berkaitan dengan sains. Penelitian ini bertujuan untuk mengeksplorasi kemampuan literasi saintifik siswa dalam experiential learning berbasis fenomena pada konsep pemuaian. Penelitian ini dilaksanakan dengan pendekatan mix method dengan desain embedded experimental model. Sampel penelitian ini adalah 32 siswa kelas XI SMA Negeri di kota Malang, Jawa Timur, Indonesia. Data dikumpulkan melalui tes literasi saintifik (r=0,53) dan wawancara terbuka kepada seluruh siswa, kemudian dianalisis secara kuantitatif menggunakan Mann Whitney U-Tes dan kualitatif menggunakan rubric penilaian bybee (1997). Berdasarkan hasil, diperoleh bahwa sebagian besar siswa mengalami peningkatan literasi saintifik siswa dari kategori SI (96,88%) menjadi CSL (46,88%). Kami menyimpulkan bahwa pembelajaran yang kami terapkan efektif untuk meningkatkan literasi saintifik siswa. Sehingga perlu upaya lebih untuk *meningkatkan kemampuan literasi saintifik siswa dengan mengintegrasikan aspek kompetensi literasi sains selama pelaksanaan pembelajaran sains di sekolah.*

Kata Kunci: *literasi saintifik; experiential learning berbasis fenomena; pemuaian*

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I. INTRODUCTION

In general, physics concepts are difficult to comprehend because most of them are abstract and frequently lead to misconceptions. When students perceive an idea based on intuition and common sense, they have a misunderstanding. They are frequently conflicting with scientific concepts [1,2]. One of them is the concept of expansion which contributes to misconceptions among students. A misconception that often occurs is the assumption that the expansion coefficient of an object does not affect the size of the expansion [3,4]. In addition, some students are also assuming that expansion occurs due to an increasing volume of the atoms [5,6]. Misconceptions among students must be addressed immediately since they impair their ability to comprehend other concepts [7]. Understanding the right concepts and applicable physics principles will affect the students' scientific literacy [8,9].

Scientific literacy is the strongest in the elements of science as a method of investigation, and the lowest in the aspect of science as a method of thinking [10–14]. Currently, scientific literacy is considered very important because it is the main goal in science learning [15]. This is because scientific literacy can support the ability of citizens both in developed and developing countries [16]. The competencies needed in scientific literacy include explaining the phenomenon scientifically, evaluating and designing scientific investigations, and interpreting data and scientific evidence [17,18].

According to the 2018 Program for International Student Assessment (PISA), Indonesian students' scientific literacy was in the very low category, with a rank of six or lower / 75 out of 80 participating nations [19]. Some studies also show that students' scientific literacy in Indonesia is still below the average [20]. The lowness in the category of scientific literacy of Indonesian students is due to the limited understanding of concepts in science learning, where students only focus on memorizing rather than understanding concepts [21]. Furthermore, most teachers cannot relate direct science learning in the classroom with a natural phenomenon, whereas science learning is closely related to nature [22,23]. One of the learning approaches that are suitable with these principles is phenomenon-based learning.

Phenomenon-based learning is a learning method where students learn a topic or concept through a holistic approach that can help in improving the quality of the learning activity by displaying new things for students in real contexts [24]. Phenomenon-based learning is following constructivist learning theory. Students build knowledge in their minds through the observed phenomenon and then relate it to an initial knowledge to obtain a complete concept [25]. A phenomenon-based learning process effectively enhances scientific literacy because a phenomenon-based learning process can show concepts from a different perspective [26]. Multirepresentation of physics phenomena can help students solve problems, increasing learning outcomes and concept understanding [27]. The learning model which is oriented towards students' experience is called *Experiential learning* [28].

Experiential learning builds knowledge with experience transformation [29]. According to several studies, experiential learning improves undergraduate students' ability to face real-world jobs by reducing cognitive load and improving students' critical thinking skills [30]. The research results on experiential learning in learning significantly affect the students' success [31]. Learning things can be achieved through experience, which shows that students must go through some background to understand a concept through observation of a real phenomenon [26]. Based on theoretical studies, experiential learning and the phenomenon-based learning process positively result in scientific literacy and match the expansion concept's characteristics. This research will explore the expansion concept with phenomenon-based physics' experiential learning. The purpose of this research is to determine the effect of phenomenon-based experiential learning on students' scientific literacy, especially in expansion sub material.

II. METHOD

This research uses a mixed-methods approach with embedded experimental models. This research is focused on the description of students' scientific literacy in the expansion sub material. The subjects of this study were 32 students of grade 9 from a Senior High School in Malang, East Java, Indonesia.Research data were collected by tests and interviews. The research instrument used was the students' scientific literacy test with a *Cronbach alpha Reliability* score of 0.53, consisting of 3 items. The students' scores are categorized in 5 assessment rubrics which are described in Table 1.

Table 1. Students' Scientific Literacy Assessment Rubric

Score	Description
0	The students are not able to solve the given problem, so that they do not give any answers.
1	The students have a limited understanding of a concept so that there are many mistakes (misconception).
2	The students are able to describe the meaning of physics concepts correctly through various sources in the form of basic facts but their understanding is very limited to the aspects of definition and understanding.
3	The students begin to be able to develop concepts, principles, laws and theories in a discipline so that they are able to relate their concepts to other disciplines.
4	The students are able to utilize various concepts and are able to relate these concepts with the events in everyday life

Interviews by using unstructured techniques were conducted on all students to confirm their answers and explore their scientific literacy skills on expansion. The steps of phenomenon-based experiential learning can be seen in Figure 1.

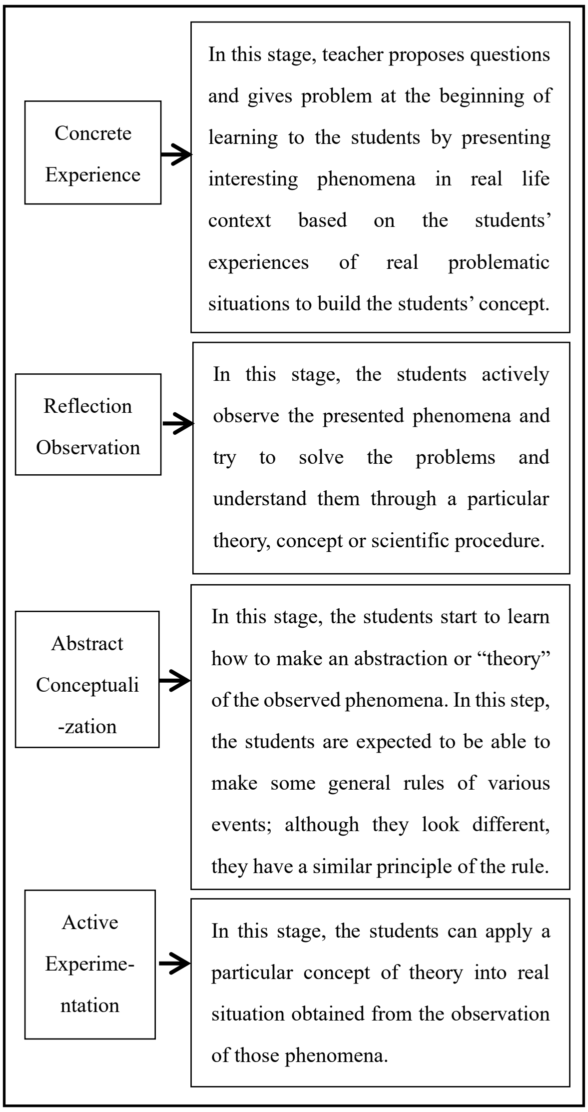

Figure 1. ***Phenomenon Based Experiential Learning* Syntax**

The results obtained from students' scientific literacy research are quantitatively and qualitatively analyzed. The quantitative data in the form of students' scientific literacy test scores at the pretest and posttest were analyzed using the Wilcoxon Signed Ranks Test, Effect Size Test, and N-Gain test. Whereas the qualitative data obtained from the results of students' interviews when completing scientific literacy tests on the pretest and posttest were analyzed by Bybee (1997) categorization as shown in Table 2.

Table 2. Students' Scientific Literacy Level [32]

Level	Description
Scientific Illiteracy (SI)	Students do not have scientific terms, scientific concepts and cannot identify problems so that they cannot solve the given problems.
Nominal Scientific Literacy (NSL)	Students have an understanding of a certain limited concept so that they undergo many misconceptions; besides, the students are easily influenced by others' statements without their ideas.
Functional Scientific Literacy (FSL)	Students can describe the meaning of physics concepts correctly through a textbook or other source in the form of basic facts, but their understanding is very limited for the aspect of definition and meaning.
Conceptual Scientific Literacy (CSL)	Students start to develop their concept, principle, law, and theory in a certain discipline. Students can correlate their concepts to other disciplines. Students have an understanding of the solution to the given problems.
Multidimensional Scientific Literacy (MSL)	Students can use their diverse concepts and connect those concepts to the phenomena in daily life.

III. RESULTS AND DISCUSSION

Based on the descriptive analysis results, it is obtained that the average scores of the students' scientific literacy on pretest and posttest of the expansion material are 21.34 and 62.91, respectively. These results indicate that the students' scientific literacy increases after applying phenomenon-based experiential learning in the learning process. The Wilcoxon Signed-Rank Test also supports this with Asymp.Sig. (2-tailed) 0.000, which shows that phenomenon-based experiential learning affects increasing the students' scientific literacy. In addition, an increase in students' scientific literacy can also be seen from the N-gain and effect size obtained, namely 0.53 in the medium category and 0.86 in the strong category, respectively.

The increase in scientific literacy of each student in the expansion sub material can be seen in Figure 2.

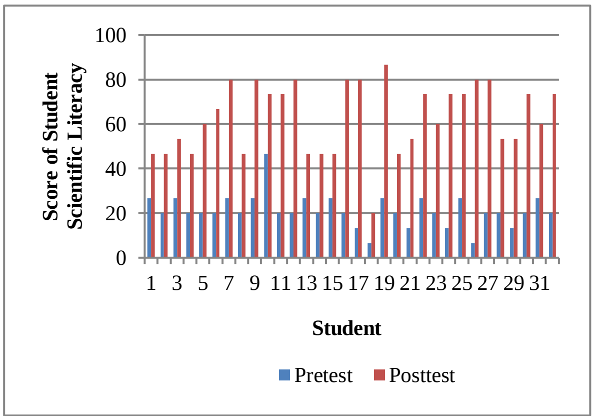

Figure 2. Students' Scientific Literacy on Pretest and Posttest

This result is in line with several previous types of research which showed that phenomenon-based experiential learning affects students' scientific literacy [33,34]. Involving the students in inquiry and discovery can train students' scientific literacy skills [35]. This is because learning through a hands-on experience enabling students to develop their abilities in cognitive, psychomotor, and affective domains [34]. Phenomenon-based experiential learning gives the students a large portion of a chance to maximize their cognitive knowledge and competencies in exploring real-life problems [29]. In addition, phenomenon-based experiential learning is also in line with constructivism learning theory which directs the students to develop meaning from the learning experiences they experienced [28,29]. The students' initial scheme about a certain concept can be formed through experience by connecting the new concepts obtained with the initial scheme stored in their long-term memory [36].

In this research, students' scientific literacy level categorizations are done by using a scoring scale from Bybee (1997), namely Scientific Illiteracy (SI), Nominal Scientific Literacy (NSL), Functional Scientific Literacy (FSL), Conceptual Scientific Literacy (CSL), and Multidimensional Scientific Literacy (MSL). The scientific literacy assessment in schools is not intended to classify whether a student is literate or not to find the "seeds of literacy" in students [37]. The percentage of students' scientific literacy in each category at the pretest and posttest is shown in Figure 3.

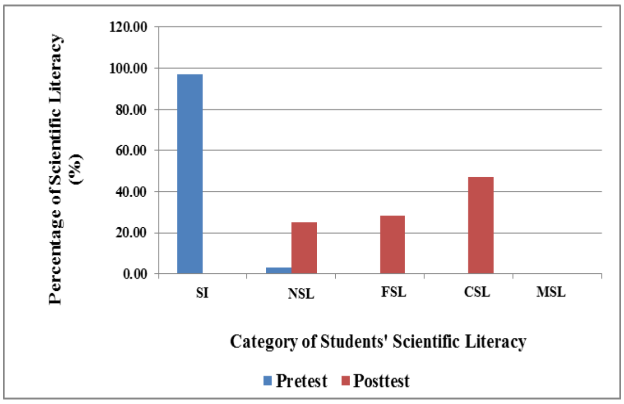

Figure 3. The Percentage of Students' Scientific Literacy in Each Category

At the time of the pretest or before the phenomenon-based experiential learning is applied, it can be seen that students' answers fall into two categories, namely SI (96.88 %) and NSL (3.13 %). In the SI category, most students solve the problems in a general way without relating them to the concept of science [38]. In addition, the students also answer questions based on the experiences they experienced every day but have not been able to pack them into a science concept. This matter causes some students to undergo some misconceptions in solving a given problem [39]. Whereas students in the NSL category, most of them solve the problems by memorizing concepts or formulas to experience confusion when given a problem different from the given examples. This is because the assessment development in high school still emphasizes the formula memorizing or in bloom taxonomy is still at stage C1 [40]. Some research results also mentioned that the high school students' scientific literacy is still in the low category or SI [41,42].

There are so many factors that cause the lowness in students' scientific literacy. One of them is the initial abilities possessed by the students [43]. The students may easily accept and understand new concepts when they have high initial ability and vice versa. This is due to the initial ability to facilitate students in understanding new concepts and relating them with the previous concepts already in their long-term memory [36].

After being taught by using phenomenon-based experiential learning, it can be seen that the students' scientific literacy is increased from initially in the SI and NSL categories into the FSL category (28.13%) and CSL (46.88%), even though there were still some students who remained in the NSL category (25.00%). This shows that most students have been able to use the right concepts to solve problems and develop and relate their understanding with other science concepts, even though there are still a few students undergoing misconceptions. This result is in line with several previous types of research, which stated that most of the students' scientific literacy is in the FSL and CSL categories [38,44]. The students in the FSL category find it difficult to explain the solutions to the given problems since the knowledge possessed by the students is limited, where the answers given are still in the macroscopic scale [37]. In addition, the lack of interest in students in science learning is one of the reasons students are in the FSL category [38]. Whereas the MSL category is still difficult to reach by the students since the application of the traditional curriculum has not been able to equip students with sufficient scientific knowledge to solve the given problems [33].

Table 3 Shows some Examples of Students' Answers in Each Category on Expansion Sub Material.

Table 3. Students Answer in Each Category

Problem: "Why does the installation of glass and its frame (Wood) requires a gap between those two items? Please explain!
Scientific Illiteracy (SI)
"To make it easier to install and replace the glass from the window"
Nominal Scientific Literacy (NSL)
"When the window (glass and wooden frame) is exposed to heat then the wood will increase in length, whereas the glass will not increase in length. So that if there is no gap between those two, the glass will break"
Functional Scientific Literacy (FSL)
"Each of the glass and the wooden frame experiences a volume expansion, however the glass has a greater expansion than the wooden frame. The gap between the glass and the wooden frame serves as a place for the expansion of the glass that is held up by the wooden frame when the air temperature rises. Since the glass will increase in volume when the air temperature rises, a gap is needed between those two, otherwise the glass will break because there is no room for the glass to increase in volume."
Conceptual Scientific Literacy (CSL)
"The glass and the wooden frame will expand when the air temperature rises and will shrink when the temperature decreases. In this case, the glass experiences a greater expansion than the wood because the wood expansion coefficient is lower than the glass, so that the glass will absorb more heat than the wood so that the glass will expand faster. If there is no gap between the two when mounting the glass and the frame, and the glass experiences expansion then the glass will break because there is no room for the glass to undergo an increase in volume."

The students in the SI category are less able to identify the given problems due to the lack of understanding of scientific concepts [32]. This leads students to answer based on their intuition without relating it with the right scientific concepts [28]. Based on the results of unstructured interviews conducted, it is found that students in the SI category do not understand the concept of expansion, so it is difficult to identify the problems, especially due to the confusing terms of the physical variables. Another reason is that the students lack interest in learning physics, which causes the students to have some difficulties in solving problems related to physics. This aligns with previous research, which stated that SI students have no interest in learning science [23,37].

The students in the NSL category have not been able to relate problems with the concept of expansion because they tend to solve problems based on the experiences they have experienced. This leads to a misconception among the NSL students. In addition, students are also still limited in understanding science terminology [32,45]. Based on the results of the unstructured interviews that have been conducted, it was found that NSL students assumed that only the wooden frames might experience an increase in volume while the glass might not. When two objects are placed at the same temperature, only one of them may increase in volume. The NSL students are also still unfamiliar with the term expansion so that students are more likely to use standard terms in solving the given problem.

Students in the FSL category can solve problems by describing the meanings and concepts correctly, but their understanding is still limited to the book's concept. So that when a slightly different from the book problem is given, the students will have some difficulty [32]. Based on the results of unstructured interviews that have been conducted, it was found that FSL students assumed that the glass and the wooden frame were both experiencing an expansion. Still, the glass would experience a greater expansion compared to that of the wooden frame when the air temperature increased. FSL students have not been able to explain why the glass would expands faster than the wooden frames.

The students in the CSL category can develop their expansion concepts and relate them with other concepts [32]. The students have a deep understanding of the solutions to the given problems. According to the findings of unstructured interviews, CSL students assumed a contribution from the object's expansion coefficient in the given problem because the glass expansion coefficient is greater than that of the wooden frame, causing the glass to expand more significantly air temperature increased. As a result, a gap between the glass and the frame is required so that when the glass expands, the glass does not break.

The limitation of this research was that the aspects of scientific literacy skills assessed were not holistic, but they were limited to competency. Therefore, further researchers are recommended to measure scientific literacy for all aspects, namely context, knowledge, competency, and attitude. This research in learning is that students can explore concepts directly through the experiences they have experienced. Besides, students' scientific literacy skills, especially in physics, can be improved through this research.

IV. CONCLUSION

Based on the results, phenomenon-based experiential learning had succeeded in significantly increasing students' scientific literacy on the topic of expansion. Most students can understand the concepts, identify the problems well, and relate them to other concepts. The limitations in this research are that the scientific literacy ability aspect is measured not as a whole but limited only to the competency aspect. For this reason, it is recommended for further research to measure scientific literacy in all aspects, namely context, knowledge, competence and attitude.

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