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Science Literacy Profile of High School Students: Implications of PBL Didactic Design on the Topic of Microplastics

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Abstract
This study aims to analyze the science literacy profile of high school students following the implementation of a didactic problem-based learning (PBL) design on the topic of microplastics. This study adopted a Didactical Design Research (DDR) methodology involving 36 high school students from Sukabumi Regency as the research sample. The selection of the participants was made to create a supportive environment for the implementation and assessment of the didactic design that had been developed. To accumulate data regarding students' scientific literacy, the assessment instruments that were designed following the PISA science framework were used. Students were tested in their capacity to give explanations for scientific phenomena, to assess and create scientific investigations, and to decipher scientific data. The teachers using these instruments then analyzed the scientific literacy data to ascertain the impact of the PBL-based didactic design. The research results indicate that the students ability to explain scientific phenomena was very strong but the ability to evaluate investigations and interpret data was rather moderate and therefore needed further support. These findings signify that the didactic PBL design facilitates students' science literacy in learning the connection of scientific concepts with real-world problems, however, the refinement of the learning activities is necessary in order to maximize the development of higher-order evaluative and analytical skills.

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INTRODUCTION

One of the competency indicators evaluated by the Programme for International Student Assessment (PISA) is science literacy. Countries that rank high on the PISA index are considered to have high educational standards and quality in the global market. Meanwhile, countries that rank below average are considered to have lower standards and quality in the global market and are expected to improve their education systems (Yanuar Anggraeni et al., 2020). Science literacy is also defined as the ability to master scientific concepts and procedures and apply science to explain phenomena in everyday life (Sutrisna, 2021). The level of science literacy greatly influences an individual's ability to make decisions related to social issues. The urgency of science literacy countinous to grow as reflected in the four domains, namely knowledge, content, competence, and scientific identity, which are very important for students. Science literacy is not only knowledge about science as a concept, but also the ability to use it in everyday life.

Regarding science literacy, the OECD released the results of the 2009-2022 PISA assessment of Indonesian students in reading, mathematics, and science. Several factors that contribute to students' science literacy, based on the graph above, include students, educators, and educational institutions. Factors that influence students include: 1) students do not yet understand the basic scientific concepts taught by educators and are hesitant to ask questions,

2) science education in schools is still traditional in nature, 3) students' lack of ability to analyze graphs or tables, 4) neglect of reading and writing skills as important competencies for students, and 5) students' lack of interest in reading and reviewing what they have learned (Hidayah et al., 2019).

In addition, the role of educators also influences low science literacy among students. Educators are in a crucial position and have an influence on students' science literacy skills (Yusmar & Fadilah, 2023). Educators are required to have specific strategies to stimulate students' interest in learning so that learning is more meaningful (Sujana et al., 2014). The need to improve the teaching system is important for educators in the learning process and is expected to increase the level of science literacy in Indonesia, one of which is through the PBL model. The PBL model emphasizes that students are required to read in order to find solutions. This unconsciously develops students' problem-solving skills, which indirectly strengthens their science literacy skills (Lendeon & Poluakan, 2022).

Recently adopted educational reforms highlight a transition from teacher-focused teaching to student-focused learning that encourages active engagement, critical thinking, and problem-solving abilities as key elements of scientific literacy (OECD, 2019; Darling-Hammond et al., 2020). In this context, Problem-Based Learning (PBL) is well acknowledged as a successful teaching method for tackling low science literacy by involving students in genuine, real-life challenges that necessitate the use of scientific principles, data analysis, and reasoning based on evidence (Hmelo-Silver, 2004; Savery, 2015). Prior research has shown that PBL greatly improves students' scientific reasoning, data interpretation abilities, and their capacity to relate scientific knowledge to socio-scientific challenges (Yew & Goh, 2016; Putri et al., 2021). Additionally, by placing students in the role of active problem solvers instead of passive information receivers, PBL fosters a deeper conceptual understanding, ongoing learning motivation, and the enhancement of higher-order cognitive skills (Hung, 2011; Lestari et al., 2017). These traits render PBL especially effective in equipping students to tackle intricate environmental and societal problems, including modern challenges like microplastic pollution (Zeidler & Sadler, 2011).

PBL is a teaching model that can integrate real-world situations as a form of learning that enables students to develop critical thinking skills, problem-solving skills, and an understanding of essential concepts in learning (Lestari et al., 2017). The PBL model focuses on problems and has the characteristic of making problems the starting point of the learning process (Siti Hanifah et al., 2021). The PBL model also presents innovation because the issues presented are closely related to students lives, so that students can easily understand concepts and develop their knowledge (Aufa et al., 2020). This demonstrates the superiority of the PBL learning model in improving students ability to deal with environmental problems and improves their ability to deal with environmental problem by encouraging critical and creative thinking (Syarif, 2020).

Science literacy is a fundamental competency that enables students to understand scientific concepts and apply them to real-world contexts. However, existing instructional practices often emphasize content acquisition rather than the development of higher-order scientific skills, resulting in suboptimal levels of science literacy among high school students. In response to this gap, this study explores the use of a Problem-Based Learning (PBL)–based didactic design to support the development of students' science literacy through the contextual and socio-scientific issue of microplastics.

METHOD

The research design used in this study was Didactical Design Research (DDR). According to Suryadi (2018), didactical research has three stages, namely: (1) Analysis of the didactical situation before learning, which takes the form of a hypothetical didactical design including ADP (Didactical and Pedagogical Anticipation); (2) Analysis of the didactic situation during learning (Metapedadidactics); and (3) Analysis of the didactic situation after learning (Retrospective), which is an analysis that links the results of the hypothetical didactic situation analysis with the results of the metapedadictic analysis.

The analysis of the didactic situation after learning (retrospective) begins with the data on students science literacy profiles obtained after the analysis of the didactic situation during learning. The students science literacy profiles were identified based on the results of their science literacy tests to provide a comprehensive picture of their abilities in three science competencies, namely explaining phenomena scientifically, evaluating and designing scientific investigations, and interpreting data and evidence scientifically.

The science literacy profile was obtained through an analysis of the results of the science literacy test given to students after the implementation of the didactic design. Science literacy, which consists of three main competencies, is included in the science literacy questions in the student worksheets which students complete during the implementation of the didactic design. The science literacy questions completed by students consisted of 15 questions focusing on the topic of microplastics. In the student worksheet, there were four questions related to the competency of explaining phenomena scientifically, two questions related to the competency of evaluating and designing scientific investigations, and four questions related to the competency of interpreting data and evidence scientifically.

The science literacy profile uses a Likert scale. The Likert scale is often used to measure the opinions, attitudes, and views of an individual or group of people on social phenomena. The Likert scale is commonly used with questionnaires.This scale is often used in survey-based research (Suwandi et al., 2018). Analysis of science literacy scores with the following calculations with percentage criteria describe in Table 1.

$$\% \text{ values} = \frac{\text{number of keywords}}{\text{the key that should be there}} \times 100\% \text{ number of keywords}$$

Table 1. Percentage Criteria

Precentage	Criteria
81–100%	Very suitable
61–80%	Suitable
41–60%	Quite Suitable
21–40%	Less Suitable

RESULTS AND DISCUSSION

The analysis of students answers for each science literacy competency was conducted by comparing their responses with keywords that served as indicators of achievement in each question item. The summary of the analysis results is presented as follows at table 2.

Table 2. Science Literacy Competency Results

Competency of Literacy	Science Number of Keywords	Ideal Average	Keywords that Appear Percentage	Suitability Category
Explaining phenomena scientifically	4	3,38571429	85	Very suitable
Evaluating and designing scientific investigations	4	3,03571429	76	Suitable
Interpreting data and evidence scientifically	4	3,09142857	77	Suitable

Based on Table 4.2, the results of the analysis in the science literacy indicator table show that the ability to explain phenomena achieved the highest score with an average keyword score of 3.39 and a suitability percentage of 85%, which is categorized as very suitable. This shows that participants are able to understand scientific concepts well and can relate them to phenomena occurring in their surroundings. Meanwhile, the indicators of evaluating and designing research obtained an average score of 3.04 with a conformity percentage of 76%, and the indicators of interpreting data and scientific evidence achieved an average score of 3.09 with a conformity percentage of 77%. Both indicators were categorized as suitable, which means that the participants' abilities were quite good but still needed improvement, especially in the aspects of critical assessment of research and interpretation of scientific data.

Overall, science literacy achievements can be considered adequate, with a predominance of the ability to explain phenomena, while the ability to evaluate research and interpret data still needs to be strengthened in order to achieve a more optimal category. This is in line with several factors that cause students' science literacy skills to remain low, including teaching and learning processes that do not sufficiently support the development of their literacy skills, teaching materials that have not been taught, and students' lack of habit in working on essay-type questions (Merta et al., 2020). Furthermore, based on data analysis, there are variations in the level of science literacy among students in each indicator that is the subject of research in the table 3.

Table 3. Distribution of Achievement per Science Literacy Competency

No	Competency Literacy	Percentage
1	Explaining phenomena scientifically	36%
2	Evaluating and designing scientific investigations	32%
3	Interpreting data and evidence scientifically	32%
	Total	100%

Based on the results of data analysis in the table 4.3, it can be seen that the highest achievement indicator for students' science literacy is the ability to explain scientific phenomena, with a percentage of 36%. This shows that students are relatively more capable of relating scientific concepts to phenomena that occur around them and conveying them in the form of logical explanations. Meanwhile, the indicators of evaluating and designing scientific investigations and interpreting scientific data and evidence each obtained a percentage of 32%. These two indicators show that students' abilities in designing research and interpreting data are still at the same level, but not as high as their ability to explain phenomena.

These results are in line with research conducted by Afina et al., (2021) and (Merta et al., 2020) students science literacy skills are at their lowest in the competencies of interpreting data and scientifically proving data to be more prominent than their competence in evaluating and designing scientific investigations and interpreting scientific data and evidence. Ideally, based on the definition of science literacy, science literacy is multidimensional in nature, not only an understanding of scientific knowledge, but more than that (Firman, 2007; Mahardika, Suwono, & Indriwati, 2016).

Low science literacy continue to be a significant problem that needs immediate attention in the Indonesian education system. This situation can be linked to various underlying causes. Primarily, conventional classroom evaluations mainly focus on recall and habitual implementation of concepts instead of intricate investigation, reasoning, and debate, which restrict students' chances to cultivate data analysis and scientific reasoning abilities (Bybee, 2013; Black & Wiliam, 2009). Students often lack opportunities to engage in learning activities that necessitate systematic data interpretation and evidence assessment, which leads to diminished confidence when encountering unfamiliar or abstract forms like tables, graphs, and experimental findings (Rahmadani et al., 2022; Osborne, 2014). These patterns suggest that the absence of inquiry-based assessments and instruction centered on reasoning plays a major role in ongoing deficiencies in students' scientific literacy.

Additionally, teaching methods that are mainly centered around the teacher usually restrict students' chances to participate actively in scientific inquiry activities, which frequently leads to superficial learning instead of significant cognitive involvement (Furtak et al., 2012; OECD, 2019). These learning settings offer limited opportunities for tasks that involve data interpretation, evidence assessment, and scientific reasoning, thus hindering the growth of advanced science literacy skills. Problem-Based Learning (PBL) is frequently described as an effective educational method for tackling these difficulties, as it embeds data interpretation and reasoning abilities within genuine, real-world problem situations and encourages active participation through continual practice of inquiry-driven tasks (Hmelo-Silver, 2004; Savery, 2015). Research in science education consistently shows that students engaged in PBL-focused instruction exhibit much greater skills in analyzing scientific evidence and assessing scientific inquiries than those taught through traditional approaches (Yew & Goh, 2016; Alatas & Fauziah, 2020; Anugrah & Astriani, 2024; Lendeon & Poluakan, 2025). The results suggest that intentionally designed inquiry-based learning activities are essential for diminishing gaps in various science literacy skills.

CONCLUSION

This research finds that employing a PBL-oriented instructional design positively impacts the enhancement of students' scientific literacy in all evaluated competencies. The results show that students exhibited their best performance in elucidating scientific phenomena, then in interpreting scientific data and evidence, while assessing and creating scientific investigations proved to be the most difficult skill. These variations indicate that students have a greater familiarity with concept-driven explanations rather than with advanced inquiry skills that necessitate data analysis and reasoning based on evidence. This study theoretically adds to the expanding research on Didactical Design Research (DDR) by emphasizing how PBL can enhance multidimensional science literacy when learning activities are framed around socio-scientific issues like microplastics. The findings suggest that when implementing PBL, there should be clear scaffolding and numerous chances for students to practice data interpretation and investigative reasoning. Enhancing these elements could assist educators in creating more impactful learning experiences that promote comprehensive growth across every aspect of science literacy.

RECOMMENDATION

Based on the science literacy profile obtained, students ability to explain scientific phenomena has developed well, while their ability to evaluate research and interpret data is still relatively low, so it needs to be the focus of reinforcement in future learning. Therefore, teachers are advised to design activities that specifically stimulate evaluative and interpretive skills, such as exercises in reading and comparing experimental data, discussions on the validity of research procedures, and assignments involving the analysis of graphs and tables. The integration of evidence-based tasks into the learning process is expected to increase student engagement in critically analyzing scientific information so that the three domains of science literacy can develop in a balanced manner. Further research is also recommended to review the effectiveness of learning strategies that focus more on improving research evaluation and data interpretation skills as part of efforts to strengthen overall science literacy achievement.

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