JPPIPA 10(11) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Fostering Student Competence in Data Interpretation and Environmental Literacy Through E-PjBL Model Assisted by Computational Simulation

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Received: May 21, 2024
Revised: September 14, 2024
Accepted: November 25, 2024
Published: November 30, 2024

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DOI: 10.29303/jppipa.v10i11.9159

Abstract: The aim of this research is to identify the effectiveness of the project-based learning model with an environmental issue approach (E-PjBL) model assisted by computational simulation in fostering environmental literacy and data interpretation competence among students. This study is a quantitative descriptive research. The sample consisted of 22 individuals. The research was conducted on students taking general chemistry courses at Mandalika University of Education. The variables studied were environmental literacy and data interpretation competence. Data were collected through descriptive tests. The tests were based on themes and data during the project conducted in the chemistry laboratory of Mandalika University of Education. The data were then described in graphical form and analyzed using the N-Gain test assisted by SPSS 22 application. The results of the E-PjBL assisted by computational simulation proved to increase environmental literacy and data interpretation competence. This statement is supported by the N-Gain test results where 50% of students were in the moderate and high categories, while the rest were in the low category. Based on these findings, it can be concluded that the E-PjBL model assisted by computational simulation is able to improve students' environmental literacy and data interpretation competence.

Keywords: Data interpretation competence; Environmental literacy; E-PjBL

Introduction

Data interpretation ability is a key skill involving one's capability to understand, analyze, and draw conclusions from information contained within a dataset. It is an essential aspect of numeracy literacy and plays a crucial role in informational decision-making (Megawati & Sutarto, 2021; Nahdi et al., 2020). As a student, possessing high-level thinking skills is necessary in the 21st century, one of which is data interpretation skills. The ability to comprehend the types of data contained within a set, including whether it's quantitative or qualitative data, is vital. This understanding also encompasses knowing how the data is collected, whether through surveys, measurements, or other data sources (Azzajjad et al., 2023; Grotlüschen et al., 2020; Kaleli-Yilmaz & Yurtyapan, 2021).

Kaleli-Yilmaz & Yurtyapan (2021) reported that fostering data interpretation skills requires data that are relevant to the contextual learning issue. Understanding the context surrounding the data is crucial. It involves questions such as why the data are collected, what the analysis's purpose is, and how the data can be applied in real-life contexts (Fitzallen & Watson, 2011; Moussavi et al., 2016). The ability to interpret data can present new findings that can lead to critical and creative thinking

How to Cite:
Anwar, Z., Bayani, F., & Hulyadi. (2024). Fostering Student Competence in Data Interpretation and Environmental Literacy Through E-PjBL Model Assisted by Computational Simulation. *Jurnal Penelitian Pendidikan IPA*, *10*(11), 8300–8310. https://doi.org/10.29303/jppipa.v10i11.9159

(Davies et al., 2012). Reading trend patterns can predict natural or social occurrences in the coming years. This skill is crucial for students to possess, enabling them to make wise decisions and design a better future. Contextual learning is essential for training students to examine events around them to bring about meaningful learning. Understanding the context in the learning process is necessary for meaningful learning to occur (Hyun et al., 2020; Huliadi, 2021; Sussman et al., 2021).

In enhancing data interpretation skills, the ability to draw logical conclusions from analyzed data is also required. This involves applying mathematical or statistical reasoning to make valid and relevant statements based on the available data. In today's modern era, data interpretation skills are highly sought-after in addressing the needs of the data-driven workforce. Data aids in decision-making. The ability to use data to make informed and precise decisions is a crucial part of data interpretation (Bousdekis et al., 2021; Brynjolfsson & McElheran, 2016; Provost & Fawcett, 2013).

The ability to make decisions based on informed information has become a fundamental skill in the era of Industry 4.0. Decision-makers must embrace technological literacy, adaptability, and collaborative approaches to navigate the complexities of this transformative industrial era successfully. With the continuous evolution of Industry 4.0, refining decision-making skills will be crucial for individuals and organizations to thrive in the ever-changing landscape (Purwanto et al., 2023; Santos & Benneworth, 2019; Zubaidah, 2018). Decision-making skills in the Industry 4.0 era are essential to master due to the profound digital transformation occurring in the industrial context. The Industry 4.0 era is characterized by massive data collection from various sources, including sensors, IoT devices, and related systems. The ability to manage and analyze large volumes of data is key to making informed decisions. Comprehensive data sources are needed in the field of education to make accurate conclusions about the issues being studied (Rosin et al., 2022). Students' ability to interpret data is crucial amid environmental issues occurring globally.

Climate change issues have become a major concern worldwide. The rise in global temperatures has led to numerous crop failures, impacting global food availability. If not addressed promptly, this condition can lead to socioeconomic instability globally (Abbass et al., 2022; Adger et al., 2003). The increase in global temperatures due to the use of fossil fuels, deforestation, and industrial activities has led to continuous carbon emissions (Akpodiogaga-a & Odjugo, 2010; Hao et al., 2016; Tol, 2018). Although we are currently experiencing the effects of global temperature rise collectively, many people still engage in activities that contribute to this rise. Students, as agents to be equipped with environmental literacy, are crucial in building environmental awareness. Students can apply their knowledge to the community to mitigate the impacts of temperature rise on the environment. Temperature rise can also adversely affect food deposits because increased temperatures can disrupt or fail agricultural production (Carleton & Hsiang, 2016; Tol, 2018). Adaptive students must be continuously molded to address the challenges of dynamically changing times (Hulyadi et al., 2023a).

Climate change has emerged as one of the most pressing global issues of the 21st century, with rising temperatures posing significant challenges to ecosystems, economies, and societies (Carleton & Hsiang, 2016; Liu et al., 2020; van Ruijven et al., 2014). The upward trend in global temperatures is primarily driven by human activities, such as the burning of fossil fuels, deforestation, and unsustainable industrial practices. These actions lead to increased greenhouse gas emissions, particularly carbon dioxide (CO_2), which trap heat in the atmosphere and contribute to global warming (Akpodiogaga-a & Odjugo, 2010; Hao et al., 2016). If these activities continue unabated, the cumulative impact on the planet could become catastrophic (Matsumoto, 2019).

One of the most concerning effects of climate change is its direct impact on global agriculture. Crop failures due to extreme weather conditions such as droughts, floods, and heatwaves are becoming more frequent, threatening food security worldwide. As the climate continues to change, agricultural yields are expected to decline in many parts of the world, especially in regions that are already vulnerable (Carleton & Hsiang, 2016). This decline in food production can result in shortages, higher food prices, and in extreme cases, famine. Furthermore, the socioeconomic consequences of these disruptions can be profound, potentially leading to political instability, mass migration, and conflict over dwindling resources (Abbass et al., 2022; Adger et al., 2003).

Environmental literacy and awareness play a critical role in addressing climate change. Students, in particular, are seen as pivotal in promoting sustainability and environmental stewardship (Lionello et al., 2014). By fostering a deep understanding of environmental issues, students can act as catalysts for change within their communities. Equipped with knowledge about the causes and consequences of climate change, they can advocate for sustainable practices, such as reducing energy consumption, minimizing waste, and supporting renewable energy sources. Their proactive involvement can help mitigate

the adverse effects of rising global temperatures (Sesana et al., 2021).

Moreover, adaptive strategies are crucial for mitigating the effects of climate change on agriculture and food systems. These include developing climate-resilient crops, adopting sustainable farming practices, and improving water management techniques. Students, as future leaders and innovators, can contribute to the development and implementation of these adaptive measures. By continuously shaping environmentally conscious and adaptive individuals, societies can better prepare for the challenges posed by the rapidly changing climate (Hulyadi et al., 2023a).

Problem-based and project-based learning tailored to local issues and potentials are essential in addressing the challenges of such a complex era (Alexander et al., 2014; Hulyadi et al., 2023a). Problem-Based Learning (PBL) has several advantages that make it an effective approach in education. PBL allows students to learn through real contexts or problem situations that resemble real-world challenges. This makes learning more meaningful and relevant for students (Almulla, 2020; Hulyadi et al., 2023b; Kokotsaki et al., 2016; Simbolon & Koeswanti, 2020). Presenting everyday environmental issues can enhance students' literacy and competence in understanding environmental issues and the solutions that can be offered. Habitualization of this learning pattern can produce adaptive and critical students in addressing environmental challenges and issues. Students engage in real problem-solving that requires critical thinking, analysis, and synthesis of information. This helps develop high-level thinking skills (Amïn et al., 2020; Bïrgïlï, 2015; Dabbagh, 2019; Masek, 2012; Nargundkar et al., 2014).

Problem-Based Learning (PBL) and Project-Based Learning (PjBL) are increasingly recognized as essential methodologies in modern education, especially for addressing complex global and local issues, such as climate change, environmental degradation, and resource scarcity (Diana et al., 2021). By tailoring these pedagogical approaches to local contexts, educators can better prepare students to face real-world challenges with a sense of relevance and immediacy (Almazroui, 2023).

PBL is a student-centered approach where learning is initiated with a problem. Unlike traditional teaching methods that focus on the passive reception of information, PBL immerses students in real-world problems that are relevant to their lives, communities, or the global context (Demelash et al., 2023; Kim et al., 2018). Through this immersive experience, students not only learn the subject matter but also how to approach and solve real problems. The advantage of this approach is that it makes learning highly meaningful and engaging (Almulla, 2020; Hulyadi et al., 2023b).

One of the main strengths of PBL is its ability to integrate multiple disciplines. When students are confronted with complex environmental challenges, they must draw on knowledge from various fields—science, technology, social studies, and economics—to fully understand the problem and propose viable solutions. This interdisciplinary approach promotes deeper understanding and enables students to appreciate the interconnectedness of different areas of knowledge (Simbolon & Koeswanti, 2020).

PBL also fosters the development of critical thinking and problem-solving skills. Students must analyze the problem, identify relevant information, assess potential solutions, and make informed decisions. This process encourages the development of high-level cognitive skills such as analysis, synthesis, and evaluation, which are crucial for addressing complex challenges like climate change, resource management, and social equity (Amïn et al., 2020; Bïrgïlï, 2015). By engaging in real-world problem-solving, students are better equipped to handle ambiguity and uncertainty, both of which are characteristic of today's rapidly changing world (Masek, 2012).

In addition to PBL, Project-Based Learning (PjBL) offers another hands-on, inquiry-based approach that emphasizes long-term, student-driven projects. Students work collaboratively on a project that typically involves investigating a significant question, problem, or challenge. These projects often require research, experimentation, and the application of knowledge to create tangible solutions or outcomes. PjBL is particularly effective for addressing local environmental issues because it encourages students to explore real problems within their communities and develop localized solutions. This not only makes learning more relevant but also empowers students to become change-makers within their own environments (Kokotsaki et al., 2016).

In both PBL and PjBL, students are tasked with solving real-world problems, which promotes a deeper understanding of the content and its applications. Through repeated exposure to problem-solving and project-based tasks, students build the capacity to adapt to evolving challenges, making them more resilient and innovative thinkers (Dabbagh, 2019; Nargundkar et al., 2014). Moreover, habitualizing this learning pattern can produce students who are not only knowledgeable but also equipped to apply their knowledge in adaptive, critical, and creative ways to address the environmental issues of today and tomorrow (Hulyadi et al., 2023b).

One of the key educational outcomes of both PBL and PjBL is the enhancement of environmental literacy.

When students are consistently presented with environmental challenges—such as pollution, deforestation, or climate change—they gain a deeper understanding of these issues. More importantly, they learn to critically analyze these challenges, propose sustainable solutions, and take action. This holistic approach to education builds students' competence in addressing environmental issues and prepares them for leadership roles in advocating for sustainable practices in their communities and beyond.

In conclusion, Problem-Based Learning and Project-Based Learning are powerful educational strategies that cultivate critical thinking, problem-solving, and high-level cognitive skills. When aligned with local issues and potential solutions, these approaches provide students with the tools to become adaptive, environmentally conscious citizens who can actively contribute to resolving the pressing challenges of our time.

Anazifa & Djukri (2017), Hariyadi et al. (2023), and Triana et al. (2020) reported that engaging problem-based and project-based learning can increase students' motivation. They are more involved because they see the direct utility of what they are learning. PBL often involves group work, allowing students to learn to collaborate, communicate, and collaborate effectively. This reflects essential skills in the real world. Students learn to identify, analyze, and solve problems. This helps them develop useful problem-solving skills in various contexts. The PBL approach allows flexibility in learning. Students can explore their own paths and solve problems in ways that suit their learning styles (Diana et al., 2021). Problem-based and project-based learning with an environmental approach has been proven to increase environmental literacy, motivation, problem-solving abilities, and 4C skills (Hariyadi et al., 2023; Harizon & Ekaputra, 2023; Masek, 2012). Problem-based and project-based learning can also build students' competencies holistically because they are built from problem exploration activities and laboratory activities.

Almulla (2020), Bransford et al. (1998), Mihić & Završki (2017), and Sumarni (2015) reported that students develop a better understanding of concepts and knowledge because they apply them directly in real contexts. This facilitates the transfer of knowledge to other situations. Through problem-based learning, students tend to grasp the material more deeply as they have to delve deeper to solve problems. Students are given the opportunity to explore creative ideas and innovative solutions as they attempt to solve problems or complete projects. Sumarni & Kadarwati (2020) reported that PBL creates a learning environment more similar to the challenges faced in the real world, preparing students with the skills and knowledge needed to succeed in various situations as they are trained to think critically and creatively. Based on the literature review above, project-based learning on green energy is crucially investigated in fostering environmental literacy and enhancing students' data interpretation skills.

Method

The research was conducted using a quantitative descriptive approach. Quantitative descriptive research is a type of research aimed at describing and analyzing a phenomenon or population through the collection and analysis of quantitative data. Unlike qualitative research, which emphasizes in-depth and interpretive understanding, quantitative descriptive research prioritizes measurement and statistical generalization of a population. This research was conducted at Mandalika University of Education with a sample of 22 individuals. The variables analyzed the effectiveness of the project-based learning model assisted by computational simulation in fostering environmental literacy and students' ability to interpret data. The project in this study was based on environmental issues regarding global temperature rise due to fossil fuel use. The introduction of new renewable energy sources that are more environmentally friendly became the project topic for students. The creation of hydrogen and biodiesel elements from waste around us was raised as the project topic to enhance students' literacy about the ways and importance of new renewable green energy in addressing the issue of global temperature rise.

Data Collection Techniques and Tools

The research used pre-test and post-test data interpretation and environmental literacy tests as data collection techniques and tools. The test consisted of 5 essay questions assessing students' competency skills in data interpretation, environmental literacy, and the test used were analyzed for validity, discrimination power, and difficulty level before use. This test was developed based on indicators of data collection, data analysis, and data interpretation competencies. The test was given to students before and after carrying out the hydrogen and biodiesel gas-making project activities. After completing the project, students' competencies were strengthened through computational simulations related to the project undertaken.

Data Analysis Techniques

Data collection techniques came from data interpretation competency and environmental literacy tests. In data processing, this research collected pre-test and post-test data before and after treatment. After the data were collected, data processing was assisted by the

SPSS 22 program. The data analysis technique used in this research is as follows: Normality test was used to determine whether the data used were normally distributed or not. This research used the Shapiro-Wilk normality test because the sample used was less than 50. Then, a homogeneity test was conducted to determine the level of similarity in data variance from the population. The next test used the N-Gain test to identify the effectiveness of the given treatment.

Result and Discussion

Environmental Literacy

Competence in global environmental issues such as climate change, loss of biodiversity, and environmental pollution, as well as their impacts on humans and the planet, are fundamental for students to master. Environmental issues are fundamental to be studied because the impacts of natural exploitation activities are so evident and felt today. The increase in global temperature disrupts agricultural activities. Disruption of agricultural activities leads to shortages of primary commodities such as rice and wheat, which are the most consumed sources of carbohydrates by the world's population. Competence adapted wisely in managing nature needs to be continuously trained and developed in the world of education. Competence in analyzing environmental information, evaluating sustainable resources, and making evidence-based decisions requires critical thinking skills (Abrami et al., 2015; Amïn et al., 2020; Bïrgïlï, 2015).

Learning models with an environmental approach are important to be continuously developed to produce individuals who are wiser in managing nature. Learning emphasizing environmental issues is important to be continuously developed. Project-based Learning (PjBL) models with an environmental approach are important to be developed to foster awareness, literacy, and environmental problem-solving skills (Benzer & Şahin, 2013; Bramwell-Lalor et al., 2020; Condliffe, 2017). Environmental literacy refers to the understanding and skills needed to comprehend environmental issues and participate in sustainable and responsible actions towards the environment. This involves knowledge of ecosystems, biodiversity, climate change, pollution, natural resource management, and various other environmental issues. In the study, the issue of environmental literacy focused on climate change due to the use of fossil fuels. The results of measuring students' environmental literacy can be seen in Figure 1.

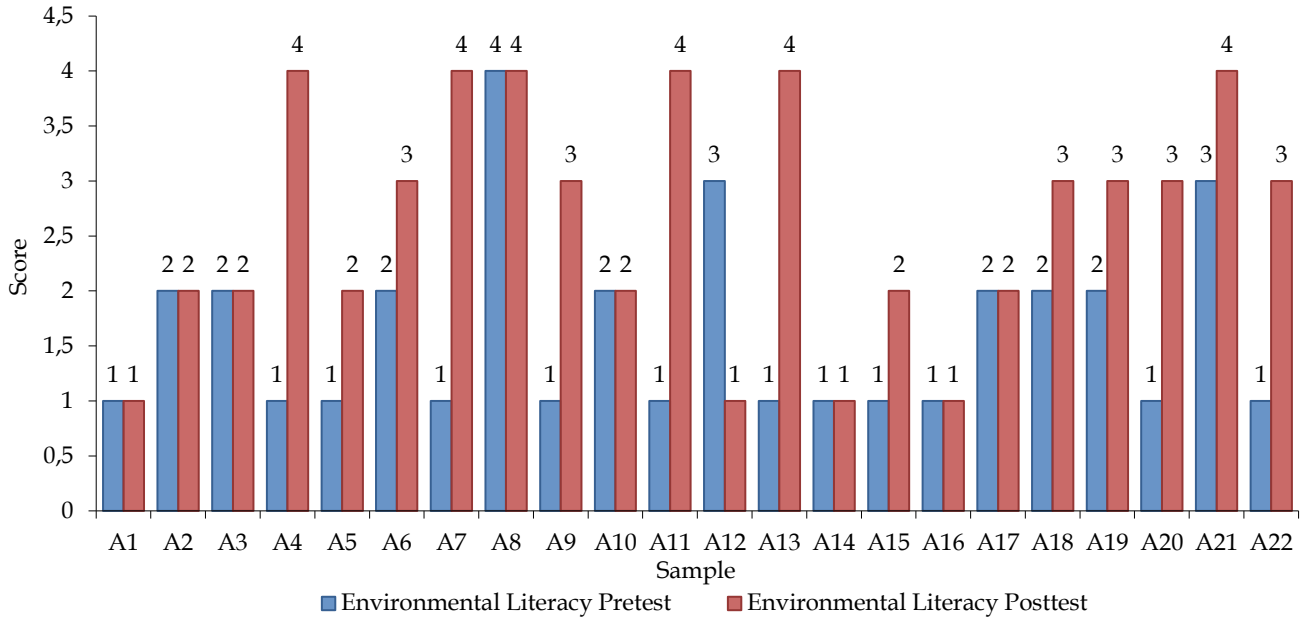

Figure 1. Summary of pretest and posttest on environmental literacy

Based on Figure 1, Project-based Learning (PjBL) with an environmental approach has a positive impact on fostering environmental literacy competencies. Environmental literacy is measured by presenting environmental change data in numerical and graphical forms. The data and graphs are extracted from empirical facts from the Web of Science. Environmental literacy is assessed based on students' abilities to analyze data and propose solutions. This activity has proven to foster students' environmental literacy. Kokotsaki et al. (2016) and O'Reilly et al. (2022) report that Project-based Learning (PjBL) is an active instructional form centered

on students and characterized by student autonomy, constructive inquiry, goal setting, collaboration, communication, and reflection in real-world practice. This activity can enhance cognitive competencies, including environmental literacy. Continuous scientific activities can cultivate critical thinking and analytical thinking competencies. Both of these competencies are fundamental foundations for fostering every competence (Loyens et al., 2023). PjBL has been explored in various contexts and educational stages, ranging from elementary education to higher education. Environmental literacy is crucial because it helps individuals and communities take sustainable steps to protect and preserve the environment for future generations. With the right knowledge and skills, we can be more effective in addressing current environmental challenges and building a sustainable future (Amïn et al., 2020). Designing learning infrastructure with an environmental problem-solving approach can create a more meaningful learning environment and enhance learning motivation (Hulyadi et al., 2023a).

Nguyen & Hess (2020) report that motivation is an internal or external drive that prompts individuals to take specific actions or achieve specific goals. Meanwhile, learning outcomes refer to students' achievements in understanding and mastering learning materials. Students with high motivation tend to be more active and diligent in the learning process. They are more likely to spend time and energy studying materials carefully, attending classes, and completing assignments (Wei et al., 2021). An individual's level of motivation can influence the learning strategies they use. Highly motivated students tend to use effective learning strategies, such as planning their learning, organizing information, and using efficient memory techniques. The presence of environmental issues, especially climate change impacting all aspects of life, is expected to stimulate learning motivation and curiosity. Environmental problems that directly impact physical and psychological aspects can stimulate curiosity, resulting in increased student competencies (McFadgen & Huitema, 2017; Nuayi et al., 2018). PjBL with an environmental approach serves as an effective learning solution in constructing students' cognition (Loyens et al., 2023). Environmental issues are global problems that must be addressed and tackled as soon as possible.

Learning designs that can influence emotions can provide high motivation, making it more likely to face challenges and obstacles in the learning process. This condition can increase perseverance and resilience in overcoming potential learning obstacles. Highly motivated students tend to achieve better learning outcomes. They are more engaged in learning, have a deeper understanding of the material, and can apply their knowledge better in real-life situations.

Data Interpretation

Data interpretation is the process of analyzing and understanding the meaning of collected or presented data within a specific context. Data interpretation involves identifying patterns, trends, relationships, or implications of the data to gain a deeper understanding of the observed phenomena. In this study, data are presented in the form of graphs and documentation of scientific work on the synthesis of hydrogen and biodiesel from used cooking oil. Students are trained to recognize patterns and trends in the treatments provided. The results of measuring students' abilities in interpreting data can be seen in Figure 2.

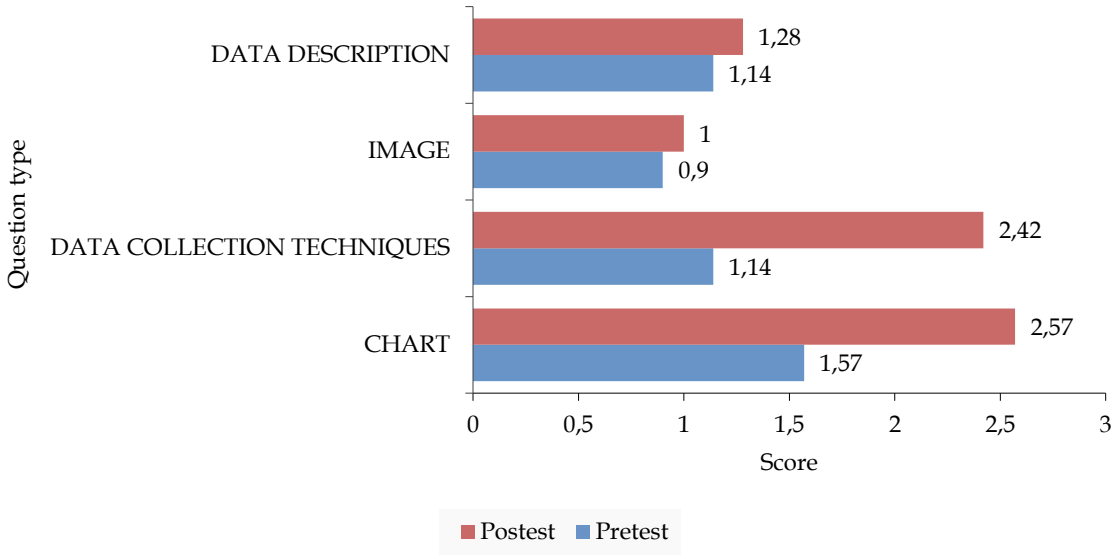

Figure 2. Summary of pretest and posttest date interpretation

Data Interpretation

The data are interpreted in the form of graphs, tables, images, and process diagrams. Students are trained to identify patterns, data trends, and interpret the scientific processes presented as problems and findings during the synthesis of hydrogen gas and biodiesel. The findings indicate that students find it easier to understand numerical data presented in graphical form compared to data presented as images. Students also experience difficulties in interpreting data presented in process diagrams. Overall, the application of the PjBL model with an environmental problem-solving approach has a positive impact on enhancing students' ability to interpret data. Initially, students faced challenges in interpreting data after engaging in scientific activities, particularly in understanding hydrogen elements. However, subsequent cognitive construction aided by computational simulations helped sharpen their understanding of the project being studied. The results were quite positive, as seen in the post-test results in Figure 2. Computational simulation studies of the atoms composing organic compounds assist students in constructing slightly better conceptualizations compared to pre-test results in Figure 2. Hulyadi et al. (2024) and Hulyadi et al. (2023b) report that computational simulations can reduce students' misconceptions in examining the structure of organic molecules. Simulations aid students with difficulties in understanding numerical data and images resulting from laboratory activities (Lamb et al., 2014). Computational simulations have been shown to influence cognition, with various learning techniques requiring different facilities to record information more comprehensively. The PjBL model, coupled with an environmental issue-based approach aided by computational simulations, has a positive impact on improving environmental literacy and data interpretation. Basu et al. (2017) report that computational simulations can lead to higher levels of cognition among students, helping to clarify abstract concepts. The improvement in learning outcomes is also tested using the N-Gain test, as shown in Figure 3.

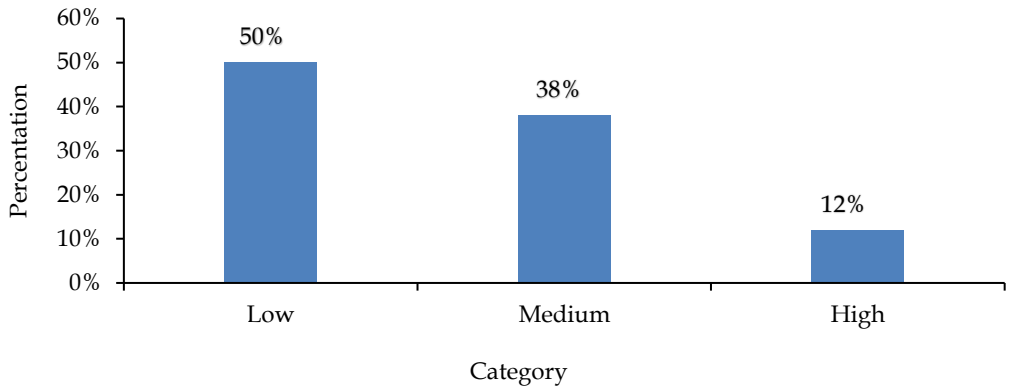

Figure 3. N-Gain test of environmental literacy and data literacy competence

Figure 3 describes that 50% of the students are categorized as moderate to high. The PjBL (Project-Based Learning) model with an environmental issue-based approach aided by computational simulations can foster students' data interpretation and environmental literacy. PjBL is an instructional approach in which students engage in various activities to develop understanding and solutions. These activities include problem identification or questioning, independent research, group discussions, teamwork, experiments or simulations, presentation and discussion of results, as well as reflection and evaluation. Through these activities, students are encouraged to develop critical thinking, communication, collaboration, and problem-solving skills that are essential for achieving deep understanding and effective solutions in the context of project-based and problem-based learning. This series of activities trains students to become solution-oriented and adaptive to the problems they face. Data collection activities, organizing them in tables, describing them in graphs become activities that can enhance the ability to read patterns and trends in data. These activities can foster data interpretation competence (Anggereini et al., 2023; Koparan & Güven, 2015; Widakdo, 2017).

Conclusion

The N-Gain test results indicate that the application of the E-PjBL model aided by computational simulations has a positive effect on fostering environmental literacy and data interpretation competence. 50% of the students are categorized as moderate to high, while the other 50% are categorized as low. Students find it easier to understand numerical data compared to documentation

(images) and process diagrams. There is a need to convert data presented in image and process diagram formats into numerical data presented in graphs. The novelty of this research lies in the collaboration of models and approaches that prioritize fundamental and urgent contextual issues for which solutions need to be found. The variable of data interpretation is explored with various types of data, which is a novelty in this research.

Acknowledgments
We would like to express our gratitude to Mandalika University of Education for providing financial support and facilities so that this research can be carried out properly and on time.

Author Contributions
Conceptualization, methodology, validation, data analysis, Z.A. and F.B.; writing and review manuscript, H.

Funding
The research team would like to express our heartfelt gratitude to Mandalika University of Education for their financial support and facilities, which allowed this research project to run smoothly and achieve the expected goals and outcomes.

Conflicts of Interest
All author declares that there is no conflict of interest.

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