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Project Based Learning with Sustainability in Chemistry Learning: Developing Scientific Literacy in the 21st Century

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ABSTRACT

Sustainability has become an increasingly important global issue in education, especially in the context of chemistry education for the 21st Century. Chemistry learning that focuses on sustainability aims to increase students' knowledge of environmental issues and equip them with the skills and values needed to create a sustainable society. Scientific literacy is one of the skills that can be developed if chemistry learning applies appropriate learning models and focuses on sustainable content. This study aims to explain how Project-Based Learning (PjBL) with sustainability content in chemistry learning can develop scientific literacy. The research method used a literature review. The study results show that PjBL with sustainability in chemistry learning can encourages scientific literacy because students actively collaborate to explore sustainability issues and involve them in real-world projects that require critical, creative, and innovative thinking to solve problems and develop sustainable solutions. If these skills are developed, they can improve students' scientific literacy.

Keywords: *Chemistry Learning; Sustainability; Project Based Learning; Scientific Literacy.*

INTRODUCTION

Sustainability has emerged as an important global issue in the 21st century, requiring it to be integrated into various sectors, including education, especially in chemistry learning. This is because chemistry plays a major role in preparing future generations to address global challenges related to sustainability (Wissinger et al., 2021). Therefore, it is important to teach chemistry by connecting it to broader environmental and social issues such as climate change, resource depletion, and public health crises, one of which is due to pollution. By embedding sustainability content into chemistry learning, educators can foster a deeper understanding of the interconnectedness of chemical processes and their impacts on the environment (Diah et al., 2023) so that it not only enriches the learning experience but also equips students with the knowledge and skills needed to contribute to sustainable development (Wissinger et al., 2021).

However, based on preliminary research conducted by the researcher, of the 45 teachers who were the objects of the study, only 21 teachers had included sustainability content in chemistry learning; the rest sometimes needed to include sustainability content in chemistry learning. In fact, in its application, chemistry learning that includes sustainability is not only to increase students' knowledge of environmental issues but also to equip students with the skills and values needed to create a sustainable society, one of which is science literacy skills. This is because integrating sustainability will empower individuals to actively participate in discussions and actions related to environmental and social issues, thereby contributing to developing students' critical thinking and leading to increased science literacy (Sjöström et al., 2024).

The development of scientific literacy in the 21st century is very much needed, especially in chemistry learning. This is because chemistry explains most phenomena that affect everyday life and the environment. Research shows that students with strong scientific literacy skills will be better prepared to engage in pressing global issues, such as sustainability and environmental management (Leal Filho et al., 2016). With sustainability integration, chemistry education may engage students meaningfully, leading to a deeper understanding of the subject and its real-world applications. This gap can result in low levels of scientific literacy because learning needs to be contextualized according to what happens in the real world (Amala et al., 2023). So, chemistry learning with sustainability content and scientific literacy have a strong relationship.

Therefore, in order to achieve the goal of promoting scientific literacy and sustainability in chemistry education, educators need to determine the right learning approach. PjBL has been identified as an effective pedagogical approach that aligns with promoting scientific literacy and sustainability in chemistry education. This is because when sustainability content is loaded in the form of a project, it will encourage students to engage in inquiry-based projects that require them to apply their knowledge so that they can grow a deeper understanding of scientific concepts such as chemical concepts (Paristiowati et al., 2022). This method not only improves students' understanding of scientific concepts in chemistry but also fosters skills that can support the improvement of scientific literacy, such as critical thinking, problem-solving, creativity, innovation, and collaboration (Hasibuan et al., 2021; Nabilatunnisa & Hernani, 2024) which competencies are not only important in the context of chemistry learning but also in the context of students' daily lives, where they must be able to apply the knowledge gained in different situations (Jegstad & Sinnes, 2015).

METHODS

This research was conducted using a literature study approach. Literature study reviews and criticizes knowledge, ideas, or discoveries from several previously written sources. Literacy data from several journals relevant to the topics raised in PjBL, including sustainability in chemistry learning and its role in developing science literacy, became the data source in the research conducted. Data collection techniques were done through digital searches of several journals and several search platforms, including articles from 2014 to 2024. Data analysis was carried out using the content method, which included selecting several journals relevant to the research scope and comparing several journals obtained from the selection process.

RESULTS AND DISCUSSION

Integration of Sustainability in Chemistry Learning through PjBL

Traditional chemistry learning often focuses on memorization and isolated concepts, thus hindering students' understanding of the real applications of chemistry (Pernaa et al., 2022). This is in line with research conducted by (Susanty, 2022) and (Febriani et al., 2024) , that the problem of students in learning chemistry is the lack of understanding between theory and practice. In fact, according to (Tarigan & Wiji, 2023), chemistry can be a fun learning experience by helping students understand the world around them. Therefore, a more relevant and contextual approach is needed in this case, as well as sustainability-related issues. According to Mitarlis et al. (2023), chemistry learning has great potential to support the achievement of the SDGs, especially targets related to responsible consumption and production (target 12) and action on climate change (target 13). The integration of sustainability in chemistry learning is important, not only to make students understand the relevance of the material they are learning and how it can relate to practice in everyday life (Aubrecht et al., 2015) but also to prepare them to face sustainability challenges in the future (Mitarlis et al., 2023). This is in line with research conducted by (Gulacar et al., 2020) chemistry learning by integrating the socio-scientific issue of phosphate sustainability can improve the ability to find relevance in the material presented with reality through discussion activity.

Integrating sustainability into chemistry learning certainly requires selecting the right strategy so that the principles of sustainability, chemical concepts, and their relationship to real-world problems can be conveyed properly. Therefore, chemistry learning through a PjBL approach can solve the existing challenges related to sustainability integration into chemistry learning. This is because PjBL provides opportunities for students to learn chemical concepts and to understand and apply sustainability principles in real contexts. Through PjBL, learning will use relevant projects, allowing students to collaborate and develop the critical skills to face future sustainability challenges (Markula & Aksela, 2022).

Educators need to design projects that are not only challenging but also relevant to sustainability issues. A good project should have a clear driving question and produce artifacts reflecting students' understanding of the concepts learned (Markula & Aksela, 2022). For example, in the context of chemistry learning, students can conduct experiments related to green chemistry as an adoption of sustainability principles, such as the synthesis of biodegradable polymers or the depolymerization process of plastic (Aubrecht et al., 2015). These activities improve understanding of chemical concepts and provide hands-on experience of how chemistry can be used to create more sustainable solutions (Mitarlis et al., 2023), so that students will have a sense of social and environmental responsibility as educated citizens *(Leal Filho et al., 2016)*. If the availability of laboratories for conducting practicums is not sufficient, utilizing simulation-based virtual laboratories can be a solution, both 2D and 3D virtual laboratories such as Augmented Reality (AR) and Virtual Reality (VR), both of which are able to improve students' skills and understanding, especially in the topic of addiction (Rina Mirdayanti & Murni, 2017; Ebinger et al., 2022).

The Role of Sustainability-Containing PjBL in the Development of Science Literacy

The importance of scientific literacy in the 21st century cannot be overstated, as scientific knowledge is the foundation of everyday life (Gultepe & Kilic, 2015). Scientific literacy is the ability to think scientifically and critically and use scientific knowledge to develop decision-making skills related to real-world issues. Scientific literacy is important for students to have for two reasons, namely, personal needs that can be shared with others; we live in this world and will be faced with many questions that can be answered through scientific information and require a scientific mindset to make decisions for personal or public interests. Therefore, PjBL ultimately emerged as an important pedagogical approach that integrates the concept of sustainability into science education so that it has the potential to contribute to improving students' scientific literacy through its nature that can give rise to critical, creative, and innovative thinking patterns in making decisions for solving problems in this case, namely the issue of sustainability.

Nabilatunnisa dan Hernani (2024) in their research, showed that the application of PjBL with a sustainability approach through green chemistry in culinary vocational education not only improves students' understanding of food additives but also strengthens their science literacy skills by improving critical thinking and environmental and health problem-solving skills because it allows them to explain scientific phenomena, design investigations and interpret data effectively. Thus, PjBL bridges theory and practice, allowing students to apply scientific knowledge in relevant situations. This is in line with Purwanti's findings, which noted that green chemistry practices within the PjBL framework foster critical thinking and problem-solving skills among students to address environmental challenges (Purwanti & Fitri Khoerunnisa, 2023).

In its application, the integration of sustainability in PjBL can be done by also integrating ethnoscience into it, and this is because the application of ethnoscience in learning allows students to understand and appreciate cultural values related to science so that they can develop a more positive attitude towards the environment and sustainability (Rusmansyah et al., 2023). By understanding how science can be applied in a local context, students are expected to make better decisions regarding environmental and social issues relevant to their community, which ultimately improves their scientific literacy. This aligns with research by Rumansyah *et al.* (2023), showing that the ethnoscience-based PjBL model can effectively improve students' cognitive learning outcomes and scientific literacy. By involving students in projects that connect scientific concepts with cultural contexts, educators can increase a deeper understanding of science related to sustainability and community needs. This approach enriches students' learning experiences and prepares them to address complex sustainability issues through informed decision-making (Rusmansyah *et al.,* 2023).

In addition, the collaborative nature of PjBL encourages students to work together, fostering a sense of community and shared responsibility for sustainability (Nabilatunnisa & Hernani, 2024). When students engage in projects that require them to consider multiple perspectives, they become more adept at adapting to sustainability issues, ultimately improving their scientific literacy (Zidny *et al*., 2021). In addition, a collaborative learning environment can foster innovative and creative approaches to solving the same problem from multiple perspectives (Paristiowati *et al*., 2022).

CONCLUSION

Traditional chemistry learning that focuses on memorization hinders students' understanding of the real-world applications of chemistry. Therefore, integrating sustainability issues into learning is essential to help students understand the relevance of the material to everyday life. The PjBL approach can be an effective solution, allowing students to learn chemistry concepts while applying sustainability principles. PjBL (PBL) also improves students' scientific literacy by encouraging understanding, critical thinking, and problem-solving skills through collaborative situations.

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